Smarter Self is a compilation of best practices and best-of-breed solutions designed to provide students and faculty members with a robust set of psychosocial skills to allow them to thrive in a post-Covid-19 social media environment.

360 is agnostic when it comes to developing custom solutions for our clients. The infamous Microsoft Not Invented Here (NIH) does not apply. If another organization has invented the ideal wheel, it is incumbent on 360 to incorporate that wheel into our newest vehicle and deliver the best possible solution for our clients.

Why has it taken so long for an organization to develop a comprehensive solution to support student's behavioral health, mental health, and academic performance and help preserve the sanity of faculty members when the need is so abundantly clear?

When potential clients are required to challenge traditional thinking and methods, the company developing the new solution is taking a significant financial risk. In this instance, 360 saw the need as so urgent we followed the Field of Dreams philosophy – If We Build it, They Will Come -- and committed the resources necessary to launch Smarter Self for the 2022 school year.

Our work at 360 is evidence-based, validated, and governed by science. Best Practices are adopted from external sources and supplemented or replaced by our work internally when results warrant a change. The documents that follow are representative of a much larger body of research assembled in the development of Smarter Self. The results of our research leave little room to doubt the efficacy of Smarter Self.

Sample Supporting Materials

1. **Brain Gym**
    a. Stress-Related Growth: Building a More Resilient Brain
    b. Adolescent Reasoning Initiative
    c. gist-reasoning and fact-learning in adolescents
    d. Inhibitory Control Gains from Higher-Order Cognitive Strategy Training
2. **Breathing Exercises**
    a. Effects of Classical Breathing Exercises
    b. Why Navy Seals Use Box Breathing
3. **Meditation Interventions**
    a. Meditation for Increased Mindfulness and Memory
    b. Effect of Meditation on Achievement, Attention, & Memory of High School Students
4. **Mindfulness**
    a. Mindfulness-based Online Intervention
    b. Mindfulness-Based School Interventions
5. **Music Interventions**
    a. Efficacy of Music Therapy on Adolescents
    b. Music Therapy Micro-Intervention
    c. Harnessing the Therapeutic Potential of Music
6. **Peer-to-Peer Support**

   a. Benefits of Peer Support Arrangements
   b. Peer Programs Helping Schools
7. **Resilience Development**
   a. The Mediating role of Resilience
   b. Effect of Inner Engineering Online
   c. Neural Mechanisms of Brain Plasticity
   d. New Hope for Students in Poverty
8. **Traditional Interventions**
   a. Rimrock SUD/OUD
   b. Transforming the Perception of Mental Health Community Services
9. **Yoga Interventions**
   a. Yoga as an Integrative Therapy for Mental Health Concerns
   b. Yoga and meditation, an essential tool to alleviate stress

Stress-Related Growth: Building a More Resilient Brain

Anna S. Ord, Psy.D., Kathryn R. Stranahan, Psy.D., Robin A. Hurley, M.D., Katherine H. Taber, Ph.D.

FIGURE 1. The baseline level of resilience (initial state) is a product of complex interactions among multiple biological, psychological, and environmental factors that play a key role in an individual's response to a stressful event (1–9). The adjustment process and the outcome also depend on the severity of stress experienced. If a stressful event is of moderate severity (tolerable stress), successful adjustment may increase resilience and promote growth (green). Events that induce little stress require little adjustment and thus are likely to result in recovery (yellow) without increased resilience (i.e., return to baseline functioning). Events that induce very high levels of stress (toxic stress) may overwhelm an individual's coping capacity, at least temporarily, and result in impairment (red). Resilience level is modulated by many factors, including aspects of cognitive flexibility (e.g., deliberative rumination, finding meaning, reappraisal, self-reflection, and internal locus of control) and emotion regulation (e.g., suppression of emotion, emotional disequilibrium, and emotional hyper reactivity) (4, 8–12).

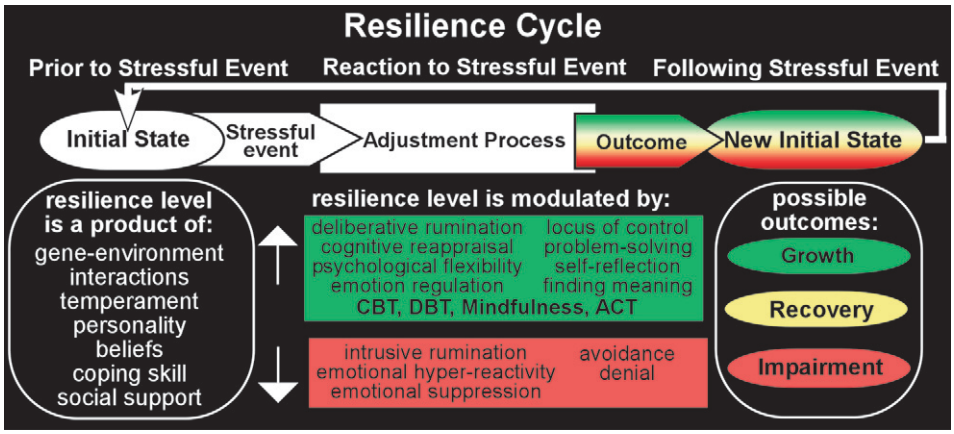

FIGURE 2 and COVER. Upper panel and Cover: Most research on the neurobiological correlates of stress-related growth (SRG) has utilized self-report questionnaires that assess retrospective perception of change. Two studies of healthy adults that explored relationships between Post Traumatic Growth Index (PTGI) score and imaging metrics identified the importance of the dorsolateral prefrontal cortex (PFC). A resting-state functional MRI (fMRI) study reported a positive correlation between PTGI scores and higher resting-activity level in two left hemisphere areas that are part of the central executive network (gold) (13). A longitudinal MRI study of individuals who experienced the East Japan Great Earthquake reported that PTGI scores were positively and significantly associated only with change in the right dorsolateral PFC volume (orange) (14). Of note, individuals with low PTGI scores had reduced volume in this area, suggesting that the direction of volumetric changes may indicate adaptive versus maladaptive responses to stress (14). Lower panel: Congruent with this hypothesis, another longitudinal MRI study that compared patients with posttraumatic stress disorder (PTSD) and healthy individuals reported that the PTSD group initially had greater cortical thickness within portions of the dorsolateral PFC bilaterally (yellow) (15). Initial cortical thickness correlated with greater symptom reduction at the final timepoint. By the final time point, cortical thickness had normalized, and cortical thinning correlated with symptom resolution, indicating a role for dorsolateral PFC in supporting recovery from PTSD (15).

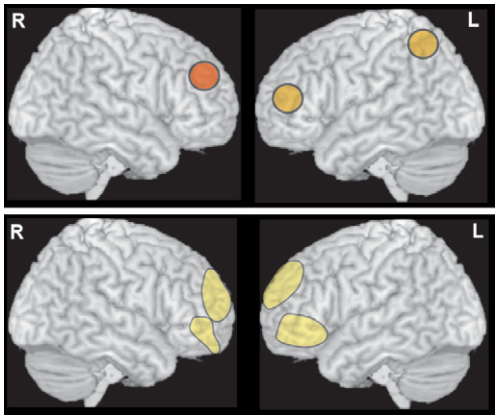

FIGURE 3. An individual's ability to dismiss unwanted memories when they intrude into conscious awareness is an important aspect of healthy emotion regulation (16, 17). This capacity is experimentally assessed by pairing items to be remembered with reminder cues and comparing results when participants are instructed to recall (Think) or instructed to not recall (NoThink) the paired items when cued. In healthy individuals, successful suppression of an intrusive memory weakens the memory trace (as indexed by decreased priming effects). Impaired ability to suppress intrusive memories on this task has been reported for multiple psychiatric disorders (16, 17). fMRI studies of healthy individuals performing the Think/NoThink task have reported that memory suppression is associated with increased activation (NoThink >Think) in frontal and parietal cortices and decreased activation (NoThink <Think) in memory-related areas (e.g., hippocampus, memory-associated domain-specific cortical areas). Approximate locations and extents of cortical activations and deactivations from two studies of healthy individuals are color-coded onto representative MRIs (18, 19). One study compared trauma-exposed individuals with and without PTSD to unexposed individuals (19). The authors reported that the PTSD group did not have the decreases in memory strength for NoThink items or the increases in top-down inhibition during suppression of intrusive memories seen in the other groups. As discussed by the authors, these findings indicate an impairment in memory regulation in the PTSD group that may be the reason memory intrusions are so persistent.

The concept that challenging life events have the potential to facilitate positive change has been explored for centuries in the areas of philosophy, theology, and the arts. However, scientific examination of stress-related growth (SRG) started in the 1990s (posttraumatic growth [PTG], thriving, finding benefits, adversarial growth) (20–24). Research over the past half-century has also established that high levels of stress increase risk for development of both psychiatric and medical conditions (25). The growing recognition that individual outcomes following exposures to challenging events are quite diverse (i.e., ranging from highly detrimental to highly beneficial) led to the development of resilience as a broader framework (5, 7, 26–28). In this context, resilience is conceptualized as a dynamic multifactorial process presenting multiple possibilities for improving outcomes (e.g., SRG)

The resilience cycle (Figure 1) encompasses ongoing interactions among a complex array of biological (e.g., genetic, epigenetic), neuropsychological (e.g., cognitive, emotional), and environmental (e.g., social, economic, and cultural) factors that affect how an individual responds to a particular stressful experience (3–9, 26–30). A resilient (hardy) individual maintains an adaptive level of physiological and psychological functioning when challenged by events. Multiple types of evidence support the importance of moderately stressful events (tolerable stress) for increasing an individual's level of resilience (stress inoculation, tempering, steeling, adversity-driven resilience) (1–5, 7). Events that induce little or no stress do not provide a resilience-building experience. Events that induce very high levels of stress may overwhelm an individual's coping capacity, at least temporarily (toxic stress). It should be noted that SRG has been identified not only in relation to stressful or traumatic external events but also in relation to recovery from serious mental illness (31, 32). A personal account of recovery from psychosis noting psychological growth following several psychotic episodes suggested that opportunities for growth (e.g., intentional introspection, meaning making, benefit finding, and positive self-disclosure) should be intentionally incorporated into treatment and recovery plans (32).

Although most research to date has focused on the construct of posttraumatic growth, this is only one aspect of a rather complex and multifaceted phenomenon of positive adaptation and development following events that are perceived as distressing regardless of valence (4, 28). An emerging body of literature indicates that growth is not limited to situations and events that have negative valence and that psychological growth may occur following any event that challenges an individual's coping resources. A recent meta-analysis of longitudinal studies examining the effects of life events on psychological well-being reported a positive trend for self-esteem, positive relationships, and mastery following both positive and negative events, with no general evidence that negative life events had a stronger effect (33). Additionally, they found that in studies utilizing control groups, results did not significantly differ between the event and control groups, indicating that changes in outcome variables cannot necessarily be attributed to the reported life events.

Multiple conceptual models for adaptive coping with adversity and fostering resilience and growth have been proposed (e.g., PTG, coping circumplex model, systematic self-reflection, cognitive appraisal of resilience, cognitive growth, and stress) (4, 9–11, 34). All include an aspect of cognitive flexibility (e.g., cognitive processing, cognitive appraisal, rumination, problem-solving, meaning making, benefit finding, and self-reflection) as a primary mechanism for strengthening resilience after exposure to life stressors that require adaptation (i.e., psychological adjustment through the process of redefinition of the self and reappraisal of one's beliefs). Several models include emotion regulation as the second key aspect of resilience (4, 9, 11). Recent reviews on the neurobiology of resilience converge on the central importance of the prefrontal cortex (PFC)-limbic circuitry (5–7, 35–37). Higher resilience is associated with greater emotion regulation capacity (i.e., top-down regulation of emotional responses). Greater engagement of PFC areas important for cognitive and emotional control enhances inhibition of limbic areas such as the amygdala, reducing reactivity to stressful stimuli. Resilience-related differences in resting-state EEG have also been reported. A study of children that compared groups with and without maltreatment reported greater relative left central activity (lower left compared with right alpha power) in high-resilience (composite index of adaptive functioning) individuals from both groups, whereas low resilience was associated with greater right hemisphere activity (38). A study of middle-aged adults reported that higher right frontal activity was associated with increased levels of blood biomarkers (interleukin-6, C-reactive protein, and fibrinogen) indicating low-grade inflammation only in the group who reported having experienced moderate to severe abuse as children (Childhood Trauma Questionnaire) (39). As discussed by the authors, these results are consistent with higher right frontal activity indicating greater vulnerability to emotionally challenging stressors (diathesis-stress model) and that this may also increase risk for inflammation-related medical conditions.

Both cognitive and emotional approaches to coping with adversity span a wide range of strategies, some of which are detrimental to functioning. For example, rumination (repetitive thinking about an event) can be either deliberate or intrusive (40, 41). Deliberate (reflective) ruminations are adaptive, voluntary purposeful thoughts focused on better understanding of the event (i.e., its meaning, consequences, and implications). Additionally, deliberate rumination may serve as a coping strategy for managing emotional responses. Intrusive (perseverative) ruminations (e.g., worry, brooding) are maladaptive, automatic unwanted thoughts or memories that increase an individual's distress. Intrusive rumination may also involve attempts to suppress thoughts about a stressful event. As would be expected, research indicates

that intrusive and deliberate ruminations play very different roles in outcomes (41). Recent longitudinal and cross-sectional studies in a wide range of trauma-exposed groups (e.g., middle school and college students, military veterans, emergency services personnel, cancer survivors, and patients with nervous system injuries) indicate that intrusive rumination is positively associated with psychiatric symptoms, whereas deliberative rumination is positively associated with SRG (10, 42–49). As noted in several studies, these results support the potential of interventions facilitating deliberative rumination during recovery to promote better outcomes. Similarly, emotional coping may be positive and lead to emotional equilibrium (i.e., adequate emotional control), or it may be negative and result in emotional disequilibrium (e.g., emotional hyperreactivity, excessive anxiety, and suppressing emotions). These concepts are consistent with the broader body of literature that has demonstrated associations between emotion dysregulation and various forms of psychopathology (50). Studies identifying specific capacities or skills associated with higher resilience and/or better recovery from challenging events provide potential targets for interventions.

Interventions that promote cognitive flexibility and/or emotion regulation would be expected to strengthen resilience. Cognitive restructuring is one of the primary techniques utilized in cognitive-behavioral therapy (CBT), which involves identifying and challenging negative and rigid thought patterns (51, 52). The goal is to facilitate resilience rather than to solve a particular problem or achieve a certain outcome, as illustrated in a recent study of patients with posttraumatic stress disorder (PTSD) comparing CBT with eye movement desensitization and reprocessing therapy (53). There were no differences in clinical efficacy, but only CBT improved general life functioning (Work and Social Adjustment Scale). Acceptance and commitment therapy (ACT) is a transdiagnostic approach that has the primary focus of fostering psychological flexibility as a pathway toward adaptation and psychological well-being (54, 55). Recent systematic reviews and meta-analyses of randomized controlled trials of interventions that included therapeutic mindfulness (e.g., ACT, mindfulness-based stress reduction, mindfulness-based cognitive therapy) reported beneficial effects on a wide range of behavioral health outcomes (e.g., anxiety, depression, fatigue, stress, quality of life, and PTG) in adults with cancer (56, 57). Mindfulness-based interventions have also been shown to decrease use of maladaptive coping strategies (e.g., avoidance or disengagement coping, negative emotional coping) (58, 59). Dialectical-behavior therapy (DBT) may also be a useful therapeutic approach to facilitate emotion regulation, because it incorporates mindfulness, emphasizes the role of difficulties in emotion regulation, and focuses on the development of emotion-regulation skills (60–62). DBT has been shown to be effective in decreasing transdiagnostic emotion dysregulation (63–65). Overall, meta-analyses and systematic reviews of various psychosocial interventions generally show that interventions based on principles of CBT and mindfulness have the strongest effect sizes in fostering resilience and psychological growth following adverse events (66, 67). Imaging studies comparing pretreatment to posttreatment resting-state and/or task-activated functional MRI (fMRI) have reported changes in brain activation patterns following treatments that correlate with symptom improvements, suggesting beneficial neuroplastic processes (53, 68–72).

Whether self-reported growth following challenging events is primarily positive is a matter of considerable debate (34, 73–81). A key problem with research in this area is reliance on retrospective reports of self-perceived growth that may not represent genuine transformation (76, 79, 82–86). The few longitudinal studies indicate that self-perceived growth does not correlate with more objective measures of psychological growth (i.e., measures of actual psychological resources) (82, 85, 87, 88). In addition, a longitudinal study assessing veterans decades after their participation in the Yom Kippur War found that self-reported growth was linked with several detrimental outcomes, including higher rates of loneliness and lower dyadic adjustment in marital relationships (78, 80). The authors suggested that self-perceived growth may be better described as a set of defensive beliefs, a potentially maladaptive strategy for coping with distress. The Janus Face model encompasses this dichotomy by proposing that self-perceived growth following traumatic events has both a functional or constructive side and an illusory (e.g., self-deceptive or dysfunctional) side that may coexist (89, 90). The constructive side is correlated with healthy adjustment, whereas the illusory side is correlated with denial. Similarly, other studies have concluded that self-reported growth can indicate an adaptive outcome of successful cognitive coping or a positive illusion that is a result of avoidance and denial (76, 91). However, the question remains whether self-perception of growth may be beneficial to individuals even if it does not reflect measurable change. On one hand, illusory perceptions (i.e., beliefs that are not grounded in reality) are generally considered maladaptive. On the other hand, some studies have demonstrated that even perceptions of positive change may be linked with more adaptive coping (i.e., positive reinterpretation), better mental health (e.g., lower symptoms of anxiety and depression, higher stress tolerance), and increased quality of life (74, 77, 92–94). Thus, illusory or self-deceptive growth is not always associated with maladjustment. If illusory perceptions of growth coexist with and do not hinder active coping (e.g., deliberate ruminations), then they may serve as a short-term adaptive palliative coping strategy helping individuals deal effectively with the aftermath of distressing events (83, 90, 95).

Most research on the neurobiological correlates of SRG has also utilized self-report questionnaires (e.g., the Post Traumatic Growth Index [PTGI]) that assess retrospective perception of change. Several studies have reported correlations between PTGI scores and imaging metrics within the dorsolateral PFC (Figure 2) (13–15). A study of healthy adults

utilizing group spatial independent component analysis of resting-state fMRI reported a positive correlation between PTGI scores and higher resting-activity level in two left hemisphere areas that are part of the central executive network (dorsolateral PFC, superior parietal lobule) (13). A longitudinal MRI study of healthy young adults identified changes in regional gray matter volume (whole brain voxel-based morphometry) between images acquired prior to and 3 months after they experienced the East Japan Great Earthquake (14). PTGI scores were positively and significantly associated only with change in the right dorsolateral PFC (14). In the region of interest analysis, PTGI scores were positively correlated, whereas posttraumatic stress symptoms (Clinician-Administered PTSD Scale [CAPS]) were negatively correlated with changes in gray matter volume in the same area. As noted by the authors, individuals with low PTGI scores had reduced volume in this area, suggesting that the direction of volumetric changes may indicate adaptive versus maladaptive responses to stress (14). Congruent with this hypothesis, an earlier longitudinal MRI study that compared patients with PTSD and healthy individuals reported that at the earliest imaging time point (average of 1.42 years since the trauma), the PTSD group had greater cortical thickness within portions of dorsolateral PFC bilaterally (Figure 2) (15). Greater cortical thickness was positively correlated with better performance on tests of executive functioning in the PTSD group. It also correlated with greater symptom reduction (CAPS score) during the previous year and by the final time point (average of 3.85 years since the trauma). Cortical thickness had normalized by the final time point, and cortical thinning correlated with symptom resolution, indicating a role for dorsolateral PFC in supporting recovery from PTSD (15).

As detailed in recent reviews, an individual's ability to dismiss unwanted memories when they intrude into conscious awareness is an important aspect of healthy emotion regulation that may be modifiable (16, 17). This capacity is experimentally assessed by pairing items to be remembered with reminder cues and comparing results when participants are instructed to recall (Think) or instructed to not recall (NoThink) the paired items when cued. Participants also report whether a memory intrusion occurred during the NoThink condition. In healthy individuals, suppression of an intrusive memory decreases the frequency of subsequent intrusions and weakens (as indexed by decreased priming effects) the memory trace (suppression-induced forgetting, motivated forgetting, adaptive forgetting, beneficial forgetting, and selective forgetting). Recent studies of suppression-induced forgetting provide evidence that both explicit and implicit memory traces are affected (96, 97). Ability to suppress intrusions varies considerably across healthy individuals, and lower ability has been associated with higher maladaptive traits (e.g., anxiety, brooding) (17). A study of college students found that higher ability was associated with higher trauma exposure, suggesting the possibility that this capacity may be increased by successfully coping with moderate levels of adversity (16, 17). Impaired ability to suppress intrusive memories on this task has been reported for multiple psychiatric disorders, including PTSD (16, 17).

Cross-sectional fMRI studies of healthy individuals performing the Think/NoThink task have reported that memory suppression is associated with increased activation (NoThink >Think) in frontal and parietal cortices and decreased activation (NoThink <Think) in memory-related areas (e.g., hippocampus, memory-associated domain-specific cortical areas) (Figure 3) (16, 18, 19). An fMRI study that utilized unpleasant images demonstrated that an area in the right dorsolateral PFC exerted parallel top-down inhibition of the hippocampus and domain-specific areas (e.g., amygdala, sensory cortices) (18). Effective connectivity analyses indicated that intrusion of memory into awareness in the NoThink condition, which triggers increased effort to dismiss the memory, was associated with increased top-down inhibition (i.e., increased negative coupling with the right dorsolateral PFC). Greater success at suppressing intrusive memories (i.e., higher memory control) was associated with reduced intrusion frequency and reduced memory-associated negative emotion, indicating weakening of both episodic and emotional memory traces (18). An fMRI study that compared trauma-exposed individuals (in the Paris terrorist attacks) with and without PTSD to unexposed individuals on this task reported that all three groups improved on suppression with practice (fewer intrusions during NoThink trials) to a similar extent (19). However, the PTSD group differed from the trauma-exposed without PTSD and unexposed groups on functional metrics. The PTSD group had neither the robust decrease in memory strength for NoThink items (i.e., decreased priming effect indicating weakening of memory traces) nor the increase in top-down inhibition (i.e., increased negative coupling between the right dorsolateral PFC and areas important for memory such as the hippocampus) during suppression of intrusive memories seen in the other groups. As discussed by the authors, these findings indicate an impairment in memory regulation in the PTSD group that may be the reason memory intrusions are so persistent (19). Multiple authors have noted that results from this task suggest that it may be time to re-examine the common belief that all forms of memory suppression are maladaptive (16–19, 97).

In conclusion, recent studies are contributing a new understanding of adaptive and maladaptive stress-related changes in the brain, resilience, and to the neuroplastic changes underlying SRG. This understanding offers promising evidence for recovery following even serious adversities and psychological traumas.

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This research was supported by the Department of Veterans Affairs Office of Academic Affiliations Advanced Fellowship Program in Mental Illness, Research, and Treatment and Clinical Psychology Residency Program.

Received May 14, 2020; accepted June 9, 2020.

J Neuropsychiatry Clin Neurosci 2020; 32:A4, 207–212; doi: 10.1176/appi.neuropsych.20050111

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Adolescent Reasoning Initiative

Teaching Students How To Learn, Not What To Learn

Reasoning, problem solving, and innovation: all necessary competencies for life success. Early adolescence is an optimal time to enhance learning, but many educators do not have the benefit of scientific methods that foster these skills.

Our training program enables middle school through ninth grade teachers to take advantage of this important brain development stage and optimize student learning for success in the classroom and beyond.

A Hands-on Approach - More than 600 teachers have benefited to date, reaching more than 82,000 students.

- Educators Receive Intensive SMART™ Training
- Teachers Become Cognitive Trainers
- BrainHealth® Experts Provide Classroom Support
- Teachers Take Annual Refreshers
- Student Growth Is Measured

In this video, hear from an educator who shares her "aha!" moment. https://youtu.be/0cK-CtoWNDM

Measurable Benefits

- Improved Executive Function More Than 50%
- 48% Reduction in anxiety and depressive symptoms
- Academic Strength Increased 50%

A Supportive Collaboration

Middle- and high-school teachers who want to boost their students' thinking partner with the Adolescent Reasoning Initiative team to learn how to implement Strategic Memory Advanced Reasoning Tactics, or SMART training, in their classrooms.

SMART is a cognitive neuroscience-based approach designed specifically to improve higher-order thinking skills.

A high school principal discusses the profound impact of the program on students and teachers alike. https://youtu.be/n_2ossPv54c

Research Highlights

Effects of Higher-order Cognitive Strategy Training on Gist Reasoning and Fact-learning in Adolescents

Findings from this study suggest young students can significantly improve gist-reasoning and fact-learning abilities by engaging in cognitive strategies that support the ability to abstract meaning.

Enhancing Inferential Abilities in Adolescence: New Hope for Students in Poverty

This study examines the effects of cognitive training in enhancing students' gist reasoning and fact recall. The ability to extrapolate essential meaning through analysis, synthesis, predictions, abstraction of ideas, and integration of relationships with world knowledge is critical for higher-order learning.

New Hope for Executive Function and Reasoning Remediation in Children With ADHD: Strategic Memory and Reasoning Training (SMART)

Teaching children with ADHD specific metacognitive strategies has the potential to improve strategic learning and executive function.

Improved Reasoning in Children with ADHD after Strategic Memory and Reasoning Training: A Novel Intervention for Strategic Learning Impairment

The results of this study demonstrate evidence for the clinical application of cognitive interventions for children with impaired reasoning ability.

Improved Reasoning in Children with ADHD after Strategic Memory and Reasoning Training: A Novel Intervention for Strategic Learning Impairment

The results of this study demonstrate evidence for the clinical application of cognitive interventions for children with impaired reasoning ability.

Inhibitory Control Gains From Higher-order Cognitive Strategy Training

Findings suggest that training higher-order executive functions can strengthen inhibitory control among middle school students.

Rimrock SUD/OUD Behavioral Concierge

Program Overview

June 2021

GOMOHEALTH

Program Introduction

Program Mission

Program Overview

- Rimrock Concierge Care provides personalized mobile engagement for Rimrock's True North and Silverleaf populations and their support networks using:
  - Care messages sent via text
  - Mobile web care pages
- Concierge Care aims to increase program success and nurture long-term client health through increased touch points that foster and develop resiliency to stay on the track to recovery.

Client Focus	Support Person Focus
✓ Keep clients in attendance	✓ Provide behavioral and emotional support
✓ Reinforce therapies outside of session	✓ Share tactics for engaging with family member
✓ Reduce the relapse rate, reducing recidivism	✓ Increase empathy for loved ones in the program
✓ Increase treatment program graduation rate	✓ Increase appropriate boundary-setting

Program Objectives and Measurements

Program Overview

Objectives	Measurements
Reduce criminal justice involvement	Reduction in the number of participating clients who report criminal involvement (self-reported)
Increase Rimrock program completion rates	Increased completion rate among participating clients
Improve long-term sobriety by providing support following program completion	Self-reported improvement in sobriety by participating clients
Increase Family Week engagement	Increase in Family Week participation from family members of participating clients

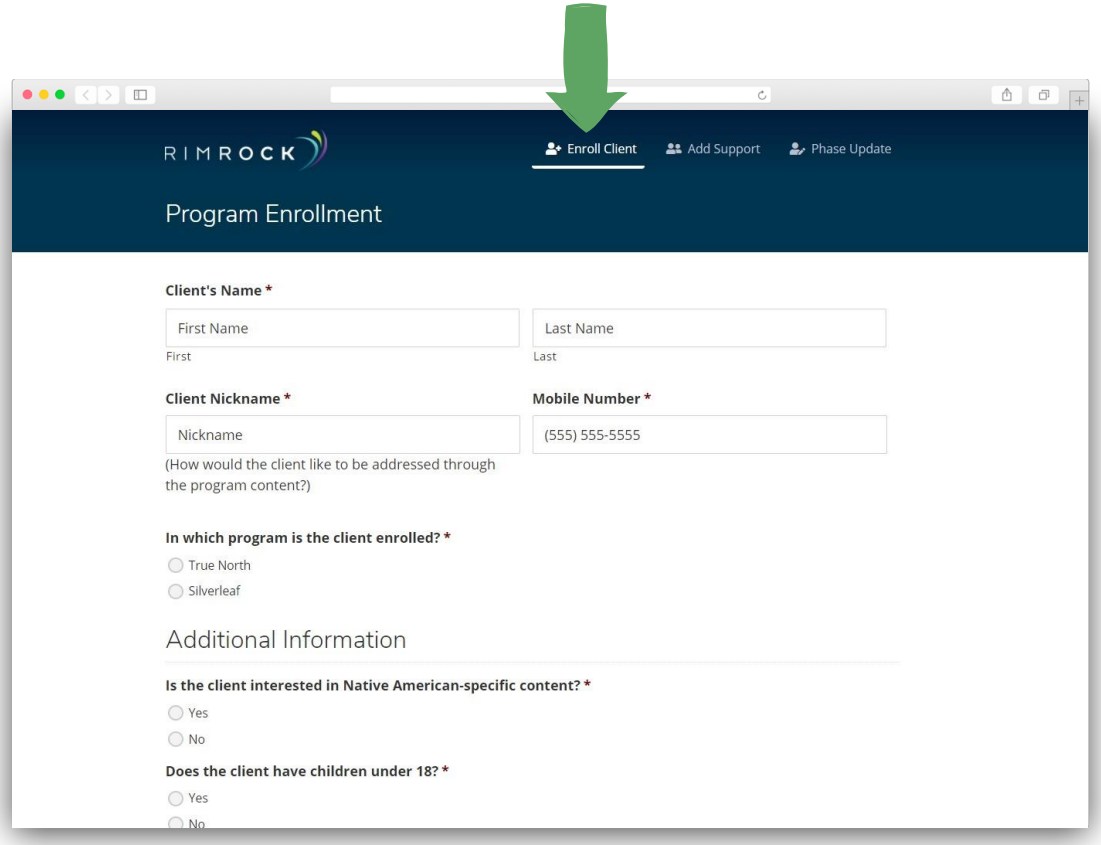
Program Enrollment

Enrollment Form

Program Enrollment

- Enrollment into the Rimrock Concierge program will be facilitated by Rimrock staff on behalf of each client in or entering the True North or Silverleaf programs.
- Clients are enrolled via a web-based **Enrollment Form**, which can be accessed online from any device at any time:
  - rimrock.gomohealth.care/enroll

*Enrolled clients and support persons may unsubscribe from the program at any time by replying **STOPALL** to a program message.*

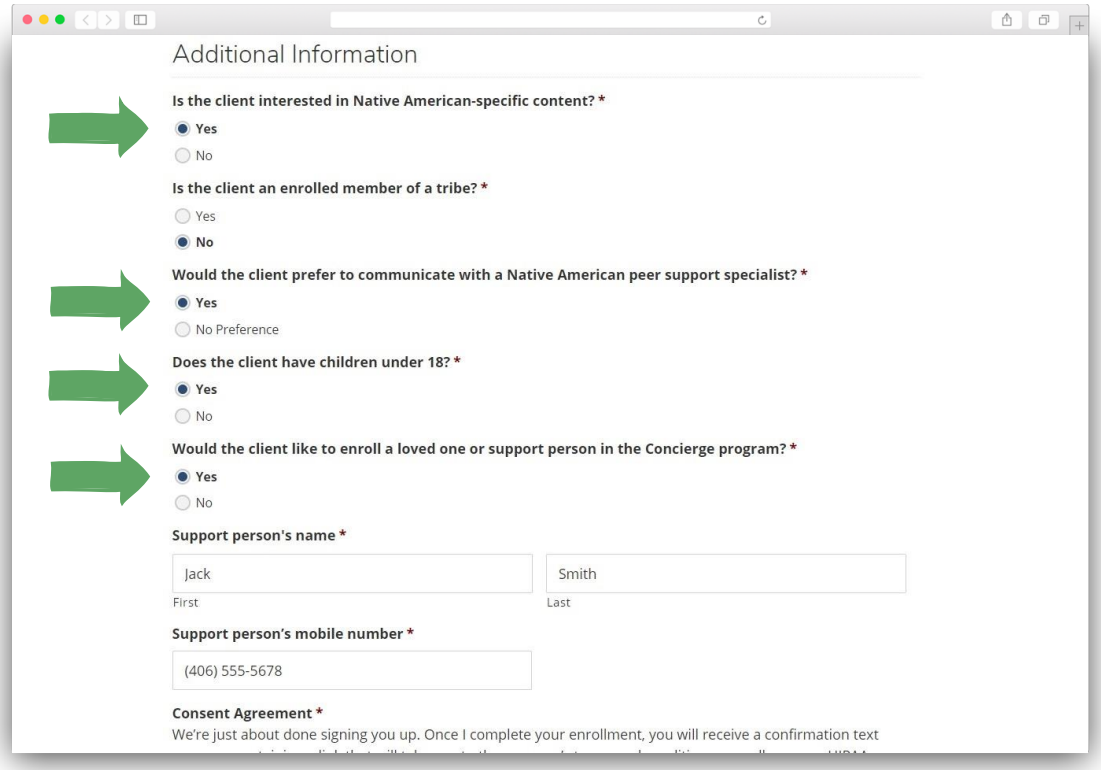


rimrock.gomohealth.care/enroll provides access to all enrollment forms.

Enrollment Form

Program Enrollment

- On behalf of the client, Rimrock staff can indicate the client's program, program phase, program start date, and any relevant court information.
- Additionally, Native American clients can identify as such and enter relevant tribal information or request a Native American peer support specialist.*
- Clients who indicate they have children under 18 will receive additional parenting content.
- Each client has the option to sign up a support person of their choice (a family member, friend, sponsor, etc.) to receive content focused on providing support through the recovery journey.

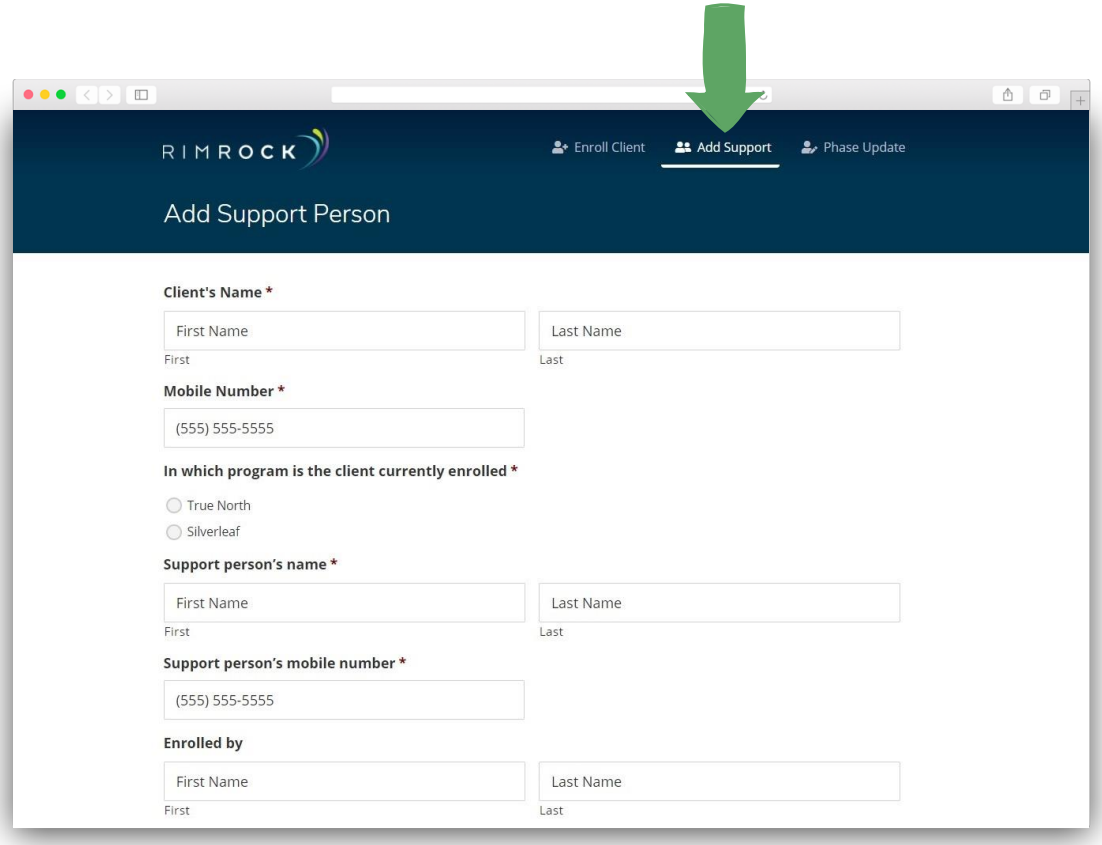


** Content and resources tailored toward Rimrock's Native American clients will be offered in a later phase of program implementation.*

Support Person Enrollment

Program Enrollment

- Support persons can also be enrolled at any time via the web-based **Add Support Person Form**:
  - rimrock.gomohealth.care/enroll/add-support/



Message Tracks – True North

Program Enrollment

Based on Enrollment Form indications, True North clients and their support persons may be enrolled into the following message tracks and will begin to receive personalized, program-specific text messaging from the shortcode 43386:

Phase	Client	Support Person
Phase 1	*Phase 1 clients will not receive messaging until they progress to Phase 2/3 because they don't have phone access.*	Support Person Messaging
Phase 2/3	• Phase 2/3 messaging • Parenting if children under 18 • GoMo Chat	Support Person Messaging

Message Tracks – Silverleaf

Program Enrollment

Based on Enrollment Form indications, Silverleaf clients and their support persons may be enrolled into the following message tracks and will begin to receive personalized, program-specific text messaging from the shortcode 43386:

Program	Client	Support Person
Silverleaf Day	• Silverleaf Day • Court track • Parenting if children under 18 • GoMo Chat	Support Person Messaging
Silverleaf IOP	• Silverleaf IOP • Court track • Parenting if children under 18 • GoMo Chat	Support Person Messaging
Silverleaf Continuing Care	• Silverleaf Continuing Care • Court track • Parenting if children under 18 • GoMo Chat	

Courts:

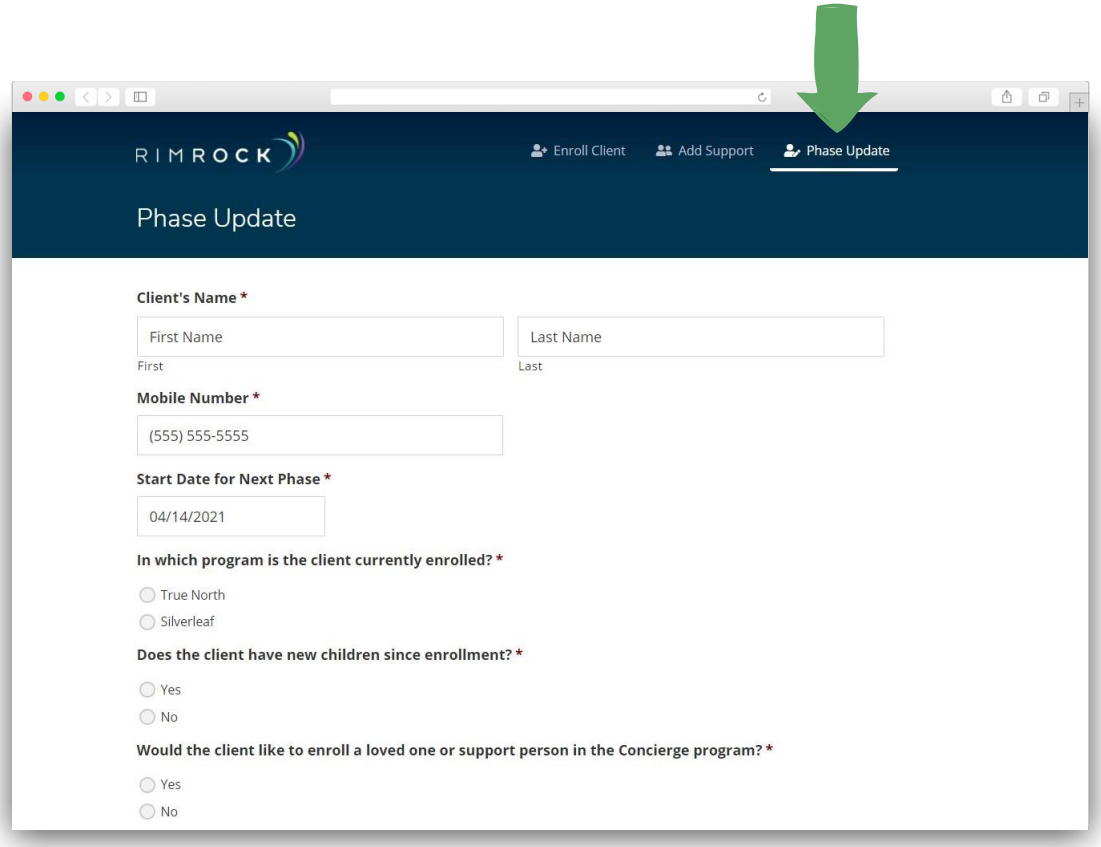
- Co-occurring Court
- Family Recovery Court
- Felony DUI Court (STEER)
- Misdemeanor Court (Drug, DUI)
- ICWA Court (Indian Child Welfare Act)
- Pilot Court
- Veteran Court (CAMO)

Phase Updates

Phase Update Form

Phase Updates

- When a client who is an existing participant of the Rimrock Concierge program completes a phase of the True North or Silverleaf program, a Rimrock staff member needs to visit the **Phase Update Form** to indicate the client's new status:
  - rimrock.gomohealth.care/enroll/update



Phase Update Form

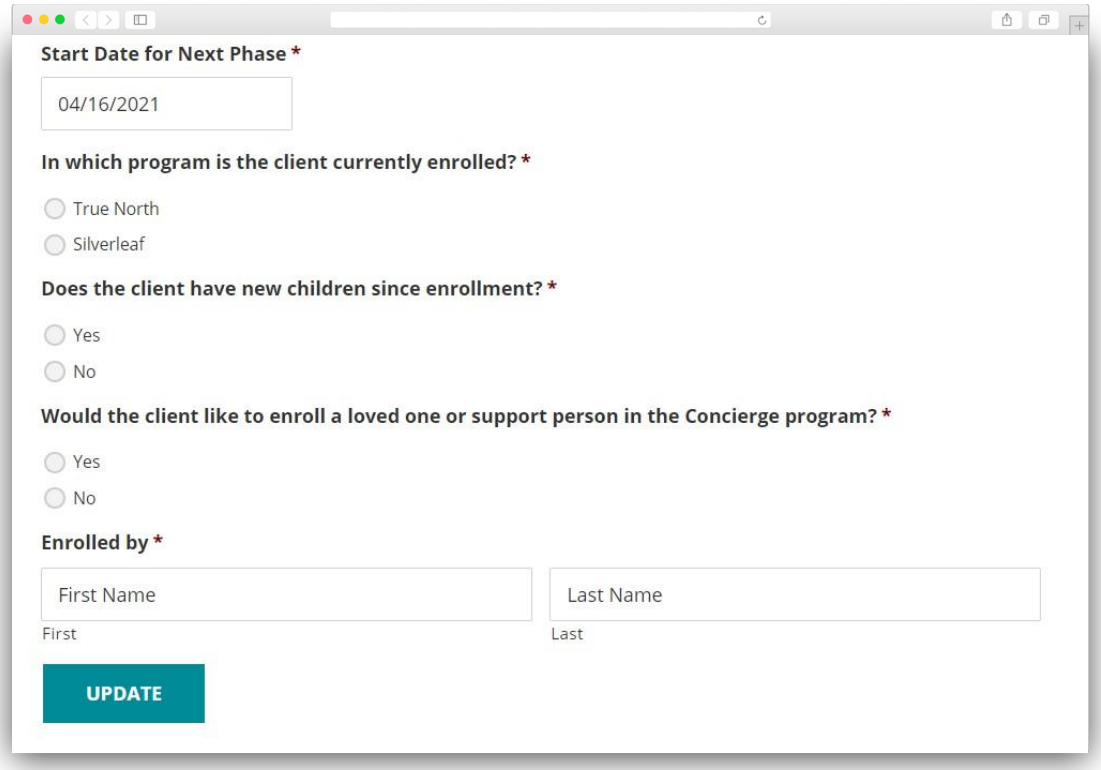
Phase Updates

- Clients, in addition to their support persons, are enrolled in:*
  - Next phase regimen

    or

  - Corresponding post-program regimen
- Clients can also enroll in the Parenting Track by indicating they have children under 18, or enroll another support person.

**The Phase Update Form will only enroll existing participants in new message regimens. New participants must be enrolled via the Enrollment Form.*



Start Date for Next Phase *

04/16/2021

In which program is the client currently enrolled? *

- True North
- Silverleaf

Does the client have new children since enrollment? *

- Yes
- No

Would the client like to enroll a loved one or support person in the Concierge program? *

- Yes
- No

Enrolled by *

First Name — First

Last Name — Last

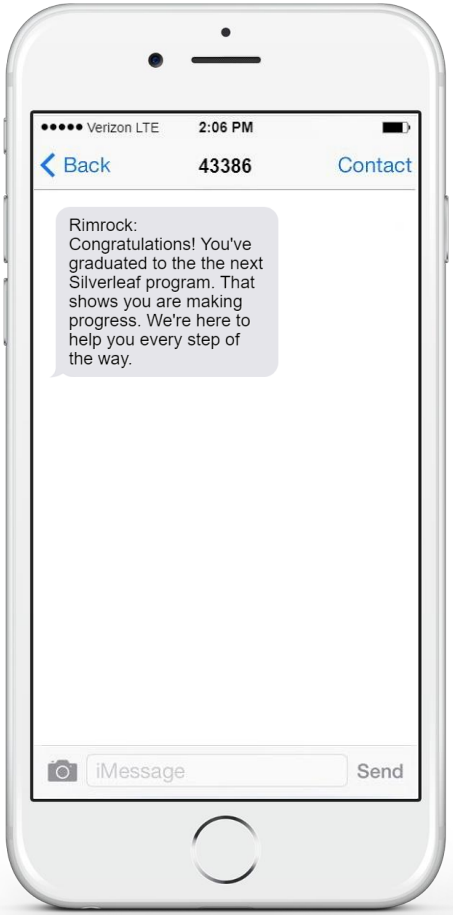
UPDATE

Transitional Messaging

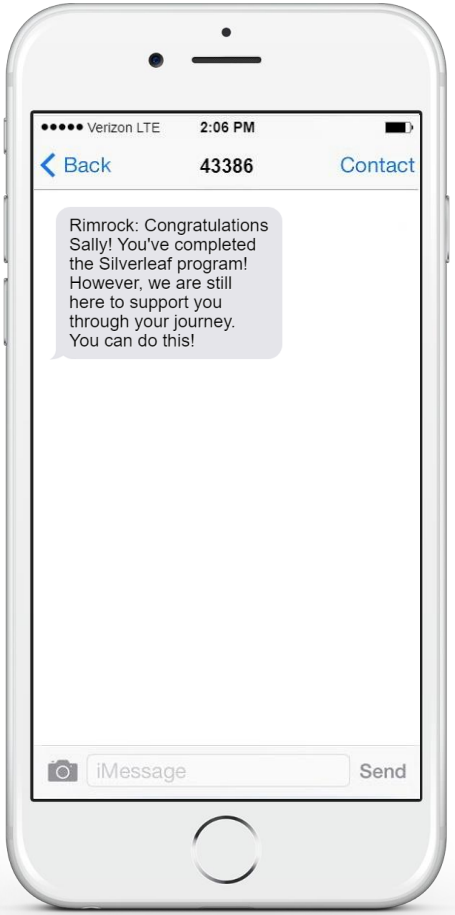
Phase Updates

- Messaging at the start of each True North and Silverleaf regimen congratulates the client and welcomes them to the new phase.
- Messaging throughout the True North and Silverleaf Post-Program tracks provides continued support and resources to help with adjusting to life beyond the program and their newfound independence.
  - The Post-Program tracks continue to send out the How Are You Doing Survey once per month.

A congratulatory note will be sent as the participant's next scheduled 7:00pm message.



Transition to Silverleaf IOP track



Completion of Silverleaf program

Program Content

Evidence-based content grounded in behavioral science principles

Addiction

- Recovery
- Urge Management
- Relapse Prevention

Cognitive Bias

- Thinking Errors
- Emotional Regulation
- Shame Resilience

Skills and Readiness

- Court
- Parenting and Caregiver
- Communication

Improvement

- Healthy living
- Self-care
- Mindfulness

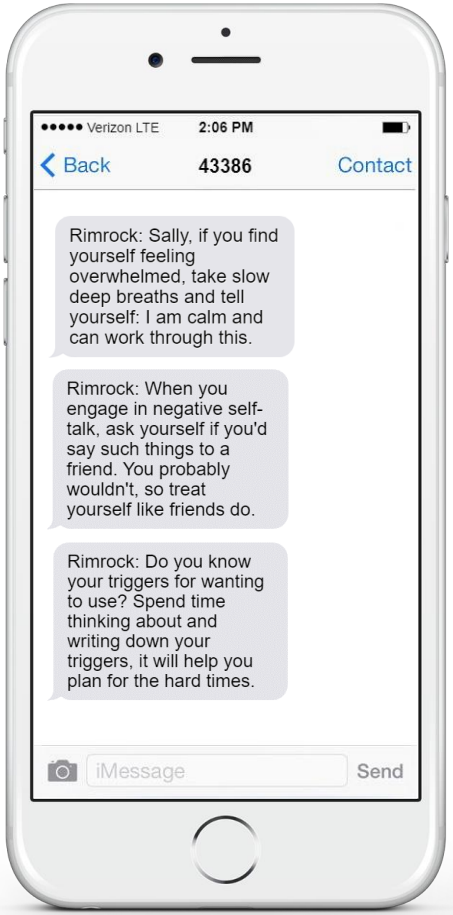
Silverleaf and True North

Program Content

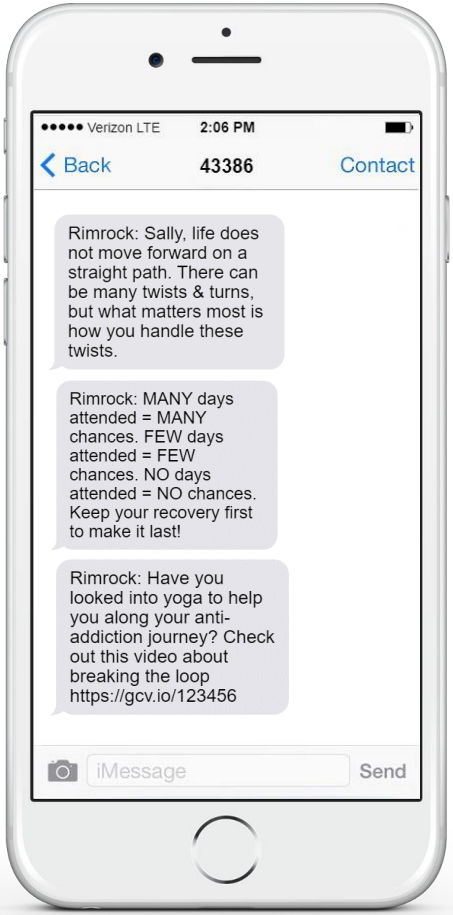
- All participants will receive messaging from either the Silverleaf or True North tracks.

1 message every day	7:00pm MT

- Messages include supportive content specific to the client's Silverleaf or True North phase and personalized to their name.
- Some messages contain links to additional program materials and external resources.



Silverleaf Client

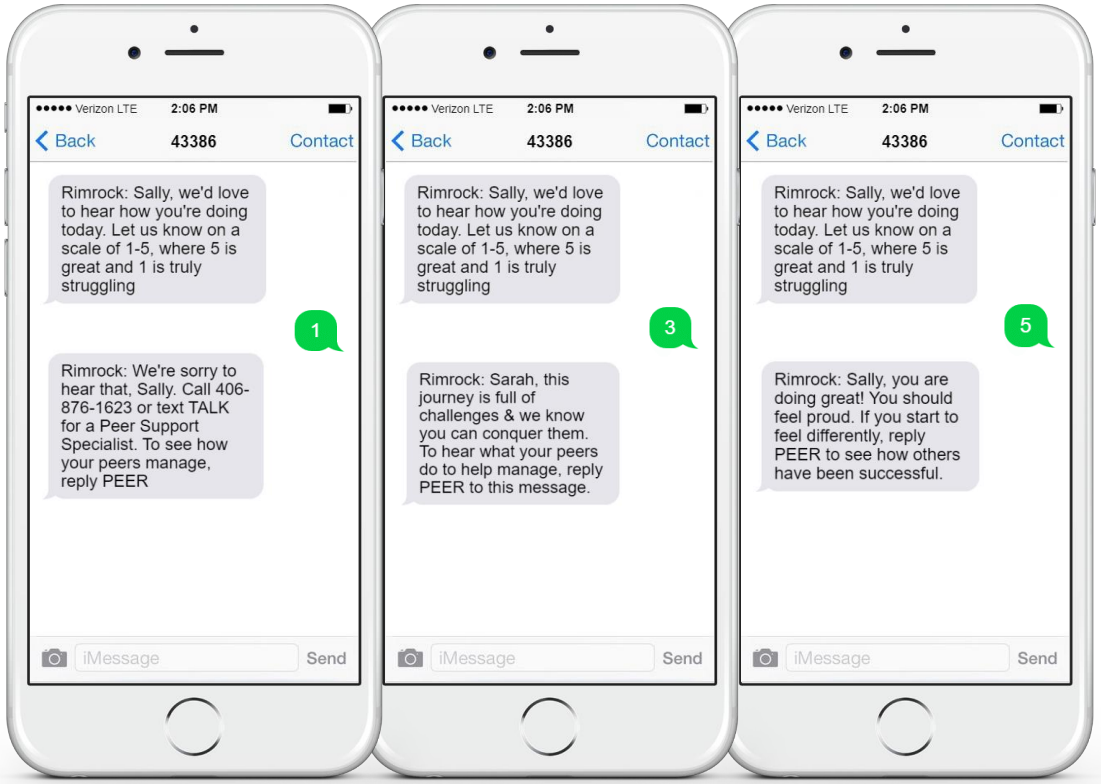


True North Client

How Are You Doing Survey

Program Content

- Once a week through the True North and Silverleaf message regimens, the program asks the client how they are doing and prompts a response on a scale from 1 to 5.
- The client's response will trigger one of three potential follow-ups:
  - **1 or 2** provides contact information for Peer Support and triggers an automatic escalation to Rimrock staff.*
  - **3** acknowledges the client's challenges and offers a way to cope.
  - **4 or 5** celebrates the client's well-being and may suggest a program resource to continue the trend.



** See Escalations for more details.*

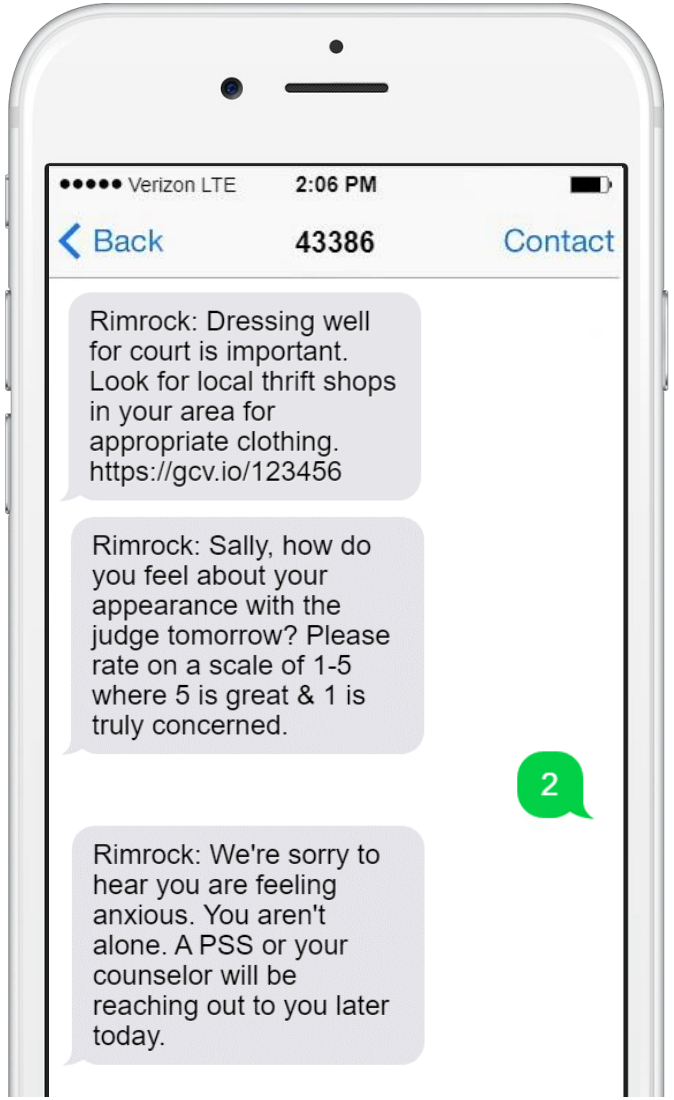
Silverleaf Courts

Program Content

- Clients in the Silverleaf program will additionally be enrolled in court-specific messaging related to the court they attend (indicated on the Enrollment Form).

1 message the morning prior to court day each week	8:45am MT

- Once a month, the court message will ask the client how they are feeling about their court appearance the next day, prompting a response on a scale from 1 to 5 (similar to the HAYD Survey).
  - A **1 or 2** response provides contact information for Peer Support and triggers an automatic escalation to Rimrock staff.*



** See Escalations for more details.*

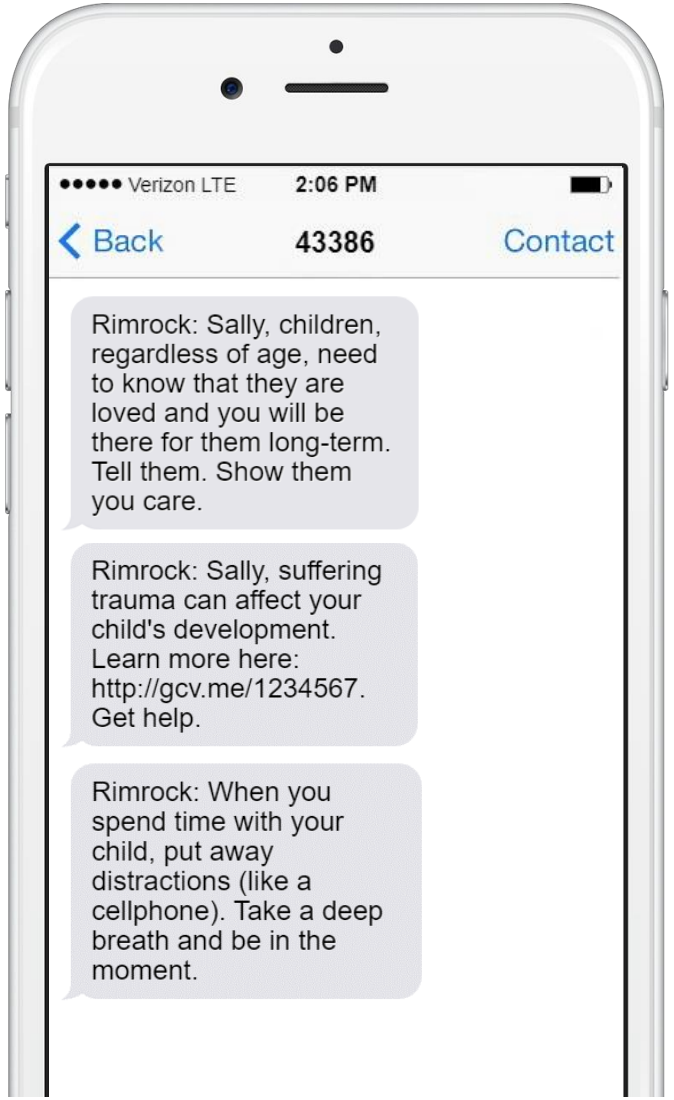
Parenting

Program Content

- Clients of either program who indicate on the Enrollment Form or Phase Update Form that they have children under 18 will be automatically enrolled in the Parenting track.

1 message every Monday and Friday	12:00pm MT

- The Parenting track provides support and resources designed for parents with kids of all ages, including content specific to children who may be affected by trauma resulting from their parent's addiction.



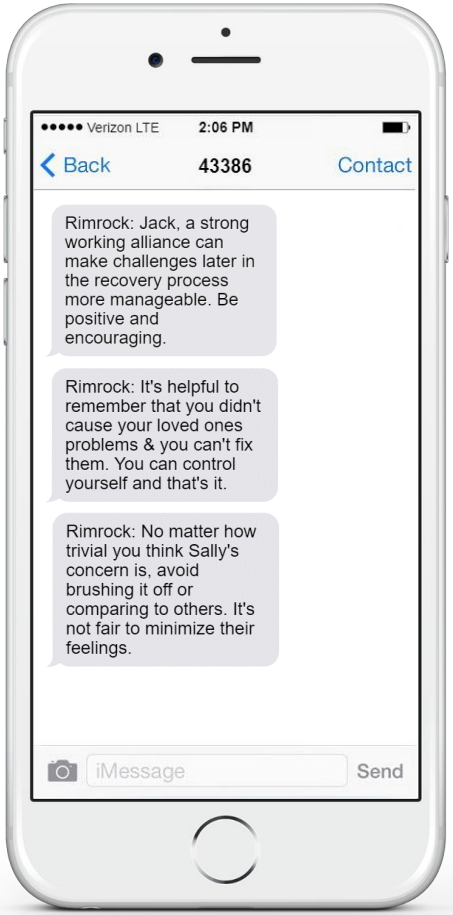
Support Persons

Program Content

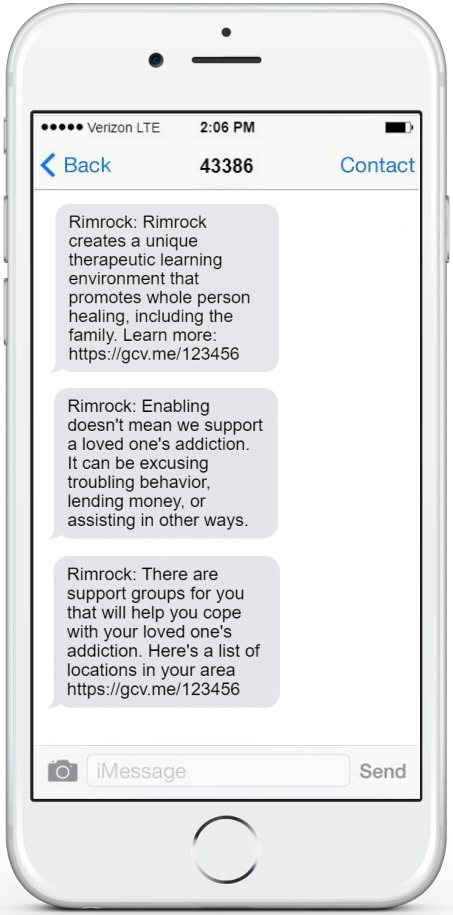
- If a client chooses to enroll a Support Person, the support person will automatically be placed into a message regimen that aligns with the client's program and phase.

2 messages per week	12:00pm MT

- The Support Person regimens provide tips and advice on supporting a loved on through the recovery journey, in addition to insight into their loved one's progress, information on Rimrock's Family Week, and resources to support the support person's own well-being.



Silverleaf Support Person

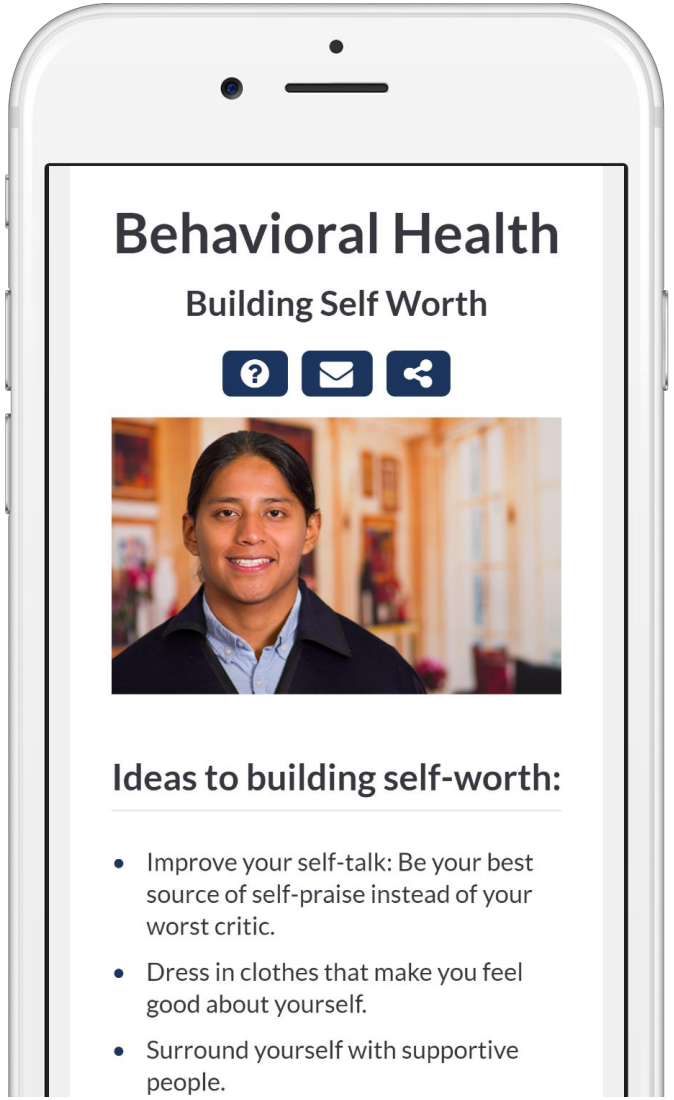


True North Support Person

Rimrock Companion

Program Content

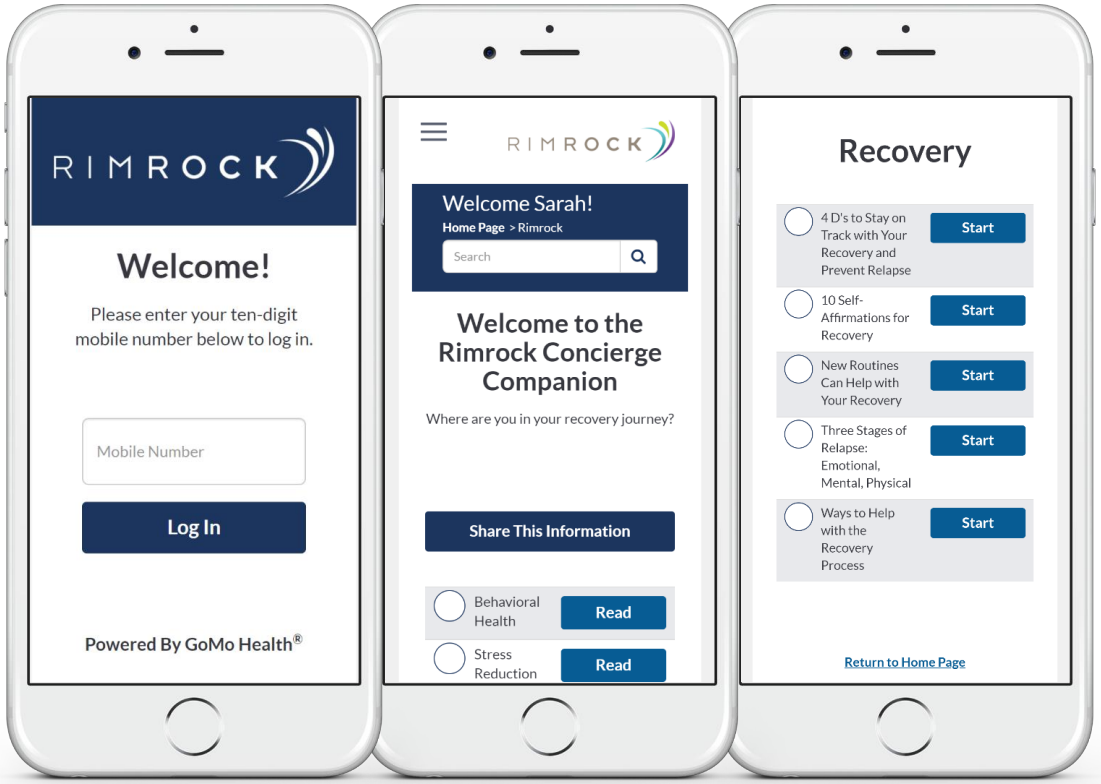
- In all message regimens, some messages contain links to additional resources.
- Some links direct to Care Pages housed in the Rimrock Companion, an online digital library of content, videos, and other resources.
- Clicking a message's Companion link will bring the client to a Care Page with more in-depth information on the message topic.



Companion Pages

Program Content

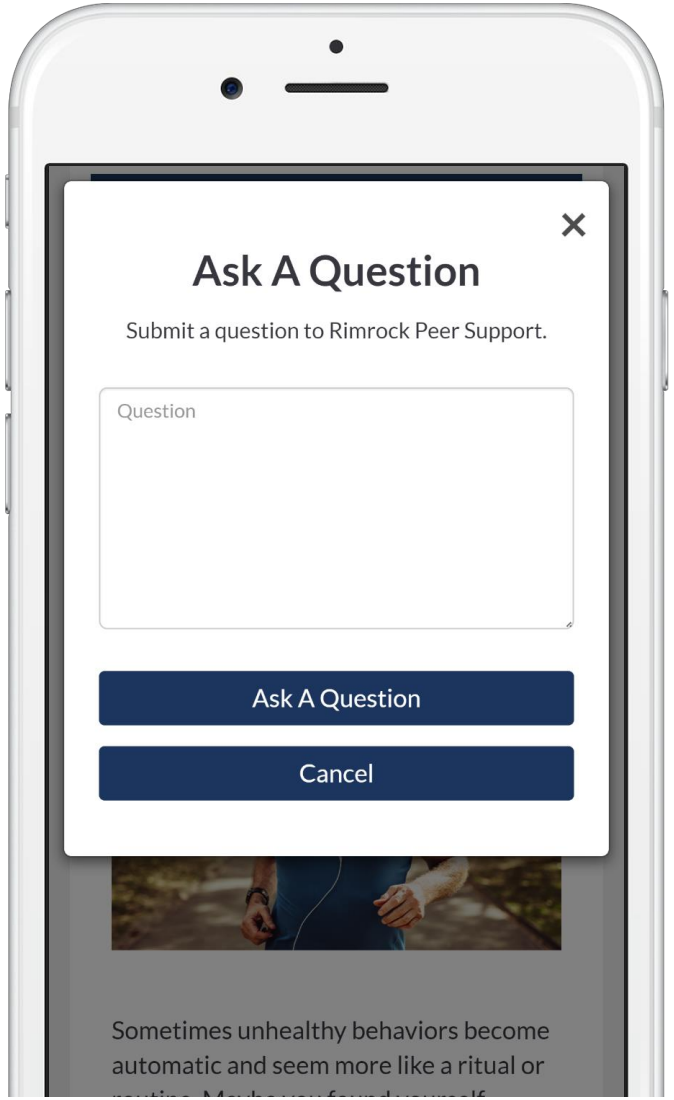
- The Companion can also be accessed at any time by directly visiting the Companion URL and logging in with the client's or support person's enrolled mobile number:
  - rimrock.gomocompanion.com
- Content topics include:
  - Behavioral Health
  - Stress Reduction
  - Health and Wellbeing
  - Recovery
  - Parenting
  - Peer Videos
  - Peer Support
  - Family Week



Ask a Question Feature

GoMo Chat

- Enrolled Rimrock Clients can also submit questions to Peer Support directly through the Rimrock Companion's Ask a Question Feature.
- If a client has a question related to or initiated by a Companion Care Page, the client can easily submit a message by selecting the question icon located at the top of each page.
- In the pop-up box, the client can type and submit their question, which will be automatically routed to GoMo Chat for Rimrock staff to respond via SMS.*

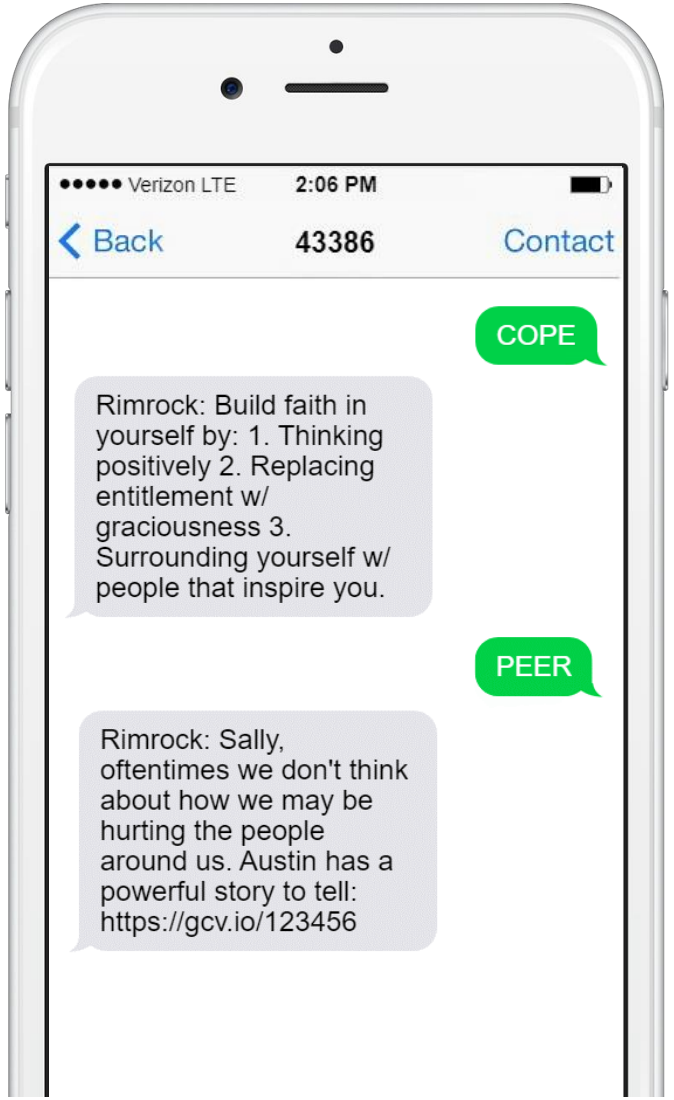


** See GoMo Chat for more details.*

Keywords

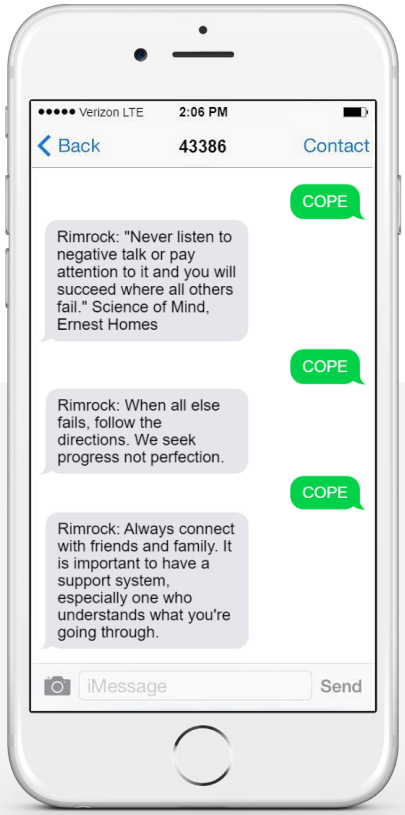
Program Content

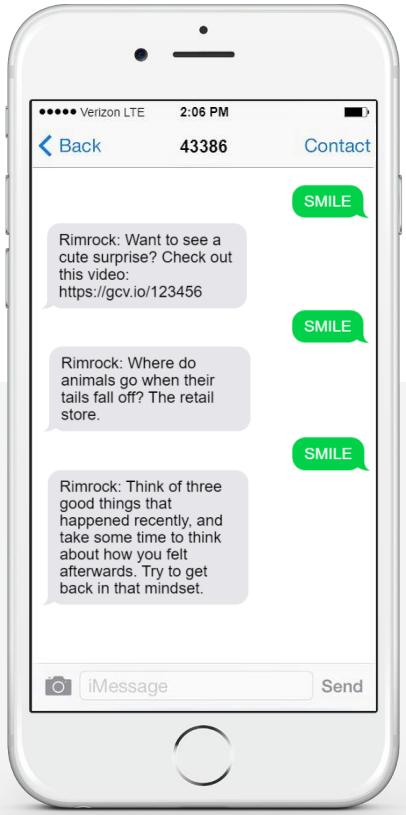
- In addition to the regular and automated regimen messaging, clients and support persons can prompt in-the-moment support at any time by texting one of the program keywords into the shortcode **43386**.
  - **COPE** prompts a message with suggested coping strategies to deal with challenging situations.
  - **PEER** prompts a message with a story or video from others who have had similar experiences.
  - **SMILE** prompts a message designed to make the client/support person smile.
  - **SUPPORT** prompts a link to a supportive resource.
  - **TALK** requests a call from a Peer Support Specialist.*

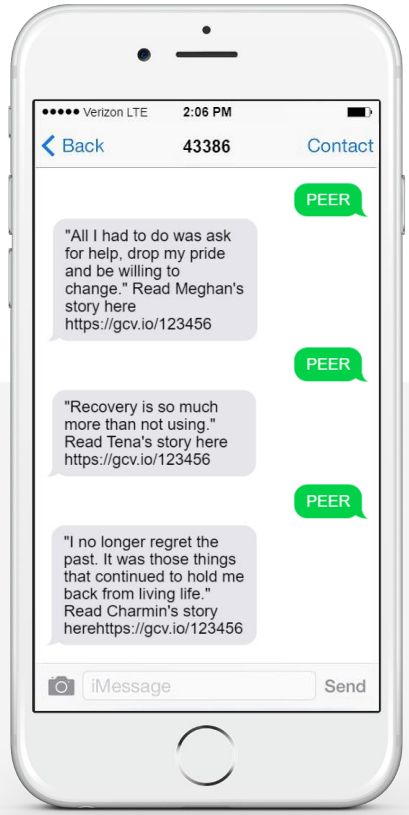


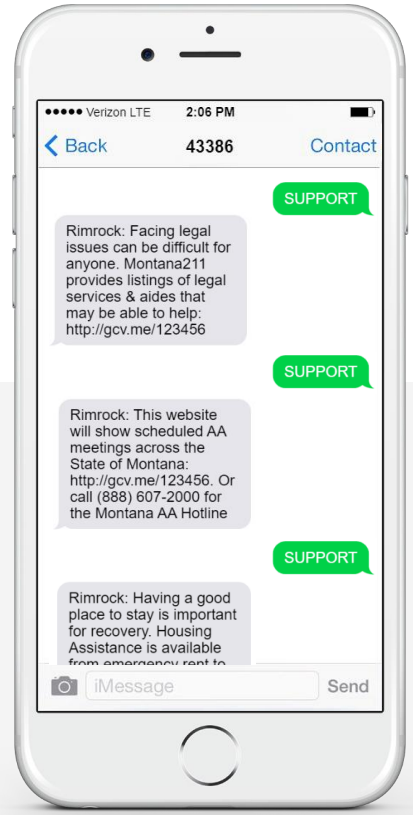
** See Escalations for more details.*

Keyword Examples







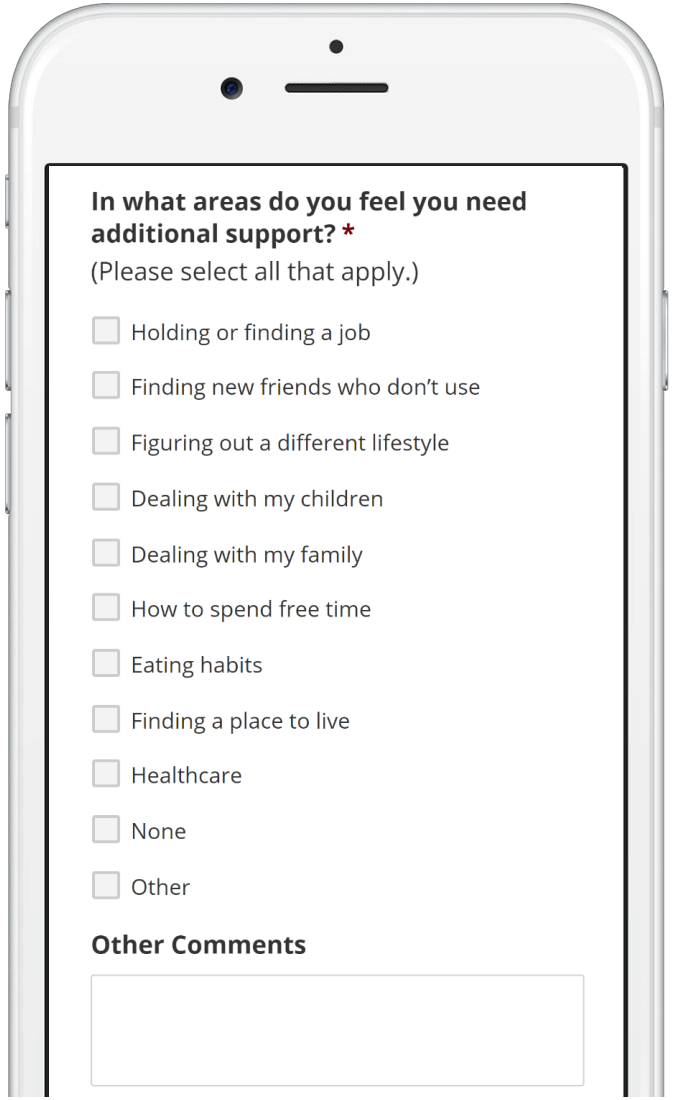


Quality of Life Survey

Program Content

- Every 3 months, each client receives a link to the Rimrock Quality of Life Survey.
  - rimrock.gomohealth.care/qol
- The client is prompted to click the link and complete the survey, which asks questions related to the client's current outlook, confidence in managing their lives, and access to resources.
- The survey offers an opportunity to request additional support in several areas. Any indications are captured and securely emailed to Rimrock staff to prompt outreach.*

Clients who complete the survey will receive a $5 coffee card reward.

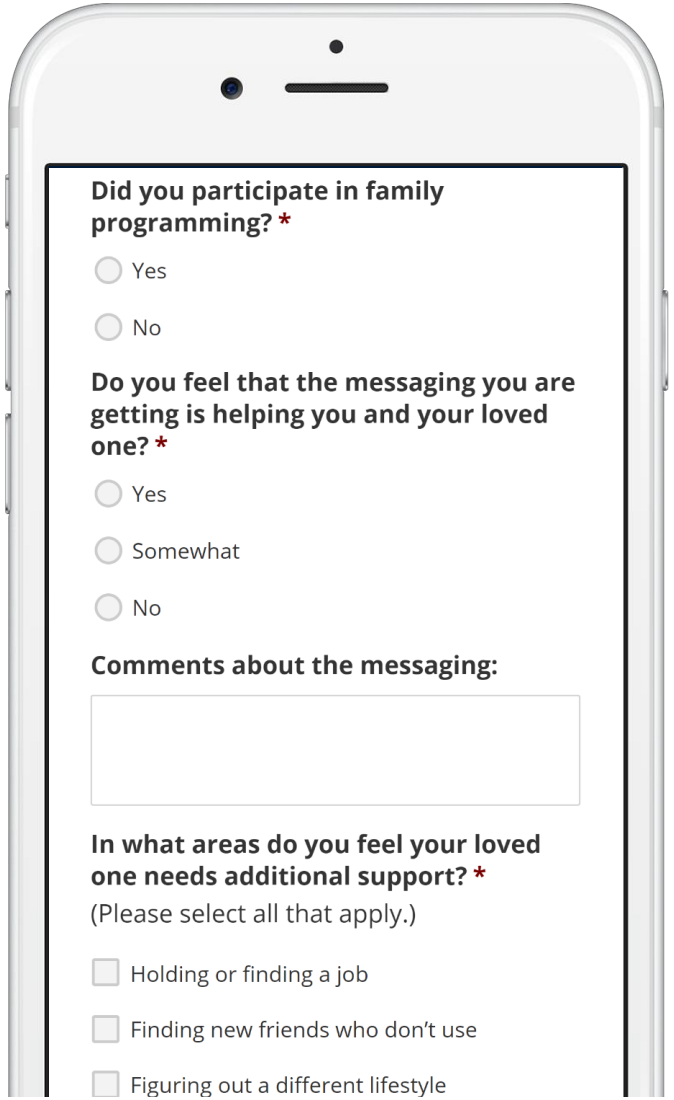


** See Escalations for more details.*

Support Person Survey

Program Content

- Every 3 months, each support person receives a link to the Rimrock Support Person Survey.
  - rimrock.gomohealth.care/support
- Questions mirror the client QOL questions from the support person's point of view.
- The survey offers an opportunity for the support person to request additional support for the client in several areas. Any indications are captured and securely emailed to Rimrock staff to prompt outreach.*



** See Escalations for more details.*

Escalations

Secure Email Notifications

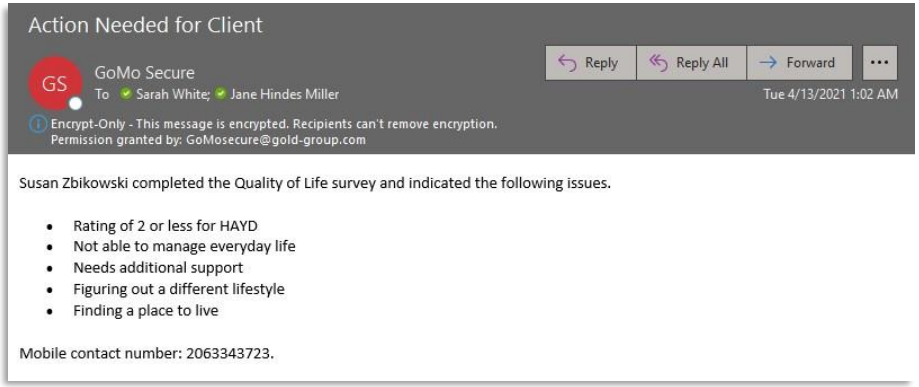
Escalations

- Certain responses to program surveys will prompt secure email escalations to Rimrock staff containing the participant's name, indicated issue(s), and mobile number.

From email:
gomosecure@gold-group.com

To email:
peersupportgroup@rimrock.org
KDuke1@rimrock.org (Silverleaf only)

Subject:
Action Needed for Client

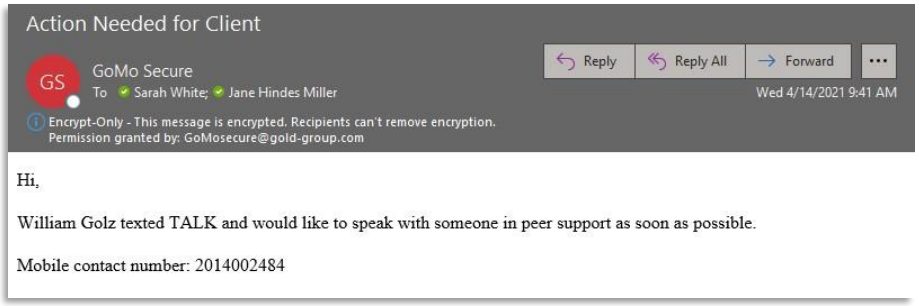

Action Needed for Client

GS GoMo Secure
To Sarah White; Jane Hindes Miller
Reply | Reply All | Forward
Tue 4/13/2021 1:02 AM
Encrypt-Only - This message is encrypted. Recipients can't remove encryption.
Permission granted by: GoMosecure@gold-group.com

Susan Zbikowski completed the Quality of Life survey and indicated the following issues.

- Rating of 2 or less for HAYD
- Not able to manage everyday life
- Needs additional support
- Figuring out a different lifestyle
- Finding a place to live

Mobile contact number: 2063343723.


Action Needed for Client

GS GoMo Secure
To Sarah White; Jane Hindes Miller
Reply | Reply All | Forward
Wed 4/14/2021 9:41 AM
Encrypt-Only - This message is encrypted. Recipients can't remove encryption.
Permission granted by: GoMosecure@gold-group.com

Hi,

William Golz texted TALK and would like to speak with someone in peer support as soon as possible.

Mobile contact number: 2014002484


Action Needed for Client

GS GoMo Secure
To Sarah White; Jane Hindes Miller
Reply | Reply All | Forward
Mon 4/12/2021 9:34 AM
Encrypt-Only - This message is encrypted. Recipients can't remove encryption.
Permission granted by: GoMosecure@gold-group.com

Hi,

Deena Cohen has concerns about tomorrow's court session and indicated that they would like follow-up from Peer Support.

Mobile contact number: 7326747769

Escalation Triggers

Escalations

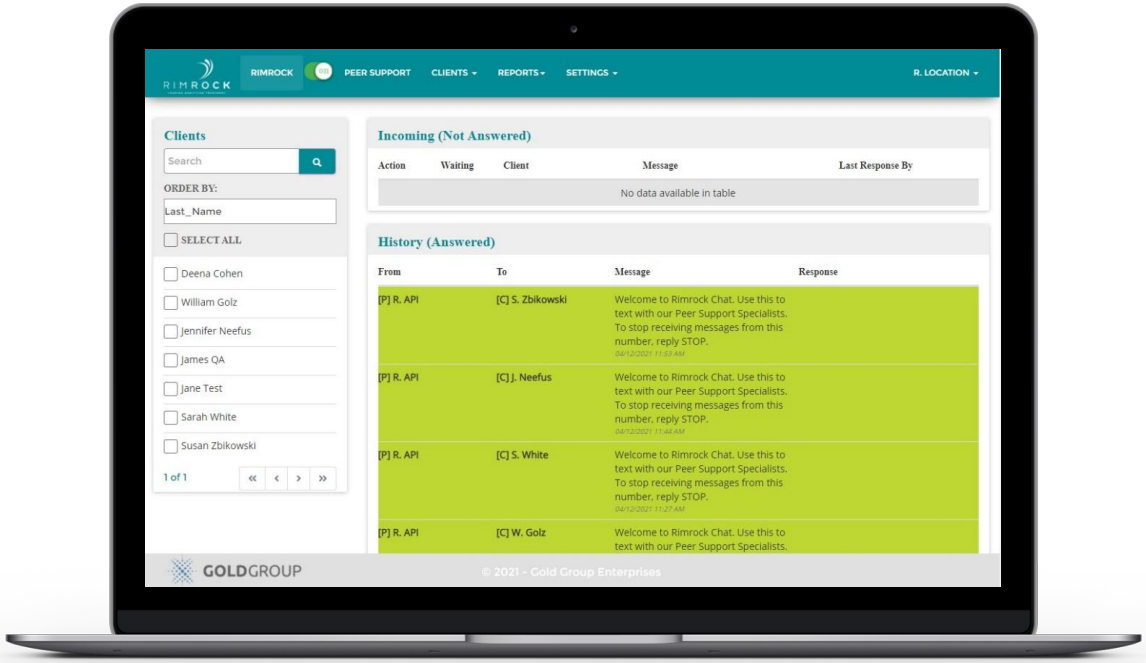
Escalation Source	Escalation Trigger
How Are You Doing Survey	• 1 or 2 response
How Are You Feeling About Court Survey	• 1 or 2 response
TALK Keyword	• Participant texts “TALK”
Quality of Life Survey	• 1 or 2 response on well-being (Question 2) • Disagree or strongly disagree on access to support and resources (Question 3b) • Indicates a need in additional support area(s) (Question 4)
Support Person Survey	• 1 or 2 response on client outlook (Question 1) • 1 or 2 response on how client is doing (Question 2) • Indicates a need in additional support area(s) (Question 9)

GoMo Chat

GoMo Chat Introduction

GoMo Chat

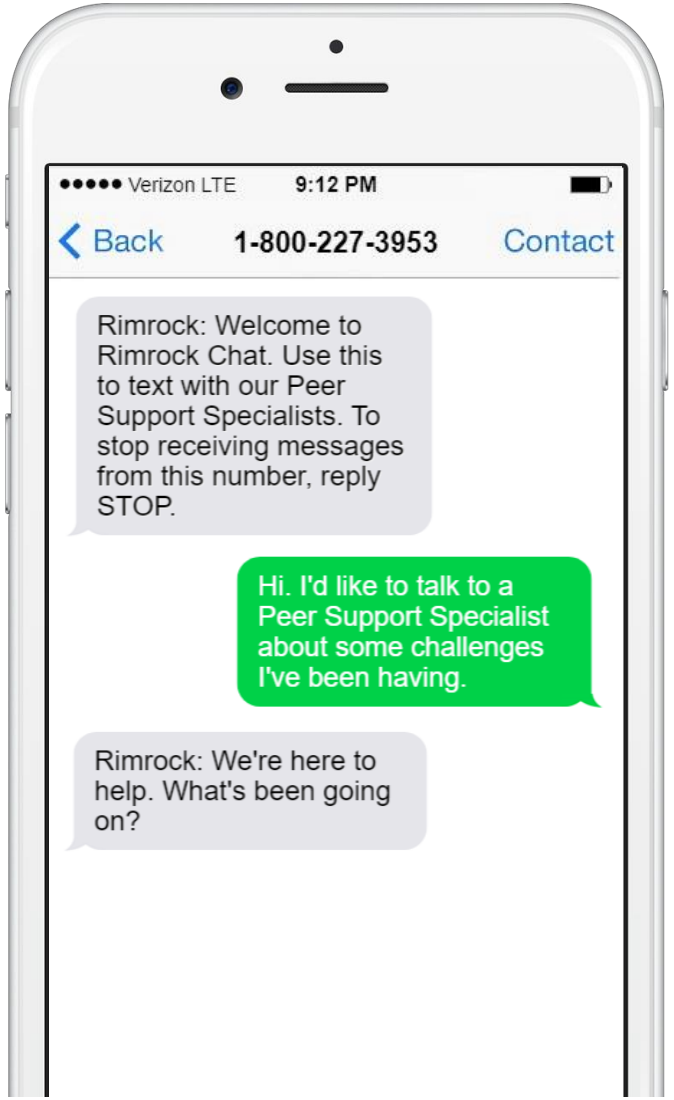
- GoMo Chat™ is a cloud-based tool that allows one-on-one communication with Rimrock clients via text message in real-time.
- GoMo Chat is implemented for Rimrock to use in contacting clients to check in, follow up on escalations triggered through program surveys, and otherwise communicate with participants.
- Clients will be automatically enrolled in GoMo Chat upon program enrollment.
- Rimrock staff can initiate or reply to client messages through Rimrock's web-based Chat portal.



Messaging

GoMo Chat

- Through GoMo Chat, Rimrock clients can chat directly one-on-one with Rimrock Peer Support Specialists and staff through SMS or Secure Chat.
- Members can text directly into Rimrock's toll-free Chat number to connect with a staff member:
  - **1 (800) 227-3953**
- Conversations are standard SMS messages by default, but the Rimrock staff member can toggle on a secure switch as needed to discuss sensitive information.
- Rimrock can set open and closed hours for the Chat inbox, notifying clients when staff is actively monitoring the messages.
- No app is necessary to download for client or staff.



Program Awareness

Rimrock Concierge Program Brochure

Program Awareness

- In support of the Rimrock Concierge Program launch, GoMo has developed a bifold brochure to be made available throughout Rimrock for client awareness.
- The brochure is geared towards clients and their loved ones to introduce the program messaging, Companion, and GoMo Chat.

Rimrock Concierge Program Brochure

Program Awareness

- The back side of the brochure serves as a handy reminder of all program keywords that can be texted in to trigger in-the-moment support.

Reporting

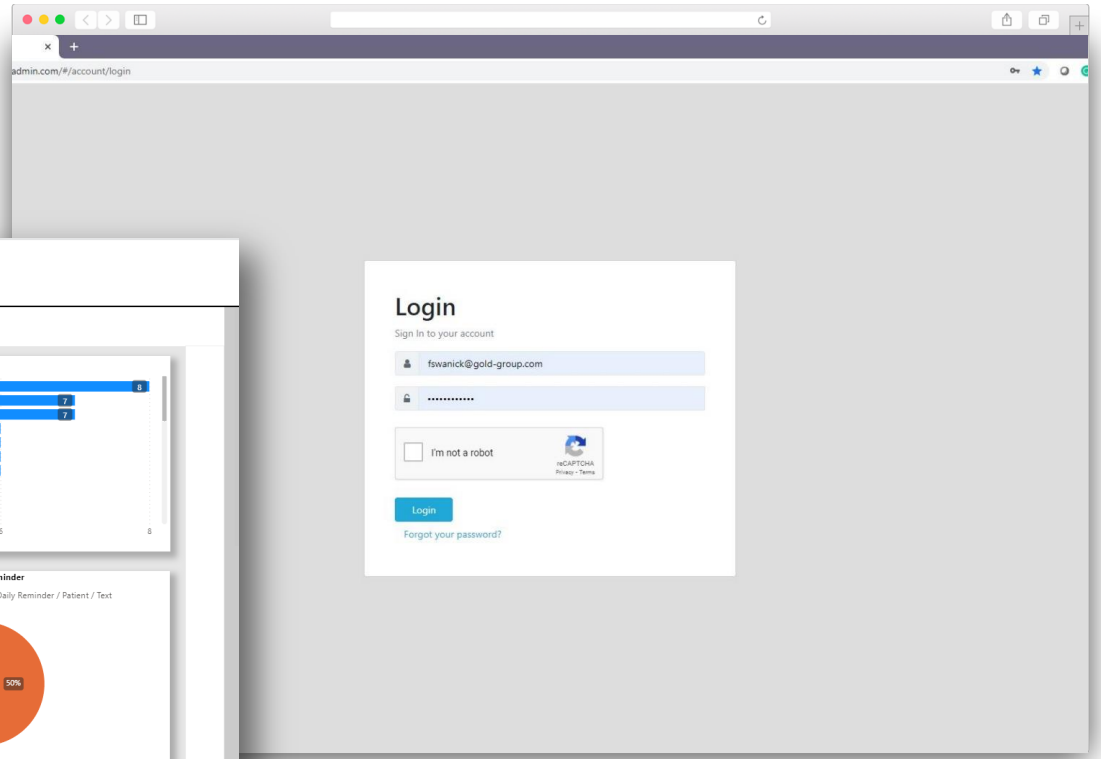
Reporting and Outcomes

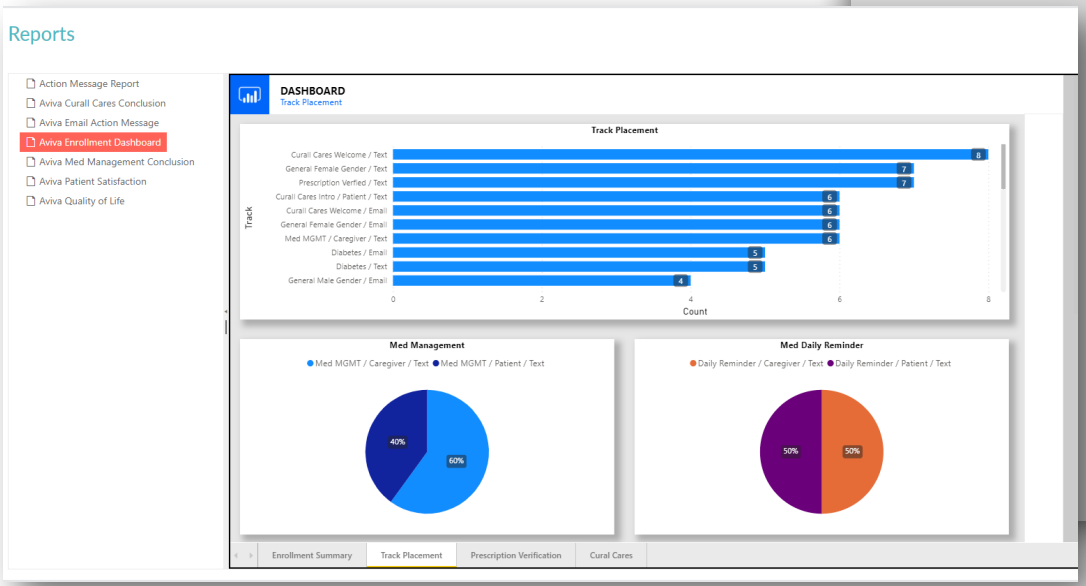
- All data and feedback from participants is tracked and analyzed.
  - Accessible 24/7
  - Used for individual participant tracking and analysis of trends
- Available reports include:

- *Enrollment Report*
- *Action Message Survey Report*
- *Quality of Life Survey Report*
- *Support Person Survey Report*
- *Client Report*
- *Escalation Report*
- *Incoming Message Detail*
- *Subscriber Detail*
- *HELP and STOP Detail*
- *Keyword Report*
- *Outgoing Message Report*
- *Shortlink Report*
- *Opt-Out Report*
- *Regimen Report*
- *Subscriber Stats Report*

Reporting and Outcomes

- Specified staff members will have separate logins created to access reporting:
  - gomoplatform.com





Sample dashboard.

Questions?

Contact Information

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jmiller@gomohealth.com

www.gomohealth.com

Cognitive Neuroscience Society
Annual Meeting Program 2009

A supplement of the Journal of Cognitive Neuroscience

ISSN 1096-8857

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www.cogneurosociety.org

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Cover Photo

Table of Contents

Mark your calendars now...
the 17th Annual
Cognitive Neuroscience Society Meeting
will be held at the Hilton Bonaventure Hotel
in Montreal, Canada
April 17 - 20, 2010

Schedule of Events

Saturday, March 21

9:00 am - 5:00 pm	Satellites
12:00 - 5:00 pm	Exhibitor Check-In, *Pacific Concourse*
2:30 - 7:30 pm	Onsite & Pre-Registration Check In, *Grand Ballroom Foyer*
3:00 - 5:00 pm	Slide sessions 1 and 2, *Grand Ballrooms A & B*
5:00 - 6:00 pm	Reception, *Grand Ballroom Foyer*
5:00 - 7:30 pm	Exhibits on Display, *Pacific Concourse*
5:30 - 7:30 pm	Poster Session A, *Pacific Concourse*

Sunday, March 22

7:30 am - 7:00 pm	Onsite & Pre-Registration Check In, *Grand Ballroom Foyer*
8:00 am	Coffee Service, *Pacific Concourse*
8:00 - 10:00 am	Poster Session B, *Pacific Concourse*
8:00 am - 7:00 pm	Exhibits on Display, *Pacific Concourse*
10:00 am - 12:00 pm	Symposium Session 1, *Grand Ballroom A*
	Slide Session 3, *Grand Ballroom B*
12:00 - 1:00 pm	Lunch Break
1:00 - 3:00 pm	Poster Session C, *Pacific Concourse*
2:30 pm	Coffee Service, *Pacific Concourse*
3:00 - 4:00 pm	Announcement of the Young Investigator Awards, *Grand Ballroom*
	15th Annual George A. Miller Prize in Cognitive Neuroscience, *Grand Ballroom*
4:00 - 5:00 pm	GAM Reception, *Grand Ballroom Foyer*
5:00 - 7:00 pm	Poster Session D, *Pacific Concourse*

Monday, March 23

8:00 am - 7:00 pm	Onsite & Pre-Registration Check In, *Grand Ballroom Foyer*
8:00 am	Coffee Service, *Pacific Concourse*
8:00 - 10:00 am	Poster Session E, *Pacific Concourse*
8:00 am - 7:00 pm	Exhibits on Display, *Pacific Concourse*
9:00 - 9:40 am	YIA Special Lecture 1, *Grand Ballroom A*
10:00 am - 12:00 pm	Symposium Session 2, *Grand Ballroom A*
	Slide Session 4, *Grand Ballroom B*

12:00 - 1:00 pm	Lunch Break
1:00 - 3:00 pm	Poster Session F, *Pacific Concourse*
2:30 pm	Coffee Service, *Pacific Concourse*
3:00 - 5:00 pm	Symposium Session 3, *Grand Ballroom A*
	Slide Session 5, *Grand Ballroom B*
5:00 - 7:00 pm	Poster Session G, *Pacific Concourse*

Tuesday, March 24

8:00 am - 5:00 pm	Onsite & Pre-Registration Check In, *Grand Ballroom Foyer*
8:00 am	Coffee Service, *Pacific Concourse*
8:00 - 10:00 am	Poster Session H, *Pacific Concourse*
8:00 am - 7:00 pm	Exhibits on Display, *Pacific Concourse*
9:00 - 9.40 am	YIA Special Lecture 2, *Grand Ballroom A*
10:00 am - 12:00 pm	Symposium Session 4, *Grand Ballroom A*
	Slide Session 6, *Grand Ballroom B*
12:00 - 1:00 pm	Lunch Break
1:00 - 3:00 pm	Symposium Session 5, *Grand Ballroom A*
	Slide Session 7, *Grand Ballroom B*
2:30 pm	Coffee Service, *Pacific Concourse*
3:00 - 5:00 pm	Poster Session I, *Pacific Concourse*

Visit the CNS 2009 Exhibitors in the Pacific Concourse

ADInstruments

American Psychological Association

BIOPAC Systems, Inc.

Cambridge Electronic Design, Ltd.

Cedrus Corporation

Compumedics USA Ltd.

Cortech Solutions, Inc.

Electrical Geodesics, Inc.

Electrode Arrays

Elsevier

Hitachi Medical Corporation

Integragen

Measurand Inc

Millisecond Software

NeuroFocus, Inc

NITRC: Neuroimaging Informatics Tools and Resources Clearinghouse

Noldus Information Technology

Northern Digital Inc.

Oxford University Press

Psychology Press

Psychology Software Tools, Inc.

Rogue Research, Inc.

SensoMotoric Instruments

Sinauer Associates, Inc.

The MIT Press

W. W. Norton & Company

Wiley-Blackwell

15th Annual George A. Miller Prize in Cognitive Neuroscience

Sunday, March 22, 2009, 3:00 - 4:00 pm, Grand Ballroom
Reception to follow, 4:00 - 5:00 pm, Grand Ballroom Foyer

The Cognitive Neuroscience Society is pleased to announce the recipient of the 2009 George A. Miller Prize in Cognitive Neuroscience:

Marcus Raichle, Ph.D., *Washington University School of Medicine in St. Louis*

The George A. Miller Prize in Cognitive Neuroscience was established in 1995 by the Cognitive Neuroscience Society and the James S. McDonnell Foundation to honor the career contributions of George A. Miller to cognitive neuroscience. The first 10 years of the prize were funded by generous support from the James S. McDonnell Foundation.

The prize is awarded to the nominee whose career is characterized by distinguished and sustained scholarship and research at the cutting-edge of cognitive neuroscience. Extraordinary innovation and high impact on international scientific thinking should be a hallmark of the recipient's work.

Each year a call for nominations for the George A. Miller Prize is made to the membership of the society. The recipient is selected by a committee with the approval of the society. The prize winner attends the annual meeting of the Cognitive Neuroscience Society and delivers the George A. Miller Lecture.

Young Investigator Award in Cognitive Neuroscience

Sunday, March 22, 2009, 3:00 - 4:00 pm, Grand Ballroom
(Immediately prior to the George A. Miller Award in Cognitive Neuroscience Lecture)

The Cognitive Neuroscience Society is pleased to announce the recipients of the 2009 Young Investigator Awards:

Lila Davachi, Ph.D., *New York University*

Clayton Curtis, Ph.D., *New York University*

The Young Investigator Awards in Cognitive Neuroscience recognizes outstanding contributions by scientists early in their careers. Two awardees are named each year by the Award Committee, and are honored at the Annual meeting of the Cognitive Neuroscience Society. Each award includes $500 to be used by the awardees toward travel costs to the meeting, or for any other purpose.

In addition to the ceremony, this year, the recipients will be giving a 30 minute talk at the CNS meeting.

YIA Special Lecture 1 – Dr. Lila Davachi

Monday, March 23, 2009, 9:00 - 9:40 am, Grand Ballroom A

FUNCTIONAL ARCHITECTURE OF THE HUMAN MEDIAL TEMPORAL LOBE MEMORY SYSTEM

How are memories formed? Approaches to this question have been based on distinctions between kinds of conscious experience or on psychological processes. While each of these approaches has its merits, it is also important to consider the anatomical inputs to and connectivity within the medial temporal lobe (MTL). Animal studies suggest that distinct regions of MTL cortex receive differential input from neocortical input structures that are associated with divergent roles in object and spatial cognition. This suggests a different viewpoint on the functional organization of the MTL such that distinct MTL cortical regions may participate in the encoding of domain-specific information while the hippocampus proper, which receives convergent input from these MTL cortical structures, contributes to the mnemonic binding of this input. In this talk, I will describe a series of studies that integrates anatomical and psychological theories to support a hybrid model of MTL function.

YIA Special Lecture 2 – Dr. Clayton Curtis

Tuesday, March 24, 2009, 9:00 - 9:40 am, Grand Ballroom A

A SINGLE CLASSIFIER PREDICTS THE DIRECTION OF SPATIAL ATTENTION, WORKING MEMORY, AND MOTOR INTENTIONS

We recently demonstrated that neural activity in the same frontal and parietal cortical areas persists when humans 1) maintain a location in working memory, 2) covertly maintain attention peripherally, and 3) maintain a spatially directed motor intention. We concluded that spatial working memory, attention, and intentions share a common neural mechanism that is implemented in these areas. To further test these conclusions, here, we use multivoxel pattern classification of fMRI data to test two hypotheses. First, we can predict the location of a working memory representation, the direction of covert attention, and the target of a motor intention based on the multivariate pattern of delay period activity. Indeed, we find that frontal and parietal cortex activity can correctly classify whether subjects are remembering, attending, and planning a movement to the right or left hemifields. Second, we show that the classifiers generalize across tasks. We trained classifiers on one task (e.g., working memory) and tested its predictive validity on the other tasks (e.g., spatial attention and motor intention). Remarkably, despite that subjects were performing a different task, we observe robust cross-task classification. A classifier trained to discriminate the position of a working memory representation can predict the direction of one's attention and the goal of one's motor intentions. These results suggest that the information contained within these areas during delay periods is not dependent on working memory, attention, or intentions. Instead, it argues that these areas implement a common mechanism that supports a variety of spatial cognitions.

CNSSA Social Night

Come and meet other students from the Cognitive Neuroscience Society and let's explore the city!

All students of the Cognitive Neuroscience Society are welcome to join us at the Hyatt Hotel Bar - The Eclipse Lounge at 7:30 p.m. on Saturday March 21st (after the poster session). Please wear your name-tags so other students can easily identify you. We will introduce everyone to each other and get acquainted, and around 8:30 p.m. we will head out to two local bar/restaurants:

Gordon Biersch
2 Harrison Street
San Francisco, CA 94105
Phone: (415) 243-8246
www.gordonbiersch.com

Palomino
345 Spear Street
San Francisco, CA 94105
Phone:(415) 512-7400
www.palomino.com

Both bars are walking distance from the hotel and from each other.

Please note that this is not a funded event and although there is no entrance fee for any of the places we are going to, you will have to pay for your own drinks and/or dinner.

Looking forward to you meeting you in San Francisco!

CNSSA Executives

Graduate Students Present

Eight to ten abstracts are chosen each year for CNS's Graduate Students Present (GSP) Award. The recipients are awarded a $500 travel award and present their 15 minute discussion on their research findings during the Cognitive Neuroscience Society Annual Meeting.

The GSP sessions will be scheduled and presented with the topically organized slide session that corresponds to the topic of their abstract. Presenters/Attendees are to check the Slide Presentation Schedule for complete presentation.

The Cognitive Neuroscience Society is pleased to announce the 2009 GSP Award Recipients:

Simon van Gaal, *University of Amsterdam, The Netherlands*

Jaap Munneke, *VU University, Amsterdam*

Andrew Butler, *Indiana University*

Gerrit Hirschfeld, *University of Muenster*

Dominique Vuvan, *University of Toronto, Canada*

Antonio Lara, *University of California, Berkeley*

Bradford Mahon, *Harvard University*

Amitai Shenhav, *Harvard University*

Julie L. Hall, *University of Michigan*

CNS Symposia

Symposia Session 1

Vertically Integrating Molecular-genetics, Cognitive Neuroscience, and Psychology

Sunday, March 22, 10:00 am - 12:00 pm, Grand Ballroom A

Chair: **Adam Green**

Speakers: **John A. Fossella, Andreas Papassotiropoulos, Joseph H. Callicott, Colin G. DeYoung**

Summary: Using cognitive neuroscience techniques to investigate neural expression of genetic variants is not only relevant for disease, it also has the potential to inform models of healthy cognitive function. The goal of this "cognitive neurogenetic" research is to integrate genes and their protein products with brain-based intermediate phenotypes and behavioral phenotypes. While the promise is considerable, so are the theoretical, statistical, and interpretive hazards. Psychological theory will be an indispensable pillar for building an understanding of gene-brain-behavior relationships, including rigorous development and validation of behavioral tasks. Another pillar will be the use of a systems approach that engages the complexity and non-specificity of gene effects as well as the interactions between and among genetic polymorphisms and brain systems. A third pillar is detailed molecular-genetic characterization of the effects of polymorphisms on gene expression. Fitting gene-(intermediate) phenotype associations to constraints established by molecular genetic data can help weed out spurious associations and provide the link to molecular-biological mechanisms that build and guide neural systems. This symposium will review vertically integrative approaches that help delineate the causal chain from gene to protein to brain to behavior, as well as statistical and methodological measures that help ensure meaningfully interpretable data.

ABSTRACTS

RECONCILING THE DEVELOPMENT OF EXECUTIVE CONTROL WITH MOLECULAR CHANGE *John A. Fossella, Mount Sinai School of Medicine* – It is well-known that children show gradual and protracted improvement in an array of behaviors involved in the conscious control of thoughtand emotion. Non-invasive neuroimaging in developing populations shows that activity in the developing cingulate cortex and fronto-striatal circuits are correlated with dissociable aspects of executive control. These brain regions, themselves, undergo protracted cellular, synaptic and molecular change in the first two decades of human development and, as such, have been implicated in mechanisms that link the development of brain and behavior. One approach to better understanding age-dependent changes in cognition is to consider the role of molecular genetic change. When developmental changes in gene expression are known, it is reasonable to begin to ask whether such changes contribute to observable correlates in brain structure, activity and behavior. A so-called imaging-genetic approach has been validated and replicated in paradigms that measure aspects of executive control in adults and is now well poised for studies on the development of executive control in children. We present a research strategy, based on a child-friendly version of the attention network task (ANT) that exploits evidence converging on the development of the anterior cingulate cortex (ACC) at the psychological, anatomical and molecular levels. The approach supports ongoing imaging-genetic experiments that are driven by explicit hypotheses.

GENETICS OF HUMAN MEMORY: UNDERSTANDING COMPLEXITY *Andreas Papassotiropoulos, Division of Molecular Psychology, University of Basel, Switzerland* – Experimental work in animals has shown that memory formation depends on a cascade of molecular events. In humans, heritability estimates of ~50% suggest that genetic factors have an important impact on this fundamental brain function. Therefore, our research aims at identifying memory-related genes and gene-clusters in humans and at translating the findings to memory-related disorders. Gene identification is done by combining unbiased genome-wide association studies, candidate gene approaches and gene clustering, and functional MRI (fMRI) in populations which are carefully tested for memory performance and for the presence or absence of diseases related to

impaired memory function. We show that variability of human memory performance is related to variability in genes encoding proteins of a core molecular signaling cascade. Functional magnetic resonance imaging reveals that this genetic profile correlates with activations in memory-related brain regions. The genome-wide association studies reveal the existence of novel genes significantly related to human memory performance, brain activation and to the risk for developing diseases related to memory impairment. The search for genes related to human memory processes provides new insights into the genetic basis of this cognitive ability and will ultimately promote the targeted treatment of memory disorders by identifying relevant genetic pathways in humans.

THE GENETIC UNDERPINNINGS OF PREFRONTAL NEURONAL INFORMATION PROCESSING: MECHANISTIC PROMISES AND METHODOLOGICAL PITFALLS *Joseph H. Callicott, National Institute of Mental Health* – Imaging genetics evolved from candidate gene studies demonstrating in-vivo effects of allelic variation tied to increased risk for complex heritable illnesses like schizophrenia. Following findings linking alterations in prefrontal cortex (PFC) information processing efficiency during working memory to allelic variations in healthy individuals, we pursued two questions related to future investigations, namely: 1) Do findings relating genes like COMT to PFC function generalize to all PFC-linked cognitive tasks or do task characteristics (e.g., cognitive demand, task complexity, or network relationships) influence these relationships? and 2) Are analyses that ignore multiple, related genetic variants (i.e., pathways) sufficient? Using fMRI data collected during two PFC tasks (Nback and DSST) in healthy subjects, we contrasted the information processing efficiency effects of a gene dependent on cognitive load (COMT) and one with general effects (the potassium channel gene KCNH2). We also contrasted gene interactions emerging in a predicted fashion from risk conferred by both genes (COMT x KCNH2) as opposed to those only evident when conditioned on risk in an interacting partner (RGS4 x COMT, GAD1 x COMT). Analyses incorporating metabolic pathway interactions and measured at differing cognitive loads should foster adaption from candidate gene to GWAS and beyond.

EXTERNALIZING BEHAVIOR AND COGNITION: DOPAMINE GENES AND COMPLEX ASSOCIATIONS *Colin G. DeYoung, University of Minnesota* – Externalizing behavior (encompassing aggression, antisocial behavior, impulsivity, and drug abuse) has been shown through studies of heritability to have a strong genetic basis. Molecular genetics and neuroimaging are crucial to understanding how genetic factors, interacting with environmental influences, shape the brain in ways that lead to the expression of externalizing behavior. A panel of genes related to the dopaminergic system has been associated with externalizing behavior and cognitive function. Here, we focus on the dopamine D4 receptor gene (DRD4) and the catechol-O-methyltransferase gene (COMT). The products of these two genes have strong influences on dopaminergic function in the prefrontal cortex, a key brain region for higher cognition and cognitive control. The research presented highlights the complexity of molecular genetic effects. For example, three studies show that variation in DRD4 moderates the typically negative association of externalizing behavior with IQ. Cognitive ability is strongly associated with working memory, and the neural circuits underlying working memory are influenced by variation in DRD4 and COMT. A large fMRI study (N =100) shows that genetic variation influences brain activity related to working memory and cognitive control and explores the relation of these effects to individual differences in externalizing behavior.

Symposia Session 2

Neurobiology of human language and its evolution: Primate perspectives

Monday, March 23, 10:00 am - 12:00 pm, Grand Ballroom A

Chair: **William D. Marslen-Wilson**

Speakers: **James K. Rilling, Angela D. Friederici, Asif A. Ghazanfar, William D. Marslen-Wilson**

Summary: The last decade has seen dramatic developments in our understanding of the neural and functional architecture of non-human primate systems that support the processing of complex auditory objects in general, and of conspecific vocal calls in particular. These developments are having an increasing influence on research into human language, making it possible to situate this work in a genuinely neurobiological and evolutionary context. This symposium explores these exciting developments in four presentations. Two speakers come from the non-human primate research community. The first speaker will discuss evolutionary changes in the neural pathways connecting frontal and temporal cortices in the macaque, chimpanzee and human brain, in areas critical for key human linguistic capacities. The second

speaker will focus on the multi-modal functional architecture underlying vocal communication in the macaque, and the implications of this for models of language evolution and function. Two further speakers come from human research exploring the cognitive neuroscience of language. The first focuses on left-hemisphere pathways supporting syntax, a faculty specific to humans, and combines research with adults and with children learning language. The second will focus on bi-hemispheric substrates for human language functions, placed in a broader primate perspective.

A B S T R A C T S

THE ARCUATE FASCICULUS IN HUMANS, CHIMPANZEES AND MACAQUES: IMPLICATIONS FOR THE EVOLUTION OF HUMAN LANGUAGE *James K. Rilling, Emory University, Anthropology* – The cognitive attribute that most obviously distinguishes humans from other primates is our capacity for language. Human language is supported by typically left hemisphere regions of temporal and frontal cortex that are connected by a white matter fiber tract known as the arcuate fasciculus. The objective of our research was to identify possible language-related specializations of the human brain by comparing human, chimpanzee and rhesus macaque brains in the region of the arcuate fasciculus with diffusion tensor imaging (DTI). Post-mortem and in vivo DTI scans were acquired from human, chimpanzee, and macaque subjects. Probabilistic tractography software (FSL) was used to reconstruct the arcuate pathway or its homologue in all three species. Tractography results suggest that connections linking the posterior superior temporal gyrus (Wernicke's region) and left inferior frontal cortex (Broca's region) exist in all three species. However, connections linking semantic processing areas of the middle temporal gyrus (BA 21, 37, 39) with Broca's area are only present in humans and chimpanzees, and are much more extensive in humans. These differences in the arcuate fasciculus language pathway between humans and chimpanzees may be relevant to the evolution of the neural substrates supporting human language.

NEURAL PATHWAYS RELEVANT FOR SYNTAX *Angela D. Friederici, Max Planck Institute for Human Cognitive and Brain Sciences* – Language has evolved from non-human to human primates and it develops in the child under external input in a predetermined manner. Both phylogenetic and ontogenetic findings indicate a strong biological foundation of language. Language functions are known to be based on the gray matter in circumscribed brain regions in the frontal and the temporal cortex. Recent findings, moreover, suggest that the white matter fibre tracts connecting these regions are of major importance for language. A number of different connections between the frontal and temporal have been identified, one of which appears to be particularly weak in non-human primates when compared to human adults. Here we show that this pathway, which connects the frontal and temporal cortex dorsally, is functionally relevant for the processing of syntactically complex sentences in the adult and that it develops only late during ontogeny. Moreover, the data indicate that children's comprehension, behaviorally not adult-like until the age of 7 years, relies on an alternative pathway. The dorsal pathway thus appears to be crucial for the adult human ability to comprehend syntactically complex sentences.

THE EMBODIED NATURE OF PRIMATE VOCAL COMMUNICATION *Asif A. Ghazanfar, Neuroscience Institute & Department of Psychology* – We are studying the neurobiology and vocal behavior of monkey agents as way of understanding the evolution and neurobiology of human communication. There are three principles that we use to guide our investigations. The first principle is that a primate's experience is profoundly multimodal and that multiple over-lapping and time-locked sensory systems enable it to learn, perceive and act in the vocal domain. Second, these communication-related sensory systems develop incrementally and their initial prematurity, and the particular trajectory they take during development, are critical to their final structure. The third principle is that sensory and motor systems will be coupled; that is, stable features of the brain, body and/or environment will be exploited to simplify vocal communication. Using these principles, our data suggest that vocal communication arises through the coupling of multiple oscillations that operate on different timescales. The facial dynamics and vocal acoustics of the signaler are linked and take the form of a coupled slow oscillation. These signals, in turn, couple with on-going oscillations in the receiver's auditory cortex. These auditory cortical oscillations then modulate faster oscillations, which in turn couple to parallel oscillations in other brain regions (including the frontal cortex and the superior temporal sulcus). We hypothesize that the oscillatory structure present in the facial dynamics and vocal acoustics exploit the structure of neural oscillations and that vocal communication emerges from these multiple oscillatory couplings. As each locus of coupling is a putative substrate for the evolution of language in humans, it is unlikely that language evolved solely through changes in key brain structures or the development of new ones.

BI-HEMISPHERIC FOUNDATIONS FOR HUMAN SPEECH AND LANGUAGE *William D. Marslen-Wilson, MRC Cognition and Brain Sciences Unit* – Current research into the biological foundations for human language emphasises the evolutionary development of specialised left hemisphere (LH) perisylvian networks, that seem to be unique to humans. This has led to undue neglect of the role of more general purpose bi-hemispheric processing capacities in supporting human spoken communication, even in the absence of syntax. In fact, functional neuro-imaging studies generally report significant RH as well as LH activity in spoken communication. Behavioral and neuro-imaging research on patients with major damage to LH perisylvian cortex reveals surprisingly effective RH capacities for lexical access from speech and for semantic-pragmatic interpretation. Recent neuro-imaging research in healthy populations, targeted at non-linguistic sources of processing complexity in lexical access shows parallel RH and LH fronto-temporal activity in response to increased perceptual complexity (for example, under conditions of increased word-internal competition between cohort competitors). These co-occur with strongly left-lateralised patterns of activation elicited by specifically linguistic sources of processing complexity (such as the presence of inflectional morphemes). These bi-hemispheric capacities for supporting vocal communication are likely to be closely related to cognate capacities that have evolved in non-human primates.

Symposia Session 3

The key to prevent the return of fear memories - extinction versus reconsolidation

Monday, March 23, 3:00 - 5:00 pm, Grand Ballroom A

Chairs: **Daniela Schiller and Karim Nader**

Speakers: **Mohammed R. Milad, Karim Nader, Marie-H. Monfils, Daniela Schiller**

Summary: The ability to modulate, suppress, or erase, fear memories is crucial for adaptive function in everyday life. Without such mechanisms, fear memories could abnormally persist and gain control over behavior. To date, two seemingly opposing mechanisms are suggested to block the return of old fear memories: 1) Extinction, where fear is suppressed by safe exposure to the fear-eliciting stimuli in the absence of the harmful outcome; 2) Reconsolidation, a phase where fear memories are labile upon retrieval, presumably in order to be strengthen or updated, but their re-storage can be dampened by pharmacological manipulations. Although both mechanisms are based on triggering the fear memory, extinction leads to new safety learning, leaving the fear memory intact, while reconsolidation results in modification of the original trace. In this symposium we will cover seminal research investigating the neural mechanisms and theoretical conceptualizations of these phenomena. The speakers will cover a wide range of topics on the neuroscience of extinction and reconsolidation from rats, to humans, to psychopathology. We will discuss recent evidence for a potentially groundbreaking technique to erase emotional memories, by combining extinction and reconsolidation. Discovering the brain mechanisms for these phenomena is enhancing our understanding of emotion systems in the brain, and has important clinical implications.

ABSTRACTS

TRANSLATIONAL RESEARCH IN THE NEUROSCIENCE OF EXTINCTION: FROM RATS TO HEALTHY HUMANS TO PSYCHOPATHOLOGY *Mohammed R. Milad, Harvard Medical School* – Some people adapt well in the aftermath of traumatic events and are quickly able to inhibit their fear responses to trauma-associated stimuli. Fear responses, however, persist for longer periods of time for others to the point where they reach a pathological state. Why are some people more resilient to trauma while others are not? What are the neural substrates that underlie fear inhibition and extinction? Are these circuits deficient in patients with anxiety disorders? In my talk, I will focus on presenting translational data from the rat and human brain with the objective of trying to provide some preliminary answers to the above stated questions. Specifically, I will review human studies indicating that prefrontal areas homologous to those critical for extinction in rats. Furthermore, I will present some data to show that those brain regions in the rat brain appear to be structurally and functionally homologous to specific brain regions in the human brain. I will also show some data suggesting that these brain regions, the ventromedial prefrontal cortex (vmPFC) and the dorsal anterior cingulate cortex (dACC), appear to be deficient in patients with posttraumatic stress disorder (PTSD). I will present some structural and functional neuroimaging and psychophysiological studies done in our lab that focused on the neural mechanisms of fear extinction, particularly extinction recall and the contextual modulation of extinction recall. These recent studies suggest that: 1) human

vmPFC is involved in the recall of extinction memory; 2) the size of the vmPFC might explain individual differences in the ability to modulate fear among humans; 3) hippocampal activation is observed during the recall of extinction memory in a context where extinction training took place but not in the initial conditioning context; 4) and the dACC may be involved in the expression of fear responses. I will also present recent neuroimaging and psychophysiological data from PTSD patients suggesting that 1) the retention of extinction memory is impaired in PTSD, and 2) the function of the vmPFC and dACC (measured by fMRI) appears to be impaired in PTSD in the context of fear extinction. Implications of these findings to the pathophysiology of anxiety disorders such as PTSD and current extinction-based behavioral therapies for anxiety disorders will be discussed.

CONSOLIDATION AND RECONSOLIDATION OF EMOTIONAL MEMORIES *Karim Nader, McGill University* – For over a hundred years memories were thought to be stored in our brain as a one time process called consolidation. They are thought to be stored as changes in the strength of connections between neurons. The molecular machinery required for memory consolidation have been relatively well described. Recently, we rediscovered that when you remember a memory that is already stored in your brain, it can become un-stored and has to be re-consolidated. If you block the memory from being restored it seems to be lost. This means that, in theory, we could manipulate the strength of memories therapeutically. I will talk about the brain mechanisms thought to be involved in memory consolidation and reconsolidation, and discuss some of the first clinical trials attempting to manipulate our memories therapeutically in patients with chronic post-traumatic stress disorder (PTSD).

RECONSOLIDATION-EXTINCTION BOUNDARIES MAY HOLD THE KEY TO PREVENT THE RETURN OF FEAR *Marie-H Monfils, University of Texas at Austin* – In the process of reconsolidation, a retrieved memory transiently returns to a structurally-labile state, during which time it is open to enhancement or disruption. This period of instability, termed the reconsolidation window, is known to persist for several hours following retrieval. Its adaptive purpose might be to enable the integration of new information present at the time of retrieval into an updated memory representation, and numerous studies have demonstrated that the blockade of this updating process, usually via pharmacological intervention within the lability window, prevents memory re-storage and produces amnesia (loss of the specific memory that was reactivated in the presence of the drug). Thus, blocking reconsolidation weakens the emotional impact of a stimulus by altering the molecular composition of the memory itself. The clinical efficacy of reconsolidation blockade is limited, since it typically requires toxic drugs. My talk will focus on a paradigm we have recently devised, in rats, that capitalizes on the mechanistic differences between reconsolidation and extinction, and provides an effective, drug-free alternative to permanently target and reduce learned fear. We show that destabilizing a memory by presenting an isolated retrieval trial prior to an extinction session leads to de-phosphorylation of GluR1, facilitates a re-interpretation of the conditioned stimulus as safe, and prevents the return of fear memories. Our results suggest that subtle modifications to a common treatment (exposure therapy) could improve clinical outcome.

PREVENTING THE RETURN OF FEAR MEMORIES IN HUMANS - INVASIVE AND NON-INVASIVE TECHNIQUE *Daniela Schiller, New York University* – Nearly all forms of behavioral therapy rely, at least partially, on extinction learning through exposure to fear arousing stimuli in a safe context. Although extinction provides a relief from fear, this relief is temporary, as extinguished fear responses often reemerge with the passage of time or following re-exposure to the original context or the original stress, or even an irrelevant stress. The fact that extinguished fear can be recovered has been taken to mean that the fear memory is not erased but rather suppressed by extinction. In recent years, research in non-human animals has attempted to erase old memories by targeting a particular phase, called reconsolidation, in which memories are rendered labile by being retrieved. Pharmacological manipulations at this stage result in an inability to retrieve the memories at later times, suggest that they are either erased or persistently inhibited. While this has important implications for the treatment of traumatic memory in humans there has yet to be convincing evidence that reconsolidation can be impaired in humans. This is in part due to obvious limitations in the use of invasive manipulations, such as drugs, and the risk of side effects. Thus, there is a critical need to develop drug-free behavioral manipulations to achieve blockade of fear recovery. In the talk, I will describe current research on human reconsolidation of emotional memories. In particular, I will describe a series of experiments on reconsolidation of fear using pharmacological and behavioral manipulations, and the initial attempts to translate animal findings to humans.

Sympoisa Session 4

The fluidity of preferences: effects of choice and context

Tuesday, March 24, 10:00 am - 12:00 pm, Grand Ballroom A

Chair: **Ray Dolan**

Speakers: **Laurie Santos, Tali Sharot, Antonio Rangel, Paul Glimcher**

Summary: Modern society presents individuals with more choices than ever before. We can select from a near-infinite number of possibilities where to live, who to marry, what to eat, and how to spend our leisure time. Traditional decision making theories assume that these choices are based on relatively stable preferences. In this symposium we argue that preferences are in fact highly unstable and susceptible to the context in which alternatives are presented. The focus of the symposium is on findings that begin to describe the cognitive and neural mechanisms mediating preference generation and their modulation by context. Santos and Sharot demonstrate how the mere act of choosing modifies our preferences; describing both the origins of this intriguing phenomenon in children and monkeys (Santos) and the underlying neural mechanisms in human adults (Sharot). Rangel will discuss how marketing strategies affect neural representations of experienced pleasure. Finally, Glimcher will present data from single LIP neurons that help explain how, and why, preferences are altered by changing choice sets. This diverse data all converge to one underlying theme: context-dependent preference volatility is a robust effect reflected in brain regions tracking subjective value (including striatum and OFC), and appears to be conserved across primate evolution.

A B S T R A C T S

HOW UNKNOWN DECISIONS AFFECT PREFERENCES: EVIDENCE FROM HUMAN CHILDREN AND CAPUCHIN MONKEYS *Laurie Santos, Yale University* – Common wisdom suggests that we make decisions based on our preferences. In contrast, a growing body of behavioral evidence suggests that our decisions can sometimes affect our preferences. In three studies, we explore the origin of this phenomenon in children and monkeys (Cebus apella). We first demonstrate that, like adults, children and monkeys change their preferences based on their decisions. We then explore whether decisions can affect preferences even when participants are unaware of their own choices. Children and monkeys made choices between similar alternatives while ignorant of the identities of these alternatives. Both groups then subsequently chose between the rejected alternative and a third similar alternative. Both populations preferred the third alternative to the blindly rejected alternative, indicating that they devalued the unchosen alternative even though they were unaware of its identity. These results demonstrate that choices can affect preferences even when the stimulus attributes of particular choices are unknown. In this way, our results provide the first evidence that choice-based preference changes are independent of stimulus factors. Our discovery of choice-based preference changes in these populations also provides further evidence that these preference changes may operate even in the absence of high-level cognitive processes.

CHOICE REVEALS AND SHAPES EXPECTED HEDONIC OUTCOME *Tali Sharot, University College London* – Humans tend to modify their attitudes to align with past action. For example, after choosing between similarly valued alternatives, people rate the selected option as better than they originally did, and the rejected option as worse. However, it is unknown whether these modifications in evaluation reflect an underlying change in the physiological representation of a stimulus' hedonic value and our emotional response to it. In two studies we addressed this question by combining participants' estimations of the pleasure (Experiment I) and pain (Experiment II) they will derive from future events, with brain imaging data recorded while they imagined those events, both before, and after, choosing between them. Participants rated the selected alternatives as better after the decision stage relative to before, while discarded alternatives were valued less. Our fMRI findings reveal that post-choice changes in preference are tracked in caudate nucleus activity. Specifically, the difference in BOLD signal associated with the selected and rejected stimuli was enhanced after a decision was taken, reflecting the choice that had just been made. This finding suggests that the physiological representation of a stimulus' hedonic value is altered by a commitment to it. Furthermore, prior to any revaluation induced by the decision process, our data show that BOLD signal in the striatum reflects the choices we are likely to make at a later time, even when an explicit valuation of the options does not.

BIASES IN THE NEURAL REPRESENTATIONS OF EXPERIENCED UTILITY *Antonio Rangel, California Institute of Technology* – Experienced utility signals provide a measure of the quality of the outcomes generated by our choices, thus providing the necessary feedback to improve future decision-making. Although multiple

human neuroimaging studies have shown that activity in the medial orbitofrontal cortex (mOFC) is correlated with reports of subjective pleasantness, little is known about which variables affect this signal. Here we report on the results of two studies investigating this question. In the first study we explored the extent to which changes in prior expectations about the quality of an experience, such as changes in the price of a product, can affect neural representations of experienced pleasantness. We tested this hypothesis by scanning human subjects using functional magnetic resonance imaging (fMRI) while they tasted wines which, contrary to reality, they believed to be different and sold at different prices. Our results show that increasing the price of a wine increases subjective reports of flavor pleasantness as well as BOLD activity in medial orbitofrontal cortex (mOFC). In a second study we showed that random events unrelated to the experience of tasting a wine, such as the payoff of a random lottery, also affect subjective reports of taste pleasantness and activity in the mOFC. Together, these results suggest that the putative experienced utility signal encoded in the mOFC is contaminated by variables that are unrelated to the objective quality of the experience being measured. These "experiential biases" might contribute to the some of the "choice biases" that have been identified by behavioral economists, as well as to the efficacy of some marketing practices.

CHOICE SET EFFECTS: RELATIVE REWARD REPRESENTATION IN PARIETAL CORTEX *Paul Glimcher, New York University* – One of the hallmarks of rational choice theory is the desirability of choice options - the more alternatives a decision-maker can choose from, the better off he will be. However, a growing literature suggests that when choice set size grows too large, decisions become difficult and people fare significantly worse. We hypothesize that such choice effects arise from how the values of alternative actions are represented in neural decision-making circuits. In the lateral intraparietal area (LIP), visuomotor neurons are strongly modulated by reward variables such as expected gain, prior probability, and reward income, suggesting that individual LIP neurons represent the subjective value of specific saccades. We recorded monkey LIP neurons during a multiple option choice task and show that the value of an action is represented in a relative form, normalized by the total value of all available alternatives. These results are well-characterized by the divisive normalization model previously proposed to explain responses in early sensory cortices, suggesting that divisive normalization may represent a canonical mechanism of cortical operation. Furthermore, such a relative value representation can be shown to modify preferences in the face of increasing numbers of alternatives, and may explain how actual choice behavior responds to multiple options and changing choice sets.

Symposia Session 5

Representational similarity analysis - characterizing visual population codes for shapes, objects, and faces

Tuesday, March 24, 1:00 - 3:00 pm, Grand Ballroom A

Chair: **Nikolaus Kriegeskorte and Geoffrey K. Aguirre**

Speakers: **James V. Haxby, Hans Op de Beeck, Nikolaus Kriegeskorte, Geoffrey K. Aguirre**

Summary: The characterization of neuronal codes in terms of their representational content constitutes a challenge fundamental to cognitive neuroscience. One promising approach that has recently gained momentum is to characterize a neuronal population code by means of a representational dissimilarity matrix. For each pair of experimental conditions (e.g. each pair of stimuli), the representational dissimilarity matrix contains an entry reflecting the dissimilarity of the activity patterns associated with the two conditions. Intuitively, the representational dissimilarity matrix encapsulates the information carried by a given representation in a brain region or computational model. Representational similarity analysis (RSA) provides data-driven characterizations of representational content and allows us to quantitatively relate the three major branches of cognitive neuroscience - behavioral experimentation, brain-activity experimentation, and computational modeling - by comparing representational dissimilarity matrices. This symposium presents a series of novel findings on high-level visual representations at the interface between perception and cognition that have been obtained by means of RSA. These studies demonstrate the power of RSA to bridge fundamental divides of our science so as to relate human to monkey representations, cell-recordings to fMRI, and brain-activity data to behavioral measures and computational theory in an information-rich, quantitative framework that is well-motivated by cognitive theory.

ABSTRACTS

CHARACTERIZING LOCAL NEURAL REPRESENTATION AS A MULTIDIMENSIONAL SIMILARITY SPACE *James V. Haxby, Dartmouth College, Psychological & Brain Sciences* – Whereas conventional univariate analysis of functional brain imaging data characterized the function of a region in terms of the conditions that activate that region, multivariate pattern (MVP) analysis characterizes local function in terms of the conditions that evoke distinct patterns of activity. Moreover, the dissimilarities of the patterns of activity for different conditions can be quantified. Thus, local neural representation can be analyzed in terms of a high-dimensional similarity structure rather than as a (short) list of functions. Functional differences among brain regions can similarly by analyzed as differences in the neural representational space rather than as different functional labels. For example, different categories of visual stimuli - faces and objects - activate and evoke distinct patterns of activity in medial occipital, inferior lateral occipital (LO), and ventral temporal (VT) cortex, including when analysis is restricted to subregions that respond maximally to faces (FFA) and places (PPA). The similarity structure of the responses to categories, however, differs significantly among these brain regions. Whereas LO demonstrates larger distinctions than does VT within animate (faces of different species) and inanimate domains (houses, chairs, and shoes), VT demonstrates larger distinctions between the animate and inanimate domains. Medial occipital cortex, on the other hand, demonstrates a similarity structure that is not dominated by the animate-inanimate distinction at all. MVP analysis, therefore, reveals how local neural representation projects information into different subspaces that emphasize different distinctions among conditions. These methods provide a powerful tool for investigating how information is processed and re-represented in hierarchical and distributed neural systems.

THE ROLE OF OBJECT FEATURES, CATEGORIES, AND LEARNING FOR THE REPRESENTATION OF OBJECT SIMILARITY IN THE HUMAN BRAIN *Hans Op de Beeck, Laboratory of Experimental Psychology, University of Leuven* – Multiple studies using functional magnetic resonance imaging (fMRI) have suggested the existence of category-selective regions in the human and monkey occipitotemporal cortex that represent between-category and within-category object similarity. We aim to understand where these category-based representations come from. First, they might reflect the existence of large-scale maps for object features that are correlated with category membership. Using multivariate fMRI analyses we have indeed shown that perceived shape is an organizational principle for object-selective regions in the human brain. These findings suggest that category selectivity might be decomposable into selectivity for simpler object features. Second, strong category selectivity might be induced by visual experience. We have found indeed that the neural representation of between- and within-category differences is altered by various forms of object learning. Thus, the strong category selectivity in the human brain might be related to a combined and dynamically updated coding of multiple object features.

THE EMERGENCE OF CATEGORICALITY ALONG HUMAN VENTRAL-STREAM STAGES OF VISUAL OBJECT PROCESSING *Nikolaus Kriegeskorte, Laboratory of Brain and Cognition, National Institute of Mental Health* – The human ventral stream is known to host high-level representations of visual objects, from which category information can be read out with linear decoders. We have previously shown that single-object-image response patterns in human inferior temporal (hIT) cortex, when grouped by similarity, reflect conventional object categories and that the categorical structure as well as the within-category similarity structure matches between human and monkey IT. Here we start at early visual cortex and follow the ventral stream through key functional regions in order to understand how categoricality emerges across stages of processing. Early visual cortex exhibits a representational similarity reflecting visual shape (predicted, for example, by the dissimilarities of the silhouette images capturing the outer boundary of the objects); its response patterns did not allow readout of category information with a linear decoder. Categoricality (in the sense of categorical clustering of fMRI response patterns) appears to suddenly emerge at the level of the lateral occipital region (LO). The major categorical division is between animate and inanimate objects; the animate cluster is further subdivided into a face and a body cluster. We relate the representation at each stage to a range of computational models and to explicit object similarity judgments from human subjects. Within category clusters, hIT represents object exemplars in a continuous object space, which may reflect a form of visual similarity. However, the hIT representation is not well accounted for by a range of low- and intermediate-complexity computational models of visual features: these representations lack the strong categorical component found in hIT. This suggests the presence of visual features explicitly optimized for distinguishing natural categories as one possible explanation. The human similarity judgments better resemble the hIT representational similarities, but are even more strongly dominated by categoricality.

THE GEOMETRY OF NEURAL SIMILARITY SPACES *Geoffrey K. Aguirre, Hospital of the University of Pennsylvania* – What is the relationship between the perceptual similarity of sensory experiences and the similarity of the neural responses that encode them? In a series of experiments we have studied the neural representation of objects and shapes in human visual cortex using this question as a guiding principle. With continuous carry-over, functional MRI (Aguirre, Neuroimage, 2007), we can measure the similarity of evoked neural responses to objects on either a focal (within voxel adaptation) or distributed (across voxel pattern) spatial scale. For simple two-dimension shapes and for faces we have found that perceptual similarity predicts neural response similarity, but that the visual information represented at focal and distributed scales differ, both within and across visual areas. Specifically, the dorsolateral potion of the "object responsive" visual area LOC represents a subset of object features with a spatially coarse code, while ventral LOC contains focal populations of neurons that represent the entire object appearance. These studies show that neural population coding of object appearance within ventral LOC reflects perceptual similarity. The precise metric properties of perceptual similarity may further predict the stimulus axes along which these representations are organized. We hypothesize that integral perceptual axes (perceived as a composite with a Euclidean distance metric) are represented by populations of neurons that are conjointly tuned to the axes, while separable axes (defined by a rectilinear metric) are represented by independently tuned neural populations. Using fMRI we may measure the geometric properties of neural adaptation to distinguish between conjoint or independent tuning for a population of neurons. For both two-dimensional shapes and for faces we find that neural tuning within ventral visual areas reflects the metric properties of perception. For shapes, curvature and thickness are independently represented while two arbitrary dimensions of shape variation have conjoint representation. For faces, left ventral areas are tuned to represent face features, while right ventral cortex modulates tuning between face features and wholes depending upon stimulus context and reflecting behavioral measures.

Slide Sessions

Slide Session 1 Language

Saturday, March 21, 3:00 - 5:00 pm, Grand Ballroom A

Chair: **Tamara Swaab**

Speakers: **Mirjana Bozic, Keith J. Duncan, Corianne Rogalsky, Peter Gordon, Gerrit Hirschfeld (*GSP Winner*), Marina Bedny, Christopher Kurby, Danielle van den Brink**

ABSTRACTS

NEURO-COGNITIVE COMPLEXITY OF DERIVATIONALLY COMPLEX WORDS *Mirjana Bozic[1], Lorraine K. Tyler[2], William D. Marslen-Wilson[1]; [1]MRC Cognition and Brain Sciences Unit, Cambridge UK, [2]Centre for Speech, Language and the Brain, University of Cambridge* – Lexical complexity plays a prominent role in modulating the activity of fronto-temporal language networks. Studies with regularly inflected words (jumped, smiled) show that the presence of morpho-phonological complexity (stem + inflectional affix) activates left-lateralised areas, while lexical-semantic complexity (presence of competing alternatives due to embedded stems, e.g., claim(clay), ramp(ram), etc) engages bilateral inferior frontal regions. The current efMRI experiment asked whether similar left-lateralised decomposition and bilateral competition processes hold for derivationally complex words (darkness, warmth), where the stem-affix relationship is strongly lexicalised and less semantically predictable. In a set of single spoken words we manipulated the presence of embedded stems and derivational suffixes with varying degrees of productivity, forming a gradient in the extent that the stimuli are predicted to trigger competition and decomposition processes. Words were contrasted with a complex auditory baseline that does not trigger a speech percept ('musical rain', Uppenkamp et al, 2006). We found that the presence of competing embedded stems engages bilateral fronto-temporal language regions, comparable to the results observed previously. In contrast, derivational affixes do not seem to selectively activate a left-lateralised subsystem. This is arguably because derivational affixes do not trigger decompositional processes in the same way as inflectional affixes. We suggest a neuro-cognitive account of the representation and processing of derivationally complex forms in English.

INVESTIGATING OCCIPITO-TEMPORAL CONTRIBUTIONS TO READING WITH TMS *Keith J. Duncan[1,2], Chotiga Pattamadilok[1,3], Joseph T. Devlin[1,2]; [1]Cognitive, Perceptual and Brain Sciences, UCL, [2]Institute of Cognitive Neuroscience, UCL, [3]Fonds de la Recherache Scientifique-FNRS & Universite Libre de Bruxelles* – The debate regarding the role of ventral occipito-temporal cortex (vOTC) in visual word recognition arises in part from difficulty delineating the functional contributions of vOTC as separate from other areas of the reading network. Here we investigated the feasibility of using transcranial magnetic stimulation (TMS) to stimulate vOTC in order to specifically explore its contributions to visual word recognition. Three visual lexical decision experiments were conducted using neuro-navigated TMS. The first two used repetitive TMS to demonstrate and confirm that repetitive stimulation of vOTC slowed word, but not non-word, responses and that the effect was specific to vOTC. The third used paired-pulse TMS to investigate the time course of vOTC processing for words and revealed activation starting as early as 80-120msec post-stimulus onset – significantly earlier than that expected based on electrophysiological and magnetoencephalography studies. Taken together, these results clearly indicate that TMS can be successfully used to stimulate parts of vOTC previously believed to be inaccessible and provide a new tool for systematically investigating the information processing characteristics of vOTC. In addition, the findings provide strong evidence that lexical status and frequency significantly affect vOTC processing, findings incompatible with pre-lexical accounts of vOTC function.

CONTRIBUTIONS OF THE ANTERIOR TEMPORAL LOBE TO SENTENCE COMPREHENSION: A LESION STUDY *Corianne Rogalsky[1], David Driscoll[2], Jessica L. Wisnowski[1], Steven W. Anderson[2], Gregory Hickok[3]; [1]Brain and Creativity Institute & Dana and David Cognitive Neuroscience Imaging Center, University of Southern California, [2]University of Iowa, Neurology, [3]Center for Cognitive Neuroscience & Cognitive Sciences, University of California, Irvine* – Broca's area has long been implicated in syntactic processing, while lesion evidence has suggested that the anterior temporal lobe (ATL) is involved in lexical retrieval. Thus, one would hypothesize that damage to either region would result in sentence comprehension difficulties, but for different rea-

sons. However, a number of recent functional neuroimaging studies have found that portions of the ATL respond preferentially to structured sentence-level stimuli (in contrast to word-lists, for example), while Broca's area activity does not track with the presence of syntactic structure. If the ATL contains sub-regions that are involved in sentence-level structure processing (and not just lexical retrieval), the sentence comprehension abilities of subjects with ATL damage should decrease as a function of sentence complexity. The present study explored this possibility by measuring sentence comprehension abilities of subjects with left frontal-insular and/or ATL lesions. Subjects completed a psycholinguistic battery to assess their phonological, lexical, and sentence-level speech comprehension and production abilities. In support of the ATL contributing to sentence processing via lexical access, the sentence comprehension (as measured by a semantic plausibility task) was positively correlated with object naming performance for subjects with damage restricted to the ATL. However, their performance declined for the most complex sentences, object-relative clause sentences, compared to subject-relative clause sentences matched for semantic content and length. Conversely, the frontal-insular patients did not demonstrate this complexity effect, although naming and sentence comprehension performances were positively correlated. These preliminary results indicate that ATL sub-regions do contribute to sentence-level structure processing. Supported by NIH-DC03681.

NEURAL MECHANISMS OF COREFERENTIAL PROCESSING IN LANGUAGE COMPREHENSION *Peter Gordon[1], Natalie Kacinik[2], Tamara Swaab[3]; [1]University of North Carolina at Chapel Hill, [2]Brooklyn College, CUNY, [3]University of California, Davis* – In previous work, we have shown that general memory mechanisms do not always guide language processing: The use of repeated names to establish relationships in discourse contexts induces processing difficulty when coreferentially repeated names are preceded by an antecedent name in discourse focus (e.g., John went to the store because John…"). This repeated name penalty (RNP) manifests as an N400 effect in ERP research. A critical question is whether different classes of corefential expressions (e.g., reflexives, pronouns, names) are allowable in terms of their syntactic relationship to their antecedents as formulated by linguistic theory. Alternatively, distinctions between types of coreference may depend on linguistic structure but not on the class of referring expression involved. To test this, we compared ERPs elicited by repeated names following prominent antecedent names that had been presented in the same clause or in a different clause with ERPs in control conditions with non-prominent antecedent names but matched syntactic structure (e.g., Suzy/Suzy's brother went to the pet store to buy/so that Suzy…). For names repeated within the same clause, significant P600s were observed, a pattern that matches those reported previously for ungrammatical reflexives. In contrast, for names repeated across different clauses, we replicated the N400 RNP effect. This shows that a single method of producing difficult-to-process coreference, repetition of a prominent name, elicits different ERP components depending on how the antecedent and repeated name are related grammatically, indicating distinct patterns of language processing in the brain that differ from those expected under standard linguistic theory.

MEG-EVIDENCE FOR MODAL AND AMODAL SEMANTIC REPRESENTATIONS IN LANGUAGE COMPREHENSION: TIME TELLS THE DIFFERENCE *Gerrit Hirschfeld[1,3], Christian Dobel[2,3], Pienie Zwitserlood[1,3]; [1]University of Muenster, Psychology, [2]Institute for Biomagnetism and Biosignalanalysis, University of Muenster, [3]Otto Creutzfeld Center for Cognitive and Behavioral Neurosciences* – Since its discovery, the N400 has shaped our thinking about semantics in profound ways. Its elicitation by multiple violations (at word, sentence, discourse, world-knowledge levels) in different modalities (visual or auditory words, pictures, sounds, videos) highlights the role of amodal representations in language comprehension. Recent theories suggest a perceptual basis of such representations (e.g. Barsalou, 1999), which we investigated with an MEG experiment with spoken sentences as contexts for picture processing. Participants listened to sentences and verified if the following picture depicted an object mentioned in the sentence or not. Targets were pictures of different objects, each photographed in two states, associated with different global object shapes (e.g. a flying duck vs. a sitting duck). Each target picture (e.g. the flying duck) appeared in three contexts: (1) a match sentence about a duck in the air, (2) a mismatch sentence about a swimming duck, and (3) an unrelated sentence without any ducks. Source localization (L2 minimum norm estimates) of the MEG data revealed a clear dissociation between late (300-450 ms) amodal effects in the left temporal lobe and early (120-145 ms) perceptual effects in the occipital cortex. The late N400 interval showed higher activity for the unrelated compared to the two related conditions, while the early interval showed enhanced activation for the match compared to the other two conditions. Our findings show specific and early top-down influences of language on perception and argue in favor of modal semantic representations preceding amodal ones.

EFFECTS OF VISUAL DEPRIVATION ON ACTION VERB REPRESENTATIONS IN THE LATERAL-TEMPORAL-CORTEX: EVIDENCE FROM CONGENITALLY BLIND ADULTS *Marina Bedny[1,2], Alfonso Caramazza[3], Talia Konkle[2], Alvaro Pascual-Leone[1], Rebecca Saxe[2]; [1]Berenson-Allen Center for Noninvasive Brain Stimulation, Beth Israel Deaconess Medical Center, Harvard Medical School, [2]Massachusetts Institute of Technology, [3]Harvard University* – How does our sensory experience shape conceptual representations during development? According to one hypothesis, the neuroanatomical organization of concepts is determined by the sensory modalities through which we learn them. For example, the meaning of the word "kick" is represented near visual motion regions activated during the visual observation of kicking. Previous research has found that conceptual and perceptual representations of actions in the lateral-temporal-cortex are distinct but occupy neighboring brain regions. In this project we investigated whether the proximity of verb regions to motion perception regions depends on having learned the meanings of our first verbs through sight. We addressed this issue by considering the neural organization of verbs in congenitally blind individuals. In Experiment 1, participants listened to auditory motion: receding or approaching tones and footsteps. In Experiment 2, participants made relatedness judgments on verb-and noun-pairs. We find that the visual motion perception system is functionally reorganized in congenitally blind adults: motion regions respond to sound in congenitally blind, but not sighted individuals. In contrast, regions that respond to verbs are unaffected by visual deprivation. We conclude that the neuroanatomical organization of event concepts is not determined by the sensory modality of learning. Instead, it is either innately specified or determined by non-sensory aspects of experience.

FMRI EVIDENCE FOR THE ACTIVATION OF MODALITY-SPECIFIC IMAGES DURING NARRATIVE COMPREHENSION *Christopher Kurby[1], Jeffrey Zacks[1]; [1]Washington University* – Perceptual theories of language comprehension argue that readers generate perceptual simulations of the events described by text (Barsalou, 1999; Zwaan, 2004). This predicts that readers engage in imagery processes routinely during comprehension and that the images should reflect the perceptual modality implied by the text. As such, we used event-related functional MRI to ask whether modality-specific representations are activated during the silent reading of extended naturalistic narratives. Participants' brain activity was recorded while reading narrative texts one word at a time. Based on separately collected imagery norms, we coded the high imagery clauses with respect to whether they elicited motor, auditory, or visual imagery. Clauses rated as producing high imagery in the motor modality selectively activated the left postcentral sulcus (somatosensory cortex). Clauses with auditory imagery selectively activated posterior regions including Wernicke's area, and anterior regions including Broca's area and adjacent regions of lateral frontal cortex, and dorsomedial prefrontal cortex. (This activation was bilateral, including the right-hemisphere homologs of Broca's and Wernicke's areas.) Clauses with high visual imagery activated left fusiform gyrus. These results support the hypothesis that modality-specific perceptual simulations are a concomitant of ongoing narrative comprehension.

SEX INFLUENCES SOCIAL LANGUAGE PROCESSING: A MATTER OF EMPATHY *Danielle van den Brink[1,2], Jos van Berkum[1,3], Marcel Bastiaansen[1,3], Jan Buitelaar[2], Peter Hagoort[1,3]; [1]Donders Institute for Brain, Cognition and Behaviour, Nijmegen, The Netherlands, [2]Radboud University Nijmegen Medical Centre, Psychiatry, The Netherlands, [3]Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands* – When a 6-year-old girl claims that she cannot sleep without her teddy bear, hardly anybody will look surprised. However, when an adult male says the same thing, this is bound to raise some eyebrows. Language interpretation, thus, relies upon context-bound aspects of language, relevant for social discourse purposes. The present event-related brain potential (ERP) study investigated inter-individual differences in the cognitive processes that mediate the integration of social information in a linguistic context. Participants (n = 36; 18 female) heard Dutch utterances with a content that either did or did not fit probabilistic inferences about the speaker's sex, age, and social-economic status, as could be inferred from the speaker's voice. Whereas women showed brain reactivity when probabilistic inferences about a speaker conflicted with the content of the message, men did not. This sex-based difference in social information processing can be explained by a specific cognitive trait, one's ability to empathize. Individuals who empathize to a greater degree revealed larger N400 effects, as well as a larger increase in gamma-band power (45-60 Hz) to socially relevant information, indicating they are more sensitive to social aspects of language.

Slide Session 2 Working memory and executive functions

Saturday, March 21, 3:00 - 5:00 pm, Grand Ballroom B

Chair: **Silvia Bunge**

Speakers: **Antonio Lara (*GSP Winner*), Simon van Gaal (*GSP Winner*), Yee Lee Shing, Mary Askren, Sari Karlsson, Sam Doesburg, Jacquelyn Gamino, Marieke van Vugt**

ABSTRACTS

ENCODING OF GUSTATORY WORKING MEMORY IN ORBITOFRONTAL CORTEX *Antonio Lara[1], Steven Kennerley[1], Jonathan Wallis[1,2]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]University of California, Berkeley* – There are two competing models regarding the organization of working memory (WM) in prefrontal cortex (PFC). The domain-specific model states that PFC areas that receive direct projections from a sensory modality maintain and manipulate that modality in WM. The operational model postulates that mid-dorsolateral (DLPFC) and ventrolateral (VLPFC) manipulate and maintain respectively all sensory information within WM. Previous studies focused on modalities that project directly to VLPFC making it difficult to distinguish the two models. Gustatory information enters PFC via orbitofrontal cortex (OFC). Thus, the domain-specific and the operational models predict that OFC or VLPFC respectively should maintain gustatory information in WM. Determining the locus of gustatory WM would help distinguish these two models. We recorded activity of PFC neurons from two animals while they performed a gustatory delayed match to sample task. Subjects had to maintain the identity of a juice in WM during a three second delay period. We delivered a water drop as a distractor halfway through the delay. During the pre-distractor delay, neurons in both VLPFC (11%) and OFC (21%) encoded the juice. After the distractor, however, more neurons in OFC (18%) continued to encode the juice compared to VLPFC (9%). Furthermore, the strength of selectivity was significantly greater in OFC relative to VLPFC. These results indicate that the OFC encodes gustatory information in WM more robustly than VLPFC in accord with the domain-specific model. The maintenance of reward in WM may be an important function of OFC and contribute to its role in decision-making.

UNCONSCIOUS ACTIVATION OF THE FRONTOPARIETAL NO-GO NETWORK *Simon van Gaal[1,2], Steven Scholte[1], Richard Ridderinkhof[2], Johannes Fahrenfort[1,2], Victor Lamme[1,3]; [1]Cognitive Neuroscience Group, Psychology, University of Amsterdam, Amsterdam, the Netherlands, [2]Amsterdam Center for the Study of Adaptive Control in Brain and Behavior (Acacia), Psychology, University of Amsterdam, Amsterdam, the Netherlands, [3]Netherlands Institute for Neuroscience, Amsterdam, the Netherlands* – Inhibitory control, as measured with the Go/No-Go task, is consistently associated with the prefrontal cortex (PFC), particularly the right inferior frontal gyrus (IFG). Here, we investigated to what extent invisible No-Go stimuli are capable of reaching cortical areas involved in inhibitory control. To do this, we recorded fMRI signals while participants performed a Go/No-Go task that included visible (unmasked) No-Go trials, invisible (masked) No-Go trials as well as Go trials. Behaviorally, participants inhibited approximately 70% of their responses to visible No-Go trials. Invisible No-Go signals did not trigger full-blown inhibition, but instead caused a substantial slow-down of responses. Replicating typical neuroimaging findings, conscious response inhibition was associated with a right-lateralized frontoparietal "inhibition network". Interestingly, invisible No-Go signals did not trigger the entire conscious inhibition network, but only a specific subset of nodes therein. This "unconscious inhibition network" included the right inferior, middle and superior frontal gyrus along with superior and inferior parietal cortices. Activity in the right IFG correlated strongly with individual variability in RT slowing to invisible No-Go trials, suggesting that this area plays a crucial role in unconscious inhibition. Though some suppose that the PFC is solely involved in conscious information processing, these results demonstrate that unconscious information is able to influence high-level control operations in the PFC. In addition, differences between conscious and unconscious control are revealed.

MODELING AGE AND INDIVIDUAL DIFFERENCES IN WORKING MEMORY WITH TIME-ACCURACY FUNCTIONS *Yee Lee Shing[1,2], Florian Schmiedek[1,2], Martin Lövdén[1], Ulman Lindenberger[1]; [1]Max Planck Institute for Human Development, Center for Lifespan Psychology, [2]Humboldt University, Berlin* – Working memory (WM), a system for the simultaneous storage and processing of information, declines with advancing adult age (Park et al., 2002). In this study, we use time-accuracy function (TAF) to characterize age-related declines in WM, and delineate potential mechanisms underlying this decline. By capturing individuals' processing rates and performance asymptotes as distinct parameters, TAFs provide a joint description of speed and accuracy (Verhaeghen, 2000). Hundred-one younger adults (YA; 20-30 years) and 103 older adults (OA; 65-80 years) completed three WM tasks, i.e., spatial n-back, numerical memory-

updating, and verbal alpha-span. For each task, difficulty was manipulated by varying stimuli presentation times. Accuracy was modeled as a negatively accelerated function of presentation time using multilevel nonlinear modeling. In all three tasks, OA reached significantly lower asymptotes than YA. In memory updating, OA also showed significantly slower processing rates than YA. The task-general difference in asymptotes demonstrates that age-related deficits in WM cannot be remediated by longer presentation times. We conclude that core processes of WM, such as the coordination of binding and updating operations, are compromised in normal aging. In additional analyses, we find that the observed age-related decline in asymptotic WM performance is robust against large amounts of practice (100 sessions). Neuronally, age-related decline in WM asymptotes and plasticity may reflect deficient hippocampal binding (Mitchell et al., 2000) and striatal updating operations (Dahlin et al., 2008). We are currently testing this interpretation by relating the TAF parameters to available covariates and fMRI data from the same participants.

ACETYLCHOLINE AND COGNITIVE CONTROL: DONEPEZIL MODULATES PREFRONTAL AND DEFAULT-MODE REGIONS IN A TASK-SWITCHING PROCEDURE *Mary Askren[1], Elise Demeter[1], Stephan Taylor[1], Martin Sarter[1], Cindy Lustig[1]; [1]University of Michigan* – Combining drug manipulations with functional magnetic resonance imaging (fMRI) can reveal how neurotransmitter systems drive task-related activations. The present experiment used a task-switching procedure to vary demands for cognitive control and donepezil hydrochloride (an acetylcholinesterase inhibitor) to vary extracellular acetylcholine levels. In the low control-demand conditions, participants performed the same task from trial to trial. In the high control-demand condition, the correct task rule switched unpredictably, so that participants had to adjust their responses accordingly. Young adults (age 18-30, n = 20 per group) performed the task-switching procedure at baseline and then were scanned 3 hours after receiving a placebo pill, 5 mg donepezil, or 10 mg donepezil. Drug administration did not influence behavioral performance: All groups showed equivalent demand-related slowing. Placebo participants showed task-related activations in prefrontal regions, particularly left inferior frontal gyrus, and task-related deactivations of default-mode regions including posterior cingulate and medial frontal cortex. Administration of 5 mg donepezil increased the demand-sensitivity of prefrontal activations, and reduction or even reversal of demand-related deactivations of the default-mode regions. The 10 mg group's activation patterns were intermediate between the placebo and 5 mg groups, suggesting a U-shaped dose-response curve. Mild enhancement of cholinergic function may potentiate attention to task-relevant information and the retrieval of task rules in the high-demand condition, whereas higher doses may disrupt these processes.

RELATIONSHIPS BETWEEN TRAIT- AND STATE-DEPENDENT DOPAMINE D1 BINDING AND FUNCTIONAL BRAIN ACTIVITY IN A SPATIAL WORKING MEMORY TASK *Sari Karlsson[1], Lars Nyberg[2], Håkan Fischer[1], Yvonne Brehmer[1], Anna Rieckmann[1], Petra Thilers[1], Per Karlsson[3], Lars Farde[3], Lars Bäckman[1]; [1]Aging Research Center, Karolinska Institutet, Stockholm, Sweden, [2]Umeå University, Integrative Medical Biology & Radiation Sciences, Sweden, [3]Psychiatry Section, Karolinska Hospital, Clinical Neuroscience, Stockholm, Sweden* – Several lines of research (animal, molecular imaging, genetic, computational modelling) have demonstrated a link between dopamine (DA) functions and higher-order cognitive processing. In this study, we used multimodal brain imaging, molecular PET imaging and fMRI, in the same participants in order to directly demonstrate a link between DA D1 binding and functional brain activity during a spatial working memory (SWM) task. Relationships between striatal trait-dependent and state-dependent DA function and BOLD activation during a SWM task were investigated in 20 younger (20-30 years) participants. Participants underwent two [11C] SCH23390 PET measurements, one while resting and one while performing a cognitive task taxing inhibitory functioning, and they also underwent an fMRI scan while performing a SWM task. Trait-dependent DA was defined as D1 binding at resting state and is thought to reflect general level of receptor function. State-dependent DA was defined as the difference between D1 binding at resting state and D1 binding during the inhibition task and is thought to reflect DA release during cognitive activity. Trait-dependent striatal DA binding was positively related to prefrontal BOLD signal, whereas state-dependent striatal D1 binding was positively related to temporal lobe activity during SWM performance. This pattern of data suggests that both trait- and state-dependent DA activity are implicated in SWM performance, but may contribute in different ways.

MEG REVEALS GAMMA-BAND ACTIVATION IN PREFRONTAL AND VISUAL CORTEX DURING VISUAL SHORT-TERM MEMORY MAINTENANCE IN CHILDREN *Sam Doesburg[1,2], Urs Ribary[2,3,4], Anthony Herdman[3], Teresa Cheung[4,5], Hal Weinberg[3], Mario Liotti[3], Ruth Grunau[1,2]; [1]University of British Columbia, Pediatrics, [2]Child and Family Research Institute, [3]Simon Fraser University, Psychology, [4]Down Syndrome Research Foundation, [5]Simon Fraser University, Physics* – The retention and manipulation of visual information in short-tem memory engages a network of brain regions including visual cortex and prefrontal cortex. In

adults, electroencephalography (EEG) has revealed increased gamma-band activation over frontal and posterior regions during the delay period of visual delayed-matching-to-sample task. This is consistent with the notion that gamma-band synchronization is relevant to active processing in task-relevant cortical areas, which in the context of short-term memory maintenance include prefrontal and visual cortex. Gamma-band synchronization is relevant to a variety of cognitive and perceptual processes, and the appearance of certain perceptual capacities during typical development coincides with the expression of gamma-band synchronization characteristic of those processes. It remains unclear, however, how gamma-band neural synchronization relevant to short-term memory processing is expressed during childhood. To investigate this, magnetoencephalographic (MEG) recordings were taken while children 6-10 years of age performed a visual short-term memory task. Preliminary beamformer source localization results indicate increased gamma-band activity within prefrontal and visual cortex during the retention of visual information. This confirms that gamma-band synchronization is relevant to maintenance of visual information in short-term memory and that these oscillations originate from a network of prefrontal and visual cortical areas. These preliminary results also expand our knowledge of the developmental continuity of oscillatory dynamics relevant to cognition and will provide a normative basis to characterize the neurocognitive development of special populations, which we will use in an ongoing study investigating visual short-term memory in children born very preterm.

NEW HOPE FOR EXECUTIVE FUNCTION AND REASONING REMEDIATION IN CHILDREN WITH ADHD: STRATEGIC MEMORY AND REASONING TRAINING (SMART) *Jacquelyn Gamino[1], Sandra Chapman[1], John Hart[1], Sandra Vanegas[1], Elizabeth Hull[1], Lori Cook[1]; [1]The University of Texas at Dallas, Center for BrainHealth* – In spite of the prevalence of poor academic performance in children with ADHD, interventions predominately address medication effectiveness and behavioral issues, not learning. Thus, little is known regarding the remediation of learning impairment and, more specifically, the efficacy of metacognitive instruction in children with ADHD. Recently, we found many children with ADHD have impaired strategic learning. Strategic learning is the process of abstracting gist-based concepts from information and is related to Barkley's concept of reconstitution (2001). Evidence for robust memory for gist-based concepts suggests this ability facilitates learning. We developed the Strategic Memory and Reasoning Training (SMART) program to investigate potential remediation of these impairments. Fifty children with ADHD between the ages of 8 and 17 participated in this study. Twenty children were included in the SMART 12-week individual intervention and 30 children participated in an intensive 2-week SMART Camp. Over the course of the intervention, the children learned metacognitive strategies that included goal setting and planning. We found that strategic learning performance significantly improved in both cohorts of the SMART intervention. In addition, the 30 children who participated in the SMART Camp showed significant improvement in working memory, initiation, organization of materials, behavioral regulation, and metacognition as measured by the Behavioral Rating Inventory of Executive Function (BRIEF). This study provides the first known evidence that teaching children with ADHD specific metacognitive strategies has the potential to improve strategic learning and executive function. SMART participants will be followed for one year to determine the transferability of the intervention to academic performance.

THE INFLUENCE OF MINDFULNESS MEDITATION TRAINING ON VISUAL WORKING MEMORY *Marieke van Vugt[1], Anastasia Kiyonaga[2], Ling Wong[3], Amishi Jha[2]; [1]Princeton University, [2]University of Pennsylvania, [3]University of California, Davis* – Recent studies suggest that training in mindfulness meditation improves attention (e.g., Jha et al, 2007). Given the close relationship between attention and working memory (WM), we investigated how intensive meditation training (MT) may affect WM. Participants (N= 29) were tested on a delayed-recognition task before (T1) and after (T2) participation in an intensive one-month mindfulness meditation retreat. The primary mindfulness practice required attending to present moment experience using the breath as the anchor of attention. Their performance was compared to an age- and education-matched control group (N=29) who received no training. Overall accuracy and d' were greater and the variability in RT was reduced for the training vs. control group at T2. To determine how decision processes in WM might be affected by MT, we applied a drift-diffusion model (Wagenmakers et al, 2007) of decision making. This model parses behavioral results into 3 latent measures: amount of information required to make a decision (decision boundary), rate of information accumulation, and non-decision factors. The modeling results revealed that the rate of evidence accumulation increased and the decision boundary decreased in the MT but not control group over time. These modeling results, together with improvements in d' scores in the MT group at T2, suggest that information may be of higher quality after MT. Thus, intensive MT may improve WM via alterations in the mnemonic representations themselves, as opposed to alterations in decisional or non-specific factors.

Slide Session 3 Long-term memory

Sunday, March 22, 10:00 am - 12:00 pm, Grand Ballroom B

Chair: **Roberto Cabeza**

Speakers: **Stephen J. Gotts, Tyler Davis, Jennifer D. Ryan, Youssef Ezzyat, Andrew Butler (*GSP Winner*), Melanie Cohn, Erika Nyhus, Ken A. Paller**

A B S T R A C T S

CONCEPTUAL BROADENING OF OBJECT REPRESENTATIONS REVEALED THROUGH FMRI-ADAPTATION *Stephen J. Gotts[1], Shawn C. Milleville[1], Alex Martin[1]; [1]Laboratory of Brain and Cognition, NIMH/NIH, Bethesda, MD* – A fundamental question for cognitive neuroscience is how neural representations are altered by experience. In monkeys, extended experience with visual objects can lead single neurons to respond more selectively to particular objects, referred to as "sharpening" of neural representations (Grill-Spector, Henson, & Martin, 2006, TICS). However, this mechanism does not make a great deal of sense for conceptual representations: a sharpening mechanism makes representations more distinct by decreasing their neural overlap, and semantic memory requires "broad", overlapping representations among associates. We have evaluated the extent to which experience with visual objects leads to sharpening versus "broadening" of neural representations by employing an fMRI-Adaptation paradigm with pictures of living things. Neural tuning was assessed along a conceptual dimension by rapidly adapting neural activity to one picture (e.g. cow) and measuring the recovered response to a different, "deviant" picture that shared a conceptual relationship to the adapted picture at one of 3 levels: exemplar (different cow), semantic associate (horse), and unrelated (lobster). The effect of experience on tuning was assessed by pre-exposing half of the adaptation stimuli in a picture-naming task prior to fMRI. Our results suggest that naming pictures leads to increased rather than decreased neural overlap among the representations of conceptual associates in left inferior frontal cortex and the fusiform gyrus, bilaterally. We suggest that this "conceptual broadening" phenomenon is consistent with an incremental learning mechanism that gradually creates and maintains overlapping neural conceptual representations in cortex, permitting similarity based recall of information and generalization to newly encountered objects.

THE NEURAL BASIS OF LEARNING EXCEPTIONS TO A CATEGORY RULE *Tyler Davis[1], Bradley C. Love[1], Alison R. Preston[1,2]; [1]University of Texas at Austin, Psychology, [2]University of Texas at Austin, Center for Learning and Memory* – A critical capacity of all organisms is the extraction, representation, and exploitation of regularities in the environment. However, it is also crucial to recognize occasions for which these regularities will not hold. Rule-plus-exception tasks have been used to study processes involved in learning items that deviate from learned regularities. In these tasks, participants learn to categorize items into categories based on the perceptual features of items while receiving feedback. The majority of items can be categorized according to a rule, however some items are exceptions to this rule and may thus be learned and represented separately. Behaviorally, such exception items are associated with enhanced recognition memory as well as elevated arousal. Recently, Love & Gureckis (2007) used model-based evidence to suggest that a network consisting of the hippocampus, surrounding medial temporal lobe (MTL) cortices, and prefrontal cortex (PFC) is engaged when learning items that are rule exceptions. Consistent with this model-based approach, the current fMRI study demonstrated greater activation in MTL and PFC when participants categorized items as exceptions than when items were categorized according to the rule. The results further revealed that correctly classifying exception items resulted in greater activation in areas of the ventral striatum that have been associated with feedback-based learning, suggesting that interactions between striatum, MTL and PFC regions may be essential to exception learning. Finally, analysis of the within-trial time series indicated that activation in these regions shifted dynamically during learning from feedback early in learning to stimulus onset late in learning.

THE BEHAVIORAL AND NEURAL SUBSTRATES UNDERLYING RELATIONAL AND TEMPORAL BINDING *Jennifer D. Ryan[1,2], Lily Riggs[1,2], Christina Villate[1], Esther Oziel[1], Steve Ly[1], Tim Bardouille[1,2], Anthony T. Herdman[3]; [1]Rotman Research Institute, [2]University of Toronto, [3]Simon Fraser University* – The construction of, and subsequent access to, representations regarding the relative spatial and temporal relations among sequentially presented objects was examined in separate studies using either eye movement monitoring or magnetoencephalography. Participants were presented with a series of single objects. Subsequently, a test display revealed the objects simultaneously and participants judged whether the relative relations were maintained. Eye movements revealed the binding of relations across study images; eye movements transitioned between the location of the presented object and the locations that were previously occupied by

objects. During test image viewing, eye movements distinguished intact displays from manipulated images through an increase in viewing to the now-empty, altered region, and through alterations in the temporal order by which objects were scanned. Significant neural responses related to the onset of the study images were found in the medial temporal lobe region, including the parahippocampus, as well as regions within the parietal and frontal cortices within 400 ms. Significant neural responses related to the onset of the test images were found in medial temporal, superior temporal, parietal and frontal cortices within 500 ms. The present findings suggest that memory representations of the visual world include information regarding the relative spatial and temporal relations among objects. Eye movements may be the conduit by which information is integrated into a lasting representation, and by which current information is compared to stored representations. Binding of, and subsequent access to, temporal and spatial relations is related to rapid engagement of the medial temporal, parietal and frontal cortices.

EVENT PERCEPTION INFLUENCES THE ORGANIZATION OF LONG-TERM MEMORY *Youssef Ezzyat[1], Lila Davachi[1,2]; [1]New York University, Psychology, [2]New York University, Center for Neural Science* – Cognitive psychological research has shown that people can easily and reliably segment continuous action into units called "events" (Newtson 1976). Previous research has also shown that event segmentation influences the online processing of stimuli. Specifically, perception of event boundaries has been shown to render previously encoded information less accessible in working memory (Morrow 1989; Speer 2005; Zwaan 1998). However, it is unclear how this processing during encoding might affect long-term memory for the events. The purpose of the present study was to test the effects of event segmentation on long-term memory and to examine the neural processing that occurs at event boundaries. While scanned using fMRI, participants read narratives containing event boundaries and were later given a recall test for information in the narratives. At test, event boundaries served as better recall cues than control sentences; at encoding, event boundaries activated right dorsolateral and anterior prefrontal cortex, as well as the left hippocampus. These results show that event segmentation influences long-term memory and suggest that brain activity at event boundaries may serve to organize stimulus information for long-term memory encoding.

CUED RETRIEVAL OF NOVEL AUDITORY OR VISUAL STIMULI ACTIVATES MODALITY SPECIFIC CORTICES REGARDLESS OF CORRECT PERFORMANCE *Andrew Butler[1], Dylan Bargatze[1], Ryan Stevenson[1], Karin James[1]; [1]Indiana University* – In this work, we investigated the effects of associating novel items that were presented in different modalities (visual and auditory) on brain activation patterns during both encoding and cued recall. Subjects were presented with cue-target associations comprised of pairs of nonsense objects, pairs of nonsense sounds, objects paired with sounds, and sounds paired with objects. Subsequently, they were required to recall the modality of the target given the cue. Because both stimuli were novel, we were assured that no known associations with a given modality would influence the results. We measured both accuracy and BOLD activation during encoding and retrieval sessions. Results replicate previous studies showing that successful retrieval of an auditory or visual target was associated with modality specific BOLD activation in the auditory (superior temporal gyrus) or visual (posterior occipital gyri) cortices, respectively. We extended these findings, however, and also showed that a) when a subject recalled the target modality incorrectly, they still had increased BOLD activation in the modality specific cortex associated with the falsely recalled target; and b) that retrieval of information from cross-modal associations activated the hippocampus, whereas within-modal associations did not. Together these findings suggest that retrieval of an auditory or visual target, regardless of whether it was correct or not, activates modality specific cortical regions. Additionally, cross-modal associations may require hippocampal involvement more than within-modal associations.

THE HIPPOCAMPUS SUPPORTS CONVERSION FROM FAMILIARITY TO RECOLLECTION *Melanie Cohn[1,2], Ayelet Lahat[2], MaryPat McAndrews[1,2], Morris Moscovitch[2,3]; [1]Krembil Neuroscience Centre, University Health Network, [2]University of Toronto, Psychology, [3] Baycrest Centre for Geriatric Care, Rotman Research Institute, Psychology* – The role of the hippocampus in recognition memory is debated. One view proposes that the hippocampus is crucial to recollection (i.e., retrieval of contextual information), but not familiarity (i.e., decontextualized feeling of 'oldness'). Another view proposes that hippocampal involvement is related to memory strength, irrespective of whether or not retrieval is accompanied by recollection of context. The current study aimed to test these proposals using event-related fMRI. We compared brain activation to items before provision of a context cue when they are judged familiar and after the cue was presented when some of the same items are judged as recollected. Participants studied pairs of words (A-B) and were scanned while performing a recognition task for the first member of the pairs (A). An uncued item, either a studied (A) or new word (C) was presented and participants indicated whether the item was new, familiar or recollected. A cued trial followed immediately, in which intact pairs (A-B) or new-old pairs (C-B) were presented; the recognition decision was again to be based only on the first item (A or C). Increased hippoc-

ampal activation (cued > uncued) was found only for items that became recollected, and not for items that remained familiar. As the only difference between those conditions was subjective experience, given that items and context cues were identical, our results are more consistent with the view that the hippocampus is selectively involved in supporting recollection per se rather than retrieval of strong memories.

RECOLLECTION REVEALED BY ITS ABSENCE: MIDAZOLAM-INDUCED AMNESIA REDUCES MEMORY FOR DETAILS AND THE ERP CORRELATE OF RECOLLECTION *Erika Nyhus[1], Tim Curran[1]; [1]University of Colorado at Boulder* – Dual process models suggest that recognition memory is supported by familiarity and recollection processes. Previous research administering amnesic drugs and measuring event related potentials (ERPs) during recognition memory have provided evidence for separable neural correlates of familiarity and recollection. The benzodiazepine midazolam, which causes anterograde amnesia, has been shown to predominantly influence recollection, with limited effects on familiarity. In addition, it has been proposed that the FN400 component indexes familiarity, and the parietal old/new effect indexes recollection. The present study examined the effect of midazolam-induced amnesia on memory for details and the proposed ERP correlates of recognition. Midazolam or saline was administered while subjects studied oriented pictures of common objects. ERPs were recorded during a recognition test one day later. During the recognition test subjects were shown studied pictures in the original orientation, studied pictures in the opposite orientation, and new pictures; and judged whether each picture was "Old Same Orientation", "Old Different Orientation", or "New". Subjects' discrimination of old and new pictures was worse when they were administered midazolam than saline; and discrimination of same orientation and different orientation old pictures was at chance when studied under midazolam, but above chance when studied under saline. Although the FN400 was similar under midazolam or saline, the parietal old/new effect was decreased with the administration of midazolam. These results provide converging pharmacological and electrophysiological evidence that recollection supports recognition for details and adds to previous research showing separable neural correlates of familiarity and recollection.

THE ELECTROPHYSIOLOGY OF REMEMBERING AND KNOWING WITH CONCEPTUALLY IMPOVERISHED KALEIDOSCOPE IMAGES *Ken A. Paller[1], Joel L. Voss[1]; [1]Northwestern University* – Contemporary memory theories distinguish between contextual recollection and acontextual familiarity as two fundamentally different types of recognition memory. It is currently unclear whether recollection and familiarity are supported by two corresponding retrieval mechanisms, or whether the same type of retrieval processing supports both phenomena through varying contributions from retrieving item and context/source information. Electrophysiological findings in humans have widely been cited as support for the two-process position, in that late-onset parietal "LPC" potentials have been linked to recollection and early-onset frontal "FN400" potentials to familiarity. However, recognition memory is generally studied using conceptually rich stimuli such as words, which leaves open an alternative interpretation that one or both of these electrophysiological signals reflect implicit conceptual processing distinct from recollection and familiarity per se. We tested this hypothesis using conceptually impoverished kaleidoscope images, such that opportunities for conceptual processing were minimized. Recollection-based and familiarity-based recognition in a remember/know paradigm were both indexed by LPC potentials. Old/new amplitude differences were greater for recollection compared to familiarity. Despite ample familiarity-based recognition, FN400 old/new effects were not observed, consistent with the contention that these potentials index conceptual processing rather than familiarity. These results cast doubt on interpretations of prior electrophysiological evidence obtained using conceptually rich stimuli as dissociating neural mechanisms of recollection and familiarity. We also found that neural events during encoding differentially predicted later recollection versus later familiarity, which suggests that the engagement of distinct encoding processes can preferentially lead to recollection versus familiarity.

Slide Session 4 Emotion

Monday, March 23, 10:00 am - 12:00 pm, Grand Ballroom B

Chair: **Kevin Ochsner**

Speakers: **Joan Y. Chiao, Roma Vasa, Virginie Czernecki, Tor Wager, Kateri McRae, Katja Spreckelmeyer, Julie L. Hall (*GSP Winner*), Jamil Zaki**

A B S T R A C T S

CULTURAL VARIATION IN AMYGDALA RESPONSE TO EMOTIONAL SCENES *Joan Y. Chiao[1], Ahmad R. Hariri[2], Tokiko Harada[1], Hidetsugu Komeda[3], Todd B. Parrish[4], Norihiro Sadato[3], Tetsuya Iidaka[5]; [1]Northwestern University, Psychology, [2]University of Pittsburgh, Psychiatry, [3]National Institute for Physiological Sciences, [4]Northwestern University, Radiology, [5]Nagoya University, Psychiatry* – Culture affects how people perceive and experience the emotional salience of events, such as threat in the environment. The human amygdala is critical to the evaluation of and response to threat-relevant signals. Although much is known about the role of the amygdala in emotional evaluation and response, very little is known about how culture affects amygdala response to threat-relevant signals in the environment. To examine the effect of culture on amygdala response to emotion, in Study 1 we used cross-cultural neuroimaging at 3T to measure neural response within the human amygdala and ventrolateral prefrontal cortex (VLPFC) during emotional evaluation and cognitive inhibition in Caucasian-Americans (CA) and native Japanese (JP). Results indicated greater bilateral amygdala response during evaluation of negative emotional scenes, but not cognitive inhibition, in JP relative to CA participants. There was no cultural variation in VLPFC during either emotional evaluation or cognitive inhibition. To determine whether the cultural variation observed in Study 1 was due to race rather than cultural environment per se, in Study 2, we measured neural response within the human amygdala and VLPFC during emotional evaluation and cognitive inhibition in Japanese-Americans (JA). Results showed no difference in bilateral amygdala or VLPFC response during emotional evaluation and cognitive inhibition between CA and JA participants. Critically, JP showed significantly greater response within bilateral amygdala during emotional evaluation, but not cognitive inhibition, compared to JA participants. Taken together, these findings provide convergent evidence of cultural variation in human amygdala response that is emotion-specific.

FMRI STUDY OF DEVELOPMENTAL DIFFERENCES IN NEURAL PROCESSING OF PICTORAL STIMULI *Roma Vasa[1], Daniel Pine[2], Tess Nelson[1], Eric Nelson[2], Christopher Monk[3], Monique Ernst[2], Maggie Bruck[4], Stewart Mostofsky[1]; [1]Kennedy Krieger Institute, Johns Hopkins University School of Medicine, [2]Mood and Anxiety Disorders Program, National Institutes of Mental Health, [3]University of Michigan, Psychology, [4]Johns Hopkins Hospital, Johns Hopkins University School of Medicine* – Adult neurobiological studies consistently implicate activity within the amygdala and prefrontal structures in response to emotional stimuli. Yet, data on involvement of these structures, particularly the amygdala, in pediatric emotional processing are inconsistent. Understanding age-related neural differences in emotion processing is crucial for developing hypotheses about risk factors and mechanisms for psychopathology across development. This study used event-related fMRI to compare the neural responses to positive and negative pictures in 18 adults and 12 adolescents. A surprise memory test was given thirty minutes postscan. The main contrasts compared brain activity associated with picture viewing versus control state as well as subsequently recalled versus not recalled pictures. During positive picture viewing, adolescents activated the right amygdala and orbitofrontal (OFC) whereas adults activated the left hippocampus and right OFC. When viewing negative pictures, adolescents activated bilateral amygdalae, the left hippocampus, right anterior cingulate and OFC. Adults similarly activated the left amygdala and bilateral hippocampi and OFC. No group contrasts were significant. The memory data revealed that adolescents, but not adults, exhibited greater activity in bilateral amygdalae and hippocampi, the right OFC and anterior cingulate when viewing subsequently recalled positive pictures compared with not recalled pictures; the groups displayed comparable memory performance. These data indicate that adolescents and adults both engage amygdala-OFC circuitry when responding to emotional pictures. Adolescents, however, exhibited greater limbic activity to positively recalled pictures; this finding may have implications for the increased reward and novelty seeking behavior observed during this developmental period.

INSULAR LOBE AND MULTIMODAL EMOTIONAL PROCESSING INTEGRATION: EVIDENCE FROM BRAIN-DAMAGED PATIENTS *Virginie Czernecki[1], Didier Grandjean[3], Sylvain Delplanque[3], Laurent Capelle[2], Carine Karachi[2], Bruno Dubois[1]; [1]Inserm U610, IFR70, Neurology, Salpetriere Hospital, Paris, France, [2]Inserm U679,*

IFR70, Neurosurgery, Salpetriere Hospital, Paris, France, [3]Swiss Center for Affective Sciences, University of Geneva, Swiss – A growing body of evidence in social affective neuroscience highlights the involvement of the insular lobe in both experiencing and observing negative emotions. The contribution of the anterior territory of insula during the recognition of emotional facial expressions and observation of emotional scenes evocating disgust or fear has been well demonstrated. Moreover, functional brain imaging studies in healthy participants have shown insular activations during the inhalation of odorants producing a strong feeling of disgust. Here we used a multimodal emotional battery in a group of fifteen patients with glioma affecting the right or left anterior part of insula before and/or after a surgical resection. Positive and negative emotions were investigated in three different ways including olfactory stimuli, facial emotional expression stimuli and words (using an emotional stroop task). All patients showed altered pattern of emotional evaluation odours evocating a strong sensation of disgust in healthy participants regardless of the side of the insular lesion. The identification of facial expressions of disgust, fear and anger was also strongly disturbed. The implicit emotional reactivity to negative words is blunted whatever the laterality and the side of the lesion. These preliminary results provide evidence that the insular lobe is a crucial part of a distributed neuronal network involved in emotional processing independently of the visual or olfactory modality and probably related to visceral/autonomic perception. The integrity of the anterior insula seems necessary to experience unpleasant feelings, particularly disgust induced through olfactory modality, and to decode facial expressions and emotional semantic meaning of words.

ANTICIPATORY BRAIN ACTIVITY PREDICTS PLACEBO ANALGESIA AND IS MEDIATED BY LIMBIC RESPONSES DURING PAIN *Tor Wager[1], Lauren Leotti[1], Lauren Atlas[1]; [1]Columbia University, Psychology* – Placebo analgesia is a model paradigm for studying the effects of expectations on affective states. Previous studies have shown placebo-induced increases in fMRI activity in dorsolateral prefrontal (DLPFC) and orbitofrontal (OFC) cortices when anticipating pain, as well as opioid release in orbitofrontal and limbic cortices. In this study, we re-analyzed data from two fMRI studies of placebo analgesia (combined N = 45), focusing on how anticipatory fMRI activity relates to placebo effects in both brain responses to pain and reported analgesia. In the combined sample, we identified a number of brain regions in which anticipatory activity predicted placebo analgesia. Multivariate clustering analyses identified three independent networks among these regions that were each independently predictive of placebo analgesia. Together, these three networks explained 77% of the variance in placebo analgesia across individuals. In two networks--a fronto-parietal network including bilateral DLPFC and parietal cortices, and another network including dorsomedial PFC and frontal pole--anticipatory increases (Placebo - Control) were associated with more profound placebo analgesia in reported pain. The third network included bilateral SII, a well-known region implicated in pain processing; in this network, anticipatory decreases were associated with placebo analgesia. Anticipatory activity was mediated by changes during pain in ventral striatum, but not SII, insula, cingulate, and other "pain processing" regions. Overall, the results suggest that anticipatory brain processes play a central role in placebo analgesia, and that these effects are mediated by changes in pain processing in limbic brain systems rather than those traditionally associated with nociception.

BOTTOM-UP VERSUS TOP-DOWN EMOTION GENERATION: IMPLICATIONS FOR EMOTION REGULATION *Kateri McRae[1], Supriya Misra[1], Aditya K. Prasad[1], Sean C. Pereira[1], Benjamin Edwards[1], James J. Gross[1]; [1]Stanford University* – Current theories of emotion suggest that emotions may be generated in at least two different ways: bottom-up and top-down. Bottom-up emotion generation involves the perception of low-level features of the stimulus itself (e.g., properties of the eyes and mouth in an emotional face). Top-down emotion generation involves the appraisal of the meaning of a stimulus considering the larger context within which an individual is operating (e.g., knowledge that a neutral face hides great disappointment). The present study tested the hypothesis that top-down emotion regulation strategies are more effective when emotions are generated top-down than when emotions are generated bottom-up. In particular, we focused upon cognitive reappraisal, which has been shown to decrease self-reported negative affect and BOLD signal from the amygdala. Twenty-four women were scanned on a 3-Tesla GE magnet while viewing top-down and bottom-up emotional stimuli under instructions to respond naturally or to use cognitive reappraisal to decrease negative affect. Measures of self-reported negative affect indicated that top-down emotions were more successfully regulated than bottom-up emotions. BOLD signal from the amygdala also showed this interaction, but paradoxically, amygdala activation was greater during regulation of bottom-up stimuli than during natural responding to bottom-up stimuli. In addition, medial prefrontal regions previously implicated in reappraisal showed greater activation during natural responding to top-down generated emotions and during reappraisal of both top-down and bottom-up generated emotions, but were not recruited during bottom-up emotion generation. This implies that the type of emotion generation moderates the success of top-down emotion regulation strategies.

DISSOCIATION OF NEURAL NETWORKS FOR ANTICIPATION AND CONSUMPTION OF MONETARY AND SOCIAL REWARDS *Katja Spreckelmeyer[1], Lena Rademacher[1], Sören Krach[1,2], Gregor Kohls[3], Arda Irmak[1], Tilo Kircher[1], Gerhard Gründer[1]; [1]RWTH Aachen University, Germany, Psychiatry and Psychotherapy, [2]Central Service Facility, [3]RWTH Aachen University, Child and Adolescent Psychiatry, Child Neuropsychology Section, Germany* – Reward processing can be dissected into phases of reward anticipation and reward consumption. It is currently a matter of debate whether these processes are mediated by the same or different neural networks. Previous research has identified the ventral striatum as key structure in reward anticipation. However, its role in reward consumption is disputed. Here, we examined the neural basis of reward anticipation vs. consumption in an incentive delay task offering either money or social approval. In both conditions participants (N=28) were given a cue indicating potential reward. In order to receive reward, a target button had to be pushed within a certain time window (adapted for individual reaction time). Reward (pictures of coins or approvingly smiling faces) was presented for 1650 ms 300 ms after target time onset. Monetary or social conditions were alternated sessionwise. Imaging was performed on a 1,5 Tesla Siemens scanner in an event-related design. Anticipation of reward resulted in activation of mesolimbic brain structures, including the ventral striatum, independent of incentive type. In contrast, consumption of monetary or social reward resulted in individual activation patterns, neither of which included the striatum. Among other structures, monetary reward specifically activated the thalamus, while social reward specifically activated the amygdala. Our results corroborate the role of the ventral striatum as modality-independent mediator of reward anticipation but cast doubt on its importance for reward consumption. Moreover, the findings implicate that the neural mechanisms underlying reward consumption are more modality-specific than those for reward anticipation.

PUT YOUR MONEY WHERE YOUR HEART IS: AN FMRI INVESTIGATION OF AFFECTIVE INFLUENCES ON FINANCIAL INVESTMENT DECISIONS *Julie L. Hall[1], Richard Gonzalez[1], Oliver C. Schultheiss[1]; [1]University of Michigan* – Traditional economic models assume that individuals are always rational when they make financial decisions. However, the current study suggests that emotions may play an important role in financial decisions. Our goal was to investigate whether affective primes could influence risk taking and anticipatory neural activation during financial decisions. Using fMRI, 24 participants viewed happy, angry, and neutral affective primes presented under subliminal and supraliminal conditions followed by an investment task where they had to decide between risky, high-payoff stocks and safe, low-payoff bonds. Our results indicate that both subliminal and supraliminal presentations of affective primes influence financial investment decisions and anticipatory neural activation in the NAcc and anterior insula. As predicted, participants showed greater NAcc activation and were more likely to make risky investment decisions after happy versus neutral face primes in both the subliminal and supraliminal presentation conditions. In addition, participants also showed greater anterior insula activation and made slightly less risky investment decisions after angry versus neutral face primes during supraliminal presentation conditions. In conclusion, our results demonstrate that facial expressions of emotion, even when they are not consciously perceived, can influence investment decisions and suggest that the inclusion of affect may lead to more accurate models of economic decision making, which better explain irrational financial behavior. They also suggest that affective states during pre-choice stages of the decision making process may alter the perception of benefits relative to costs, leading to changes in financial risk taking depending on whether the affective state is positive or negative.

THE NEURAL BASES OF EMPATHIC ACCURACY AND AFFECTIVE EXPRESSIVITY *Jamil Zaki[1], Jochen Weber[1], Niall Bolger[1], Kevin Ochsner[1]; [1]Columbia University, Psychology* – How do people understand the thoughts and feelings of others, and effectively communicate their own internal states? While much research in cognitive neuroscience has addressed the mechanisms involved in sharing the sensory and emotional states of others, the mechanisms underlying accurate understanding those states have remained largely unexplored. We used a novel empathic accuracy (EA) paradigm to address this gap in extant knowledge. Brain activity was recorded from 16 perceivers using fMRI while they watched videos of social targets describing emotional autobiographical events, and continuously rated how positive or negative they believed targets felt. Correlations between these ratings and targets' own affect ratings served as measures of EA, and were used as predictors in subsequent fMRI analyses. This allowed us to explore brain activity tracking with perceivers' accuracy in understanding target affect. We found that periods of accurate – as opposed to inaccurate – inferences were supported by frontal and parietal activity associated with mental state attribution, and sensorimotor structures within the mirror neuron system. Furthermore, targets who scored high on a trait measure of emotional expressivity were more affectively "readable" – that is, they produced higher levels of EA across perceivers – and this was in part because target expressivity predicted the magnitude of perceivers' neural activity in several brain regions related to mental state attribution. Overall, these data demonstrate that multiple social cognitive processes are employed in concert to understand the emotions of others, and that the characteristics of social targets affect perceivers' neural and cognitive processes.

Slide Session 5 Attention

Monday, March 23, 3:00 - 5:00 pm, Grand Ballroom B

Chair: **B. J. Casey**

Speakers: **Nathan Parks, Jaap Munneke (*GSP Winner*), Mark Stokes, Jane Couperus, Aarlenne Khan, Søren K. Andersen, Kathy Niu, Richard Young**

ABSTRACTS

STEADY-STATE SIGNATURES OF PERCEPTUAL LOAD, NEURAL COMPETITION, AND MULTIMODAL DISTRACTOR FILTERING *Nathan Parks[1], Matthew Hilimire[1], Paul Corballis[1]; [1]Georgia Institute of Technology* – The perceptual load theory of attention posits that the level of selection is dependent upon the perceptual demands (load) of the task, with early selection occurring under high load and late selection under low load. Using a steady-state evoked potential (SSEP) paradigm we investigated 1) the modality specificity of distractor filtering, 2) the effect of perceptual load on target-specific processing, and 3) neural-competitive interactions between target and distractor stimuli. Participants performed a central RSVP task that varied in perceptual load, requiring identification of a feature singleton under low load and a feature conjunction under high load. The RSVP task was performed in isolation and in the presence of irrelevant visual and auditory distractors. Task, visual distractor, and auditory distractor stimuli were modulated at unique frequencies (2.5 Hz, 8.5 Hz, and 40.0 Hz, respectively), allowing the cortical response of each to be tracked independently in the frequency-domain. Analysis of frequency-domain signal strength revealed: 1) High perceptual load decreased signal strength of within-modality visual distractors but had no effect on between-modality auditory distractors, suggesting perceptual-level distractor filtering is modality-specific; 2) High load increased task-specific parietal signal strength, consistent with top-down modulation of perceptual processing by a frontal-parietal network; 3) Within-modality visual distractors attenuated task-related signal strength, suggesting mutual suppression of target and distractor stimuli through neural competition. This competition further interacted with perceptual load such that signal suppression was present only under low load, a result suggesting that increased perceptual load biased competition in favor of task-relevant stimuli.

RETINOTOPIC ACTIVATION IN PRIMARY VISUAL CORTEX DURING SPATIAL WORKING MEMORY *Jaap Munneke[1], Dirk Heslenfeld[1], Jan Theeuwes[1]; [1]VU University, Amsterdam* – Prior research indicated that spatial working memory and spatial selective attention share a distributed large-scale cortical network consisting of fronto-parietal regions. Similar patterns of neural activity have been observed in these regions during these tasks. We investigated whether the overlap in neural structures could be extended to the visual regions of the occipital cortex and in particular to primary visual cortex (V1). In the current study, participants conducted a spatial working memory task and a spatial attention task while the BOLD response was measured. While the instructions in both tasks differed, the trials were basically identical. Our results indicated that (1) the neural overlap between spatial working memory and spatial selective attention extends beyond the fronto-parietal network and can be observed in the visual cortex as well. (2) The primary visual cortex is involved in both tasks, indicating that V1 is more than a simple relay station passing on information coming from the retina and that top-down procedures can modulate the neural response in early visual cortex. The current results fit with a hypothesized model of working memory, claiming that shifts of spatial attention are required for maintenance during spatial working memory.

SELECTIVE ACTIVATION OF STIMULUS-SPECIFIC POPULATION CODES IN VISUAL CORTEX DURING TOP-DOWN ATTENTIONAL CONTROL *Mark Stokes[1,2], Russell Thompson[2], Anna Christina Nobre[1], John Duncan[2]; [1]Oxford University, Experimental Psychology, [2]MRC Cognition and Brain Sciences Unit, Cambridge University* – Previously, we demonstrated that top-down control mechanisms can access stimulus-specific population codes in high-level visual cortex (Stokes et al., 2008). Using multivoxel pattern analysis (MVPA), we found that visual imagery activates content-specific perceptual representations stored in visual cortex, even in the complete absence of differential visual input. Here, we further examine top-down control over visual cortex for non-spatial selective attention. During fMRI, participants were cued via an auditory tone to attend to either the letter "X", or the letter "O", on a trial-by-trial basis. During a pattern localiser condition, participants were also scanned whilst viewing either the letter "X" or "O", thereby enabling us to define the neural signature pattern for the visual codes corresponding to the contents of visual attention. Consistent with the well-established capacity of MVPA to resolve differential activation profiles that index distributed population coding, we could reliably differentiate between the patterns of visual activity associated with the two alternative perceptual states. Unique to the current study, however, we also found that pattern

analysis of the same areas in visual cortex that code for visual perception also differentiate between the corresponding attentional states: attending for either the letter "X" or the letter "O". We conclude that top-down mechanisms for selective attention can accurately modulate activity in visual cortex to bias functionally distinct, yet spatially overlapping, neural populations.

SEPARABLE MECHANISMS OF SIGNAL ENHANCEMENT AND SIGNAL SUPPRESSION DURING VISUAL-SPATIAL SELECTIVE ATTENTION *Jane Couperus[1], George R. Mangun[2]; [1]Hampshire College, [2]University of California Davis* – Selective attention modulates activity at early levels of visual processing, as is reflected in changes in the P1 event-related potential (ERP) component. Although some have suggested that the process of selection involves primarily signal enhancement (e.g., Mangun et al., 1991), others have suggested that it involves both the enhancement of the signal of the attended stimulus as well as suppression of the unattended stimulus (e.g., Awh, Matsukura, and Serences 2003; Dell'Acqua et al., 2007). Using a spatial cuing paradigm, we examined target and distracter processing as a function of the expectancy of distracter presence versus absence. In Experiment 1, in different blocks of trials, distracters appeared frequently (70% of trials) or infrequently (30% of trials). Analysis of distracter-present displays (consisting of two stimuli, the attended target and unattended distracter in the opposite visual hemifield) showed that in addition to target enhancement of the occipital P1 ($F(1,18)=17.22$, $p=.001$)in the hemisphere contralateral to the target, processing of distracters was reduced in the frequent condition as compared to the infrequent condition ($F(1,18)=5.54$, $p=.03$) in the hemisphere contralateral to the distracter. Experiment 2 replicated these findings with the presence of the distracter cued from trial-to-trial rather than within a block design ($F(1,19)=13.58$, $p=.002$ and ($F(1,19)=5.71$, $p=.027$) respectively) . These findings suggest that both active enhancement and active suppression are involved in visual-spatial selective attention. Moreover, the engagement of suppression mechanisms may be critically dependent on distracter presence, that when anticipated results in the use of suppression mechanisms.

SACCADE PLANNING IS DISSOCIATED FROM PRE-SACCADIC ATTENTIONAL FACILITATION AFTER DAMAGE TO THE POSTERIOR PARIETAL CORTEX *Aarlenne Khan[1], Annabelle Blangero[2], Yves Rossetti[2], Romeo Salemme[2], J. Luaute[2,3], Heiner Deubel[4], Werner Schneider[4], N. Laverdure[2], Gilles Rode[2,3], Laure Pisella[2]; [1]Smith-Kettlewell Eye Research Institute, San Francisco, California, [2]INSERM U864, Espace et Action, Bron, France; Université Claude Bernard, Lyon 1; Institut Fédératif des Neurosciences de Lyon (IFNL), Lyon, France, [3]Hospices Civils de Lyon, Lyon, France, [4]Ludwig-Maximilians-Universität, Munich, Psychology, Germany* –
Numerous studies have suggested that saccades to a location trigger an automatic attentional shift to the saccade goal, which enhances perceptual processing at that location. Here, we argue for a functional dissociation between pre-saccadic perceptual enhancement and saccade planning. A patient with a lesion in the right posterior parietal cortex participated in a dual saccade and letter discrimination task. The patient made saccades to the left or right visual field. During the saccade latency a letter was briefly presented at the saccade goal and the patient was asked to discriminate the letter after he completed the saccade. The patient was able to make the normal saccades to the left, impaired visual field that could not be distinguished from saccades to the right, healthy, visual field. However, he was unable to discriminate the letters presented at the saccade goal on his left visual field whereas his performance was excellent in his right visual field. By presenting letter changes at locations that were either closer to or further away from to the saccade goal location, we also tested whether this inability to discriminate a letter at the saccade goal in the impaired visual field was attributable to a distorted attentional shift. The patient performed at chance for all letters presented in the contralesional visual field. We conclude that the leftward saccades were made without an anticipating attentional shift, whereas the rightward saccades were accompanied by a normal attentional shift.

A SPLIT SPOTLIGHT OF FEATURE-SELECTIVE ATTENTION? *Søren K. Andersen[1]; [1]Institut für Psychologie I, Universität Leipzig, Leipzig, Germany* – Previous studies have demonstrated that spatial attention can be 'split', i.e. divided between non-contiguous locations. Here we asked the question whether feature-selective attention can be split in an analogous way. Two completely overlapping random dot kinematograms (RDKs) of two different colors were presented on either side of a central fixation cross. Sustained attentional selection was measured by means of steady-state visual evoked potentials (SSVEPs) elicited by these frequency-tagged RDKs. Participants performed a divided attention task, in which they had to attend to two RDKs, one each side of fixation. We compared conditions in which both to-be-attended RDKs had the same color with conditions in which the colors of both RDKs were different. While the 'same' conditions were characterized by good behavioral performance and clear enhancement of SSVEP-amplitudes to attended stimuli, behavioral performance in the 'different' conditions was strongly reduced and there were no effects of attentional selection on SSVEP-amplitudes. This clearly shows that it is not possible to simultaneously direct attention to different features at different locations. This is in line with previous studies

that have reported a global effect of feature-selective attention, i.e. features are selected across the entire visual field. Our results provide evidence that global selection is not only the modus operandi of the visual system but that such selection can not be prevented even when it explicitly conflicts with task demands.

AUDIOSPATIAL ATTENTION EVOKES SIMILAR BRAIN ACTIVATION PATTERN TO VISUALSPATIAL ATTENTION *Kathy Niu[1], Ben Davis[1], Chris Rorden[1]; [1]University of South Carolina, Columbia* – Neuroimaging studies suggest that a fronto-parietal network is activated when we expect visual information to appear at a specific spatial location. Here, we examine whether a similar network is involved for auditory. We used a block design, continuous functional magnetic resonance imaging (fMRI) experiment to infer brain activation while participants performed spatial and temporal order judgment (TOJ) tasks with auditory stimuli. Each trial presented two different sounds (a viola and a bassoon) that were separated perceptually in time and space. During the TOJ task, participants identified which of the two sounds came first. For the spatial task, half of the participants were instructed to select the sound that appeared further to the left in space, and half were instructed to select the one further to the right. Crucially, the same stimuli were presented for both tasks, and the same motoric mapping was used for responses (index finger for bassoon, middle finger for viola). Thus, the statistical contrasts of the spatial blocks with the TOJ blocks should give a pure measure of task-related differences, uncontaminated by differences in low-level perception or motoric response. Furthermore, task difficulty was controlled as measured by response time and accuracy. More activation was observed for the spatial task than the TOJ task in the bilateral temporal parietal junctions (TPJ), bilateral superior frontal regions near the frontal eye fields (FEFs), and bilateral intraparietal sulci (IPS), as well as bilateral occipital temporal junctions. These regions are similar to those reported for spatial attention for visual stimuli.

VALIDATION OF DRIVING STUDIES FROM THE LAB TO THE ROAD USING ERPS *Richard Young[1,2], Li Hsieh[2,3], Sean Seaman[2,3,4]; [1]Wayne State University, School of Medicine, Psychiatry and Behavioral Neurosciences, [2]Wayne State University, Institute of Cognitive and Applied Neuroscience, [3]Wayne State University, Communication Sciences and Disorders, [4]Wayne State University, Psychology* – Most investigations into driving performance involve the use of simulators, and this is especially true of neuroscience studies of driving performance (e.g., Hsieh et al., 2008; Bowyer et al., 2008). What is often lacking, especially in the neuroscience domain, is a validation of these simulators using neuroscience tools, which is especially important given 1. the cognitive complexity of a real-world driving task and 2. the policy implications of driving performance research. In this study, we used EEG and an array of behavioral measures to estimate the effects of a simulated cellular phone conversation on driving performance. EEG was measured in the vehicle using a laptop computer, a battery-powered 64-channel amplifier, and a shielded EEG cap. Participants drove on real roads in a test vehicle, and responded to simulated road events using light stimuli positioned around the driver's field of view in the vehicle. In the lab, this was simulated using a steering stimulator and light events presented on a computer. In both environments, participants' reaction times to visual events were assessed, and ERPs were recorded to the visual events. While driving, participants answered pre-recorded questions to simulate a cellular phone conversation. The goal of the study was to evaluate the reliability of both behavioral and EEG measures. Results show that behaviorally, the effects of conversation on the road and in the lab were consistent, showing a small increase in RTs and negligible patterns of inaccuracy in both environments. ERPs also show consistency across sites.

Slide Session 6 Perception

Tuesday, March 24, 10:00 am - 12:00 pm, Grand Ballroom B

Chair: **Reiko Graham**

Speakers: **Dominique Vuvan (*GSP Winner*), Bradford Mahon (*GSP Winner*), Emily S. Cross, Lawrence Ward, Jessica Wisnowski, Jessica Cantlon, Psyche Loui, V. S. Ramachandran**

ABSTRACTS

THE COGNITIVE-PERCEPTUAL EFFECTS OF AUDIO GAME TRAINING *Dominique Vuvan[1], Claude Alain[1,2]; [1]University of Toronto, Toronto, Canada, [2]The Rotman Research Institute, Baycrest, Toronto, Canada* – The study reported here was designed to explore whether playing an audio game can yield improvements in auditory perception, attention, and memory. All participants underwent two laboratory assessments 14 days apart. These assessments included four tests of basic auditory function (pure tone thresholds, speech in noise, mistuned harmonic detection, and gap detection), and two cognitive-perceptual tasks (auditory

working memory and auditory attentional blink). Auditory event-related brain potentials were recorded during the cognitive-perceptual tasks. Half of the participants were asked to play Troopanum 2.0 (a complex audio game designed for the blind that is analogous to "Space Invaders") for 30 minutes per day over the 14 days between assessments. The other half served as a control group and did not undergo training. On the second test session, participants who played the audio game showed greater improvements in performance on both the working memory and attentional measures than those who did not play the game. These performance gains were mirrored by changes in sensory and cognitive ERPs. In addition, trained participants also exhibited a significant decrease in mistuned harmonic detection thresholds relative to controls. No corresponding improvements were seen for the three remaining basic psychophysical measures. The results from this study show that playing audio games may lead to enhanced auditory perceptual and cognitive skills, and parallel findings from research in the visual domain.

CATEGORY-SPECIFIC ORGANIZATION IN THE HUMAN BRAIN DOES NOT DEPEND ON VISUAL EXPERIENCE *Bradford Mahon[2], Stefano Anzellotti[2], Jens Schwarzbach[1], Massimilano Zampini[1], Alfonso Caramazza[2]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy, [2]Harvard University, Psychology* – Functional imaging studies of the normally developing human brain have shown that lateral regions of ventral occipital-temporal cortex show neural specificity for living things (faces, animals) while medial regions show neural specificity for nonliving things (tools, houses). The neural principles that give rise to this lateral-to-medial organization by semantic domain within ventral occipital-temporal cortex are actively debated. Here we show using fMRI that the same regions of occipital-temporal cortex that exhibit neural specificity for artifacts and animals in sighted adults exhibit neural specificity for the same categories in congenitally and late blind adults. Sighted and blind participants performed a size judgment task over animal and nonliving stimuli. Stimuli consisted of auditory words, and were blocked by semantic category (animal vs. nonliving) into twenty second blocks. Sighted participants also viewed pictures corresponding to the same animal and nonliving stimuli in a subsequent localizer scan. For the size judgment task over auditory stimuli, regions within the medial fusiform gyrus were more activated in all groups of participants (sighted, late and congenitally blind) for nonliving compared to living stimuli. In contrast, regions within lateral occipital-temporal cortex were more activated for all groups of participants for animal stimuli compared to nonliving stimuli. The same regions were identified based on the picture-viewing localizer for the sighted subjects. These findings demonstrate that category-specificity within the human visual system does not depend on visual experience, and suggest the operation of innately determined domain-specific constraints on the organization of object knowledge.

NEURAL REPRESENTATIONS OF STATIC PLAUSIBLE AND IMPLAUSIBLE BODY POSTURES *Emily S. Cross[1,2], Emilie C. Mackie[3,4], George Wolford[4], Antonia F. de C. Hamilton[2]; [1]Max Planck Institute for Human Cognitive & Brain Sciences, Leipzig, Germany, [2]University of Nottingham School of Psychology, Nottingham, UK, [3]University of British Columbia, Vancouver, BC, [4]Center for Cognitive Neuroscience, Dartmouth College, Hanover, NH, USA* – Understanding other's movements and interacting socially require a representation of other people's bodies. Research into the neural underpinnings of body representation implicates several regions in this kind of processing. One set of such regions, known as the mirror neuron system (MNS), comprises premotor and parietal cortices and responds to dynamic and familiar stimuli, especially moving bodies of other people. Another brain region, the extrastriate body area (EBA), is located within the lateral occipital cortex and is activated when viewing static body postures. It is less clear how these regions respond to unfamiliar contorted body postures. We examined which brain regions show viewpoint-independent responses to static images of plausible and implausible body postures, using a repetition suppression design in functional magnetic resonance imaging. Participants were scanned while observing static images of a contortionist in either plausible postures or in contorted, implausible postures. Greater activity emerged in bilateral EBA when participants viewed plausible compared to contorted postures. The inverse contrast revealed greater activity within the middle frontal gyrus. Repeated presentation of the same body posture lead to suppressed responses in inferior frontal gyrus and inferior parietal lobe, two regions classically associated with the MNS. These regions did not distinguish the plausibility of the posture. Overall, our data demonstrate that both the MNS and EBA are involved in static body posture coding. These results contrast with some previous studies of the neural representation of possible and impossible actions, and thus present new challenges for theories of body representation in the human brain.

RHYTHMS OF CONSCIOUSNESS: BINOCULAR RIVALRY REVEALS LARGE-SCALE OSCILLATORY NETWORK DYNAMICS MEDIATING VISUAL AWARENESS *Lawrence Ward[1,2], Sam Doesburg[3], Jessica Green[4], John McDonald[4]; [1]University of British Columbia, Psychology, [2]Brain Research Centre, University of British Columbia, [3]University of British Columbia, Pediatrics, [4]Simon Fraser University, Psychology* – Consciousness has been proposed to emerge from functionally integrated large-scale ensembles of gamma-syn-

chronous (30-50 Hz) neural populations that form and dissolve at a theta band (4-7 Hz) frequency. We propose that discrete moments of perceptual experience are implemented by transient gamma-band synchronization of relevant cortical regions, and that disintegration and reintegration of these assemblies occurs according to an ongoing theta oscillation. In support of this hypothesis we provide evidence from 64-channel EEG data recorded from 14 subjects during binocular pattern rivalry. We measured phase-locking values, calculated from phases measured by the Hilbert transform-analytic signal method, between narrow-band signals from dipole sources seeded in brain regions located using BESA beamformer. We report that (1) rivalrous perceptual switching is time-locked to theta-modulated gamma-band synchronization, indicating that the onset of new conscious percepts coincides with the emergence of a new gamma-synchronous assembly that is locked to an ongoing theta rhythm; (2) the recurrent generators of these gamma rhythms are in prefrontal and parietal brain regions; (3) theta-modulated gamma-band phase synchronization is observed between these activated brain regions. These results suggest that ongoing theta modulated-gamma mechanisms periodically reintegrate a large-scale prefrontal-parietal network critical for perceptual experience. Moreover, activation and network inclusion of inferior temporal cortex and motor cortex uniquely occurs on the cycle immediately preceding responses signaling perceptual switching. This suggests that the essential prefrontal-parietal oscillatory network is expanded to include additional cortical regions relevant to tasks and perceptions furnishing consciousness at that moment, here image processing and response initiation.

IS DAMAGE TO THE FUSIFORM FACE AREA SPECIFICALLY RELATED TO FACE RECOGNITION IMPAIRMENTS? *Jessica Wisnowski[1], David Rudrauf[2], Sonya Mehta[2], Thomas Grabowski[2], Daniel Tranel[2], Steven Anderson[2], Hanna Damasio[1]; [1]Brain and Creativity Institute and the Dana and David Dornsife Cognitive Neuroscience Imaging Center, University of Southern California, [2]Division of Behavioral Neurology and Cognitive Neuroscience, Department of Neurology, University of Iowa* – An important and still unanswered question in cognitive neuroscience is whether the Fusiform Face Area (FFA), a small region in the right posterior temporal-occipital gyrus, has evolved to specifically process facial information or whether it is involved more generally in the visual recognition of concrete entities. We employed a novel approach to test the specificity of FFA by utilizing voxelwise logistic regression to analyze visual recognition data pertaining to the categories of famous faces, animals, fruits/vegetables and tools/utensils in 191 patients with focal brain lesions. This approach allowed us to identify regions where damage was significantly associated with impairments in the recognition of faces, after removing the variance that could be attributed to impairments in the other categories. The areas where damage was relatively specific for face recognition impairments were: the right lateral temporal-parietal-occipital junction, the right mesial temporal pole, and areas in the white matter underlying and interconnecting those areas. FFA was not included. We then examined a subgroup of 19 patients whose damage likely included FFA and found that they were impaired at recognizing animals (mean z-score = -4.5), fruits/vegetables (-5.0) and faces (-2.6), but not tools/utensils (-0.67). Finally, five patients with the largest lesions in FFA all performed poorly on the recognition of fruits/vegetables and animals; however, only 3 were impaired in the recognition of faces while 2 were entirely normal. We conclude that FFA is part of the system involved in visual recognition, but that it is not a neural substrate specifically subserving unique facial recognition.

CORTICAL ORGANIZATION OF VISUAL CATEGORIES IN EARLY CHILDHOOD *Jessica Cantlon[1,2], Kevin Pelphrey[2]; [1]Duke University Center for Cognitive Neuroscience, [2]Yale University, Psychiatry* – Cortical regions along the inferior temporal and fusiform gyri exhibit greater responses to images of real objects compared with scrambled images and the like (e.g., Grill-Spector, Knouf, and Kanwisher, 2004). Within these cortical regions, certain object categories such as faces, houses, and symbolic strings evoke preferential responses in predictable subregions. How does this category-selective pattern of neural activity develop? We recorded brain activity (using fMRI) in four- to five-year-old children (N=14) and adults (N=14) as they passively viewed images from each of four categories (faces, numbers, letters, and shoes) in addition to their scrambled image counterparts. Four- to five-year-olds exhibited a similar degree of selectivity in the fusiform gyrus and occipito-temporal cortex to adults for faces and objects. Moreover, voxels that exhibited the strongest response to faces in children were within the typical adult fusiform face-selective region whereas voxels that responded more strongly to symbols (letters and numbers) were in the typical adult fusiform/inferior temporal word form area. Interestingly, the visual word form region that exhibited a response bias for both letters and numbers in children exhibited a bias only for letters in adults—perhaps because experience attunes this brain region to the specific symbolic elements relevant for reading words. These findings suggest that category-selectivity already may be developing by four years of age but it is not fully mature. The degree of category-selectivity in the ventral stream may be important for the development of adult-like visual recognition.

CORTICAL HYPERCONNECTIVITY IN ABSOLUTE PITCH MUSICIANS *Psyche Loui[1,2], Charles Li[1], Anja Hohmann[1], Gottfried Schlaug[1,2]; [1]Beth Israel Deaconess Medical Center, [2]Harvard Medical School* – The ability to categorize sound is crucial for language, music, and effective functioning in the environment. Sound categorization recruits temporal lobe structures and is extraordinarily accurate among possessors of Absolute Pitch (AP), who can name the appropriate pitch category of any given tone without a reference. While the incidence of AP is rare in the general population (< 1%), its prevalence depends inversely on age of exposure to pitch information (i.e. via musical training and/or tonal languages), suggesting that heightened pitch exposure may either trigger the development of neural circuitry essential for sound categorization, or may interfere with developmental pruning of naturally-present circuitry. Using Diffusion Tensor Imaging (DTI), we tested the hypothesis of heightened neural connectivity in superior temporal regions of AP possessors. Tractography was conducted using bilateral seed regions of interest in the superior temporal gyrus (STG) and middle temporal gyrus (MTG). AP possessors had significantly higher-than-control volume of white matter tracts connecting the left STG and MTG. Furthermore, the leftward asymmetry of white matter volume connecting perception and categorization areas (STG and MTG) was significantly correlated with the degree of AP possession (AP1 vs. AP2) as defined by behavioral performance on a pitch naming task. The present finding of hyperconnectivity within temporal regions of AP musicians extends previous research showing increased superior temporal lobe asymmetry in AP and provides a new model for studying the neuroplasticity and heightened local connectivity that have been proposed as possible biological bases of savant skills and cases of exceptional creativity.

TREATMENT OF INTENSE LEFT HEMI-FACIAL PAIN OF TRIGEMINAL NEURALGIA USING MIRROR VISUAL FEEDBACK *V. S. Ramachandran[1], Eric Altschuler[1,2]; [1]UCSD, Center for Brain and Cognition, [2]UMDNJ, PM&R* – A gentleman had been suffering from left hemi-facial pain (tic douloureux) for nearly 12 years and had gone through numerous conventional treatments which proved to be completely ineffective. Indeed, this pain is often considered intractable. Following a suggestion from one of us (VSR), the gentleman looked at his face in a double reflecting mirror. Unlike a normal mirror, a double-reflecting mirror (two mirrors taped at right angles) does NOT optically reverse your face. So, if you look in the mirror and someone touches the actual RIGHT side of your face it creates the illusion that the LEFT side of your face is being touched (because the normal "expected" reversal doesn't occur). The patient made ingenious use of the technique: Obviously he couldn't massage the left side of the face; the very attempt to get close to it or actually touching it lightly provoked excruciating pain. He looked in the mirror watched his wife's hand massaging his right face so he SAW his left (painful) side being "massaged" without provoking pain; thereby progressively causing the "learned pain" to be unlearned. Astonishingly, the pain dropped from about 6 down to zero after 10 minutes and with repeated 10 minute treatments stayed at zero for months. Massage applied to the right face WITHOUT looking in a mirror was completely ineffective. The patient reports that the mirror procedure has changed his life. Controlled studies of mirror visual feedback for hemi-facial pain, and, if effective, the neurophysiologic correlates underlying the treatment, may be warranted.

Slide Session 7 Reasoning and decision making

Tuesday, March 24, 1:00 - 3:00 pm, Grand Ballroom B

Chair: **Chair: Kalina Christoff**

Speakers: **Roi Cohen Kadosh, Marinella Cappelletti, Oshin Vartanian, Adam Green, Elizabeth O'Hare, Amitai Shenhav (*GSP Winner*), Leonhard Schilbach, Penelope Lewis**

ABSTRACTS

MODULATING NUMBER-SPECIFIC NEURONS IN THE HUMAN PARIETAL CORTEX *Roi Cohen Kadosh[1], Neil Muggleton[1], Juha Silvanto[2,3], Vincent Walsh[1]; [1]Institute of Cognitive Neuroscience, University College London, London, UK, [2]Beth Israel Deaconess Medical Center and Harvard Medical School, Laboratory of Noninvasive Brain Stimulation, Boston, USA, [3]Psychology, University of Essex, Colchester, UK* – Numbers can come in many forms; we can represent the same quantity, as a verbal number "TWO", a digit (2), in Roman numerals (II), non-symbolically (??), in a temporal series, or with other verbal numbers (pair, duo, brace). The question of how we represent numbers and whether there is a unitary cognitive and neuronal basis for all forms of numerical representation (i.e., abstract representation) is therefore an important problem in numerical cognition, neuronal specialisation, education, and remediation from dyscalculia. To examine the commonly held view that numbers are represented in an abstract fashion in the intraparietal suclus, a core area for

numerical representation we used a novel transcranial magnetic stimulation adaptation (TMSA) paradigm. TMSA provides superior functional resolution by allowing one to selectively stimulate even within overlapping populations of neurons. We show that the intraparietal suclus, an area that is believed to hold an abstract numerical representation, is equipped with a specialized non-abstract representation. Moreover, we show here that, akin to similar results in single-cell neurophysiology in monkeys, TMSA modulated neurons with preference for the adapted digit, a symbolic, acculturated number, in the parietal lobes of numerate humans, and this TMS effect decreases as the numerical distance from this digit increases.

THE ROLE OF THE RIGHT AND LEFT PARIETAL LOBES IN THE CONCEPTUAL PROCESSING OF NUMBERS *Marinella Cappelletti[1], Hwee Ling Lee[3], Elliot D. Freeman[1,4], Cathy J. Price[2]; [1]Institute of Cognitive Neuroscience, University College London, 17 Queen Square, London, UK, [2]Wellcome Trust Centre for Neuro-imaging, Institute of Neurology, University College London, London, UK, [3]MPI for Biological Cybernetics, Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [4]Brunel University, Psychology, School of Social Psychology, Uxbridge* – Neuropsychological and functional imaging studies have associated the conceptual processing of numbers with bilateral parietal regions (including the intraparietal sulcus, IPS). However, the processes driving these effects remain unclear because both left and right posterior parietal regions are activated by many other conceptual, perceptual, attention and response-selection processes. To dissociate parietal activation that is number-selective from parietal activation related to other stimulus or response-selection processes, we used fMRI to compare numbers and object names during exactly the same conceptual and perceptual tasks while factoring out activations correlating with response times. We found that right parietal activation was higher for conceptual decisions on numbers relative to the same tasks on object names, even when response-time effects were fully factored out. In contrast, left parietal activation for numbers was equally involved in conceptual processing of object names. We suggest that left parietal activation for numbers reflects a range of processes, including the retrieval of learnt facts that are also involved in conceptual decisions on object names. In contrast, number-selectivity in the right parietal cortex reflects processes that are more involved in conceptual decisions on numbers than object names. Our results generate a new set of hypotheses that have implications for the design of future behavioural and functional imaging studies of patients.

THE ROLE OF RIGHT PREFRONTAL CORTEX IN REAL-WORLD PLANNING *Oshin Vartanian[1,2], Vinod Goel[2], Angela Bartolo[3], Lila Hakim[2], Anna Maria Ferraro[2], Carla Budriesi[4], Ildebrando Appollonio[5], Valeria Isella[5], Paolo Nichelli[4]; [1]DRDC Toronto, [2]York University, [3]Université Charles-de-Gaulle Lille III, [4]University of Modena and Reggio Emilia, [5]University of Milano - Bicocca* – While much evidence has linked injury to the prefrontal cortex (PFC) to impairments in planning, much less is known about the underlying cognitive processes that are compromised as a consequence of PFC damage. In addition, the differential contributions of left and right PFC to planning remain controversial. To address these issues, we administered a real-world travel planning task to thirty participants comprised of six patients with focal frontal lesions to left PFC, six patients with focal frontal lesions to right PFC, six patients with posterior lesions, and twelve normal controls. Furthermore, we employed the methodology of verbal protocol analysis, enabling us to go beyond simple task performance and to analyze the underlying cognitive processes and strategies that underlie plan formulation. The results revealed that patients with right PFC lesions formulated significantly worse plans than patients with left PFC lesions and normal controls. No other comparison reached significance. To explore the underlying reasons for the planning impairment exhibited by right PFC patients, we computed the ratio of concrete to abstract problem-solving statements between the groups. The results demonstrated that right PFC patients had a significantly higher concrete-to-abstract ratio of problem-solving statements than left PFC patients and normal controls. No other comparison reached significance. We conclude that the role of right PFC in real-world planning involves the formulation and maintenance of abstract ideas as a function of task demands.

ANALOGICAL REASONING ABILITY MEDIATES THE RELATION BETWEEN INTELLIGENCE AND CREATIVITY *Adam Green[1], Joseph Kim[1], Michael Cohen[1], Colin DeYoung[2], Jeremy Gray[1]; [1]Yale University, [2]University of Minnesota* – People who are intelligent are often creative as well. However the relationship between intelligence and creativity is not well understood. One likely mediator is Analogy. Analogy, a form of relational reasoning, is related to crystallized and especially to fluid intelligence. Analogy is also widely indicated to be an important cognitive mechanism for supporting creative insight and innovation. Work in our laboratory and elsewhere has reliably implicated frontopolar cortex in the neural implementation of analogy. Here, we tested whether a form of analogical reasoning that preferentially engages frontopolar cortex mediated the relation between intelligence and creativity in 160 participants. Analogical reasoning ability was measured by a task in which participants selected word-pairs to correctly complete four-word propositional analogies of the general form, 'A is to B as C is to D' (i.e., participants were pro-

vided with A:B and asked to select C:D from a list). Analogical reasoning ability significantly mediated the effect of intelligence (a latent variable comprising full-scale I.Q., and d-prime for verbal 3-Back performance) on creativity (a latent variable comprising the Creative Achievement Questionnaire, and creative verb generation). Notably, this mediation effect was driven by performance on cross-domain (semantically distant) analogies, a type of analogy for which frontopolar cortex shows preferential recruitment. These data provide new evidence that analogy is a key mechanism by which intelligence supports creativity, and indicate the intriguing hypothesis that frontopolar cortex mediates the link between intelligence and creativity.

MAPPING RELATIONSHIPS BETWEEN CORTICAL THICKNESS AND FLUID REASONING IN TYPICALLY DEVELOPING CHILDREN AND ADOLESCENTS *Elizabeth O'Hare[1], Kirstie Whitaker[1], Zdena Op De Macks[2], Brian Johnson[1], Emilio Ferrer[3], Silvia Bunge[1,4]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]Leiden University, Developmental Psychology, The Netherlands, [3]Dept. of Psychology, University of California, Davis, [4]Dept. of Psychology, University of California, Berkeley* – Fluid reasoning, or the ability to solve novel problems, is a core component of human cognition. Functional brain imaging studies in adults and children have implicated anterior prefrontal and inferior parietal regions in reasoning and relational integration. To date, however, no studies have examined potential brain structural correlates of fluid reasoning ability in a developmental population. We studied typically developing children and adolescents (ages 6-18) with high-resolution MRI at 3 Tesla (current N=18). All participants performed a series of fluid reasoning tasks. Semi-automated methods were used to match cortical geometry across subjects and to measure cortical thickness at every surface vertex. We then computed statistical maps of the correlation between thickness and cognitive performance at matched anatomical points. Statistical maps demonstrated that increased cortical thickness was significantly correlated with better performance on measures of fluid reasoning in left supramarginal gyrus (BA 40), independent of age (peak vertex, r=0.70, p=0.001). Additional correlations between cortical thickness and fluid reasoning ability were observed in left ventrolateral and left anterior prefrontal cortex (BA 10), where decreased thickness correlated with better reasoning performance (peak vertex r=-0.61, p=0.006). These results suggest that brain structure in prefrontal and inferior parietal regions correlates with fluid reasoning ability in children and adolescents. Furthermore, the observation of a significant relationship between fluid reasoning and cortical thickness in inferior parietal cortex that is independent of differences associated with age suggests that this region is a key source of individual differences in fluid reasoning ability during development.

UTILITARIAN CALCULATIONS, EMOTIONAL ASSESSMENTS, AND INTEGRATIVE MORAL JUDGMENTS: DIFFERENTIATING NEURAL SYSTEMS UNDERLYING MORAL DECISION-MAKING *Amitai Shenhav[1], Joshua D. Greene[1]; [1]Harvard University, Psychology* – Recent research suggests that moral judgments are influenced by utilitarian reasoning (e.g. judging it acceptable to save five lives at the cost of one because of the net benefits) as well as automatic emotional responses that, in some cases, favor non-utilitarian judgments (e.g., judging it unacceptable to sacrifice one life to save five). When utilitarian reasoning conflicts with automatic emotional responses, a more integrative "all things considered" judgment may require the engagement of moral judgment processes that go beyond simple utilitarian calculations and automatic emotional responses. The present study aims to better isolate the neural bases of these distinct components of moral judgment using fMRI. In a within-subject design, participants undergoing fMRI were presented with moral dilemmas in which maximizing the number of lives saved requires harming one ore more individuals. After reading each dilemma, subjects responded by indicating which of the two available options (a) will produce better overall results (utilitarian calculation), (b) evokes more negative feelings (emotional assessment), or (c) is more morally acceptable (integrative moral judgment). We found that fast emotional assessments recruited bilateral amygdala and hippocampus more strongly than fast integrative moral judgments, but that fast integrative moral judgments and utilitarian calculations more strongly recruited bilateral dorsolateral prefrontal cortex and anterior cingulate cortex.

MINDS MADE FOR SHARING: INITIATING JOINT ATTENTION RECRUITS REWARD-RELATED NEUROCIRCUITRY *Leonhard Schilbach[1], Marcus Wilms[2], Simon Eickhoff[2], Sandro Romanzetti[2], Ralf Tepest[1], Gary Bente[3], Nadim Shah[2], Gereon Fink[2,4], Kai Vogeley[1,2]; [1]University of Cologne, Psychiatry, [2]Institute of Medicine, Research Centre Juelich, [3]University of Cologne, Social Psychology, [4]University of Cologne, Neurology* – The ability and motivation to share attention with someone is a unique aspect of human cognition. To investigate the neural correlates of joint attention we made use of a novel, interactive research paradigm in which participants' gaze behavior - as measured by an eyetracking device - was used in real time to control the gaze behavior of a computer-animated character. Convinced that the character on the stimulus screen was controlled by a real person outside the scanner, 21 participants interacted with the virtual other while undergoing functional magnetic resonance imaging (fMRI). Experimental variations

focused on leading vs. following the gaze of the character when fixating one of three objects also shown on the screen. Results demonstrate, firstly, that following someone else's gaze and engaging in joint attention recruits the ventral portion of medial prefrontal cortex (MPFC) known to be involved in the supramodal coordination of perceptual and cognitive processes. Secondly, directing someone else's gaze towards an object activated the ventral striatum which – in light of ratings obtained from participants – appears to underlie the hedonic aspects of sharing attention. The data supports the idea that other-initiated joint attention relies upon recruitment of MPFC previously related to the 'meeting of minds'. In contrast, self-initiated joint attention leads to a differential increase of neural activity in reward-related brain areas which might contribute to the uniquely human motivation to engage in the sharing of experiences.

NEUROANATOMICAL CORRELATES OF HIGH ORDER *Penelope Lewis[1,2], Roozbeh Rezaie[3], Rachel Browne[4], Neil Roberts[5], Robin Dunbar[6]; [1]School of Psychological Sciences, University of Manchester, [2]Institute of Cognitive Neuroscience, University College London, [3]Health Science Center at Houston, University of Texas, [4]MARIARC, University of Liverpool, [5]Division of Medical and Radiological Sciences, School of Clinical Sciences and Community Health, University of Edinburgh, [6]Institute of Cognitive & Evolutionary Anthropology, University of Oxford* –
The Social Brain Hypothesis proposes that mammalian brain size has evolved to support the demands of managing increasingly large numbers of complex social relationships in bonded groups. Underpinning this are 2 assumptions: that the number of social relationships is a function of neural processing power, and that evolutionary increases in prefrontal cortex volume have been driven, in part, by increased demand for this type of processing. This study tested the related prediction that people capable of a higher degree of intentionality processing have larger prefrontal grey matter volume (GMV). We used 5 stories followed by T/F questions to determine the intentionality and working memory ability level (failure point on a continuous scale of levels 2-6 intentionality/working memory) of 45 subjects. A separate questionnaire determined social group size. We obtained anatomical MRI scans for all subjects and used optimised voxel-based morphometry (VBM) to test for correlations between GMV and these measures. Behaviorally, we observed a positive correlation between intentionality ability and social network size ($p<0.04$). Anatomically, we observed a correlation between GMV and intentionality but not working memory ability in dorsolateral prefrontal cortex (s.v.c. $p<0.05$). Furthermore, GMV in right orbitofrontal and subgenual cingulate correlated with sympathy group size (s.v.c. $p<0.05$). Finally, a conjunction analysis revealed that GMV in orbitofrontal cortex and right hemispheric tempero-parietal junction correlated both with intentionality score and sympathy group size ($p<0.005$ uncorrected). These findings support a link between intentionality, social network size, and prefrontal cortex, and are in keeping with the Social Brain Hypothesis.

Poster Schedule

The presenting author must be present at least one full hour during the assigned session and the other authors should be present during the remaining time. You may post your materials on the board assigned to you at any time after the "Set-up Begins" time (listed above), but before the beginning of the assigned poster session. You must remove your poster promptly no later than the time listed above in "Take-down Complete." Any posters left up after the "Take-down Complete" time may be discarded. Do not leave personal items in the poster room.

On Saturday, the doors to the poster room close and lock at 8:00 pm. On Sunday-Monday the doors close and lock at 7:30 pm. On Tuesday, the doors close and lock at 5:15 pm. No attendee or exhibitor will be allowed to enter the exhibit hall once the doors are locked.

Poster Session	Date & Time	Set-up Begins	Session Begins	Session Ends	Take-down Complete
A	Saturday 3/21/09	5:00 pm	5:30 pm	7:30 pm	7:45 pm
B	Sunday 3/22/09	*7:30 am	8:00 am	10:00 am	11:30 am
C	Sunday 3/22/09	11:30 am	1:00 pm	3:00 pm	3:30 pm
D	Sunday 3/22/09	3:30 pm	5:00 pm	7:00 pm	7:30 pm
E	Monday 3/23/09	*7:30 am	8:00 am	10:00 am	11:30 am
F	Monday 3/23/09	11:30 am	1:00 pm	3:00 pm	3:30 pm
G	Monday 3/23/09	3:30 pm	5:00 pm	7:00 pm	7:30 pm
H	Tuesday 3/24/09	*7:30 am	8:00 am	10:00 am	12:30 pm
I	Tuesday 3/24/09	12:30 pm	3:00 pm	5:00 pm	5:15 pm

** Please note that only scheduled poster presenters may enter the exhibit hall during the early morning set-up time. All other attendees may only enter when the exhibit hall opens at 8:00 am.*

Poster Session A

Attentional processes: Auditory

A1

INDEPENDENT FACILITATION AND INHIBITION MECHANISMS IN AUDITORY SELECTIVE ATTENTION *Constanze Mikyska[1], Aurelie Bidet-Caulet[1], Robert T. Knight[1,2]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, CA, [2]University of California, Berkeley, CA* – In a recent intracranial study, auditory selective attention has been shown to operate not only by enhancing the sensory responses to relevant sounds, but also by reducing these responses to irrelevant information in auditory cortices (Bidet-Caulet et al., 2007). Previous work in the visual modality indicates that cognitive load differentially affects facilitation vs inhibition. We employed a working memory load manipulation to assess whether facilitation and inhibition represent a unique gain control mechanism or two independent mechanisms in audition. We adapted the classic auditory selective attention paradigm employing a two selection task (Hansen & Hillyard, 1980) by adding a third condition (control condition) in which all sounds received the same amount of attention. Subjects had to detect deviants in the right or left ear or binaural targets (control condition) while they were keeping in memory a short auditory sequence to perform an easy or difficult acoustic comparison. We recorded EEG at 64 scalp electrodes in 16 subjects and compared event-related potentials (ERP) to the same sounds when they were attended, ignored or heard. We found differential effects of memory load on attention mechanisms. An early sensory ERP (P50) was inhibited only under memory load condition. A late negative frontal ERP (200-300 msec) showed less inhibition in the high memory load compared to the low memory load. The present results reveal evidence of independent excitatory and inhibitory mechanisms and support perceptual and cognitive load theories.

A2

SELECTIVE ATTENTION TO SPEECH IN MULTI-TALKER ENVIRONMENTS ACTS AS CONTINUOUS GAIN CONTROL *Jess R. Kerlin[1], Antoine J. Shahin[1], Lee M. Miller[1]; [1]Center for Mind and Brain, UC Davis* – Our ability to actively select a single talker in an environment with multiple competing speech sounds is a remarkable perceptual feat that serves a critical social function. Although many studies of auditory selective attention in the brain have been conducted for decades, there remains an ongoing debate about the neural mechanisms of sustained selective attention. One idea is that attention acts as a gain-control of bottom-up processing. Alternately, it may be a process without gain, but rather a redirecting of attention to stable bottom-up content. Furthermore, very few studies have addressed the unique nature of the selection of speech as a temporally extended and complex auditory object. We hypothesized that sustained selective attention to a particular speech stream in a multi-talker environment would act as a gain control mechanism on the early auditory cortical representations of speech. Using high-density electroencephalography and a template-matching method novel to the field, we discovered a signal of selective gain to the continuous speech content of the attended speaker, greatest at a frequency of ~2-6 Hz, in auditory cortex. This measure of attention, which appears to be related to the temporal speech envelope, may offer greater insight into the content-specific process of selective attention to speech.

A3

ANTICIPATION RELATED ALPHA DESYNCHRONISATION IN AUDITORY CORTEX FOLLOWING VISUAL CUES *Nadia Müller[1], Winfried Schlee[1], Thomas Hartmann[1], Isabel Lorenz[1], Nathan Weisz[1]; [1]University of Konstanz* – In most daily life situations we can anticipate external events and prepare our neuronal system for efficient processing. One way how the responsiveness of the brain is adjusted involves changes in oscillatory ongoing alpha activity: Alpha power decreases have been shown to be functionally related to an increased excitability of the accordant brain area. However, these observations mainly stem from the visual and somatosensory/motor modality whereas the mechanisms in the auditory system are largely unknown. Recent results point to a role of alpha in auditory attention, but cannot disambiguate alpha to be exclusively top-down modulated, e.g. in absence of acoustic stimulation. By recording MEG we here investigated alpha power changes in the auditory cortex in response to visual cues. Thereby, we ruled out the possibility that bottom-up processing of the cue stimulus had an effect on the reported results. Time Frequency Analysis of the induced responses show prominent alpha power decreases peaking around 10Hz, in the second part of the cue-target period. These reductions in alpha power were then localized to auditory, left motor (emerging from subsequent right hand button press) and occipital cortex. Interestingly, following right cue presentation, alpha power was significantly reduced in both auditory cortices whereas after left cue presentation just a trend towards an alpha power reduction in the right auditory cortex was observed. To conclude, the responsiveness of the auditory cortex is indeed top-down modulated and shaped by the side of the cue. Finally, the functional relevance of occipital regions has to be further investigated.

A4

ERP COMPONENTS REFLECTING THE FOCUSING OF ATTENTION WITHIN AUDITORY SCENES *Marissa L. Gamble[1,2], Steven J. Luck[1,2]; [1]University of California, Davis , [2]Center for Mind and Brain* – Humans must often focus attention onto a relevant sound source in the presence of simultaneous irrelevant sounds. In the visual domain, this has been extensively explored with the N2pc component, a negativity occurring approximately 200-300 ms over posterior scalp sites contralateral to a target within a bilateral stimulus array. In the present event-related potential studies, we searched for an analogous neurophysiological correlate of auditory attention. In experiment 1, two sounds were presented simultaneously for 750 ms, one from each of two laterally placed speakers. For each trial, participants indicated whether one of the two sounds was a pre-defined target. We found a negativity contralateral to the target at anterior and central sites. Further analyses indicated that this contralateral negativity was actually composed of two separate contralateral negativities. We observed a left anterior negativity for right-side targets starting approximately 100 ms poststimulus and a right antero-central negativity for left-side targets starting approximately 200 ms poststimulus. In addition, we observed a contralateral positivity over occipital cortex starting approximately 300 ms poststimulus, perhaps reflecting a link between visual and auditory orienting. In experiment 2, using a similar experimental design with different stimuli, we were able to replicate these effects. This set of contralateral-ipsilateral differences could be used to study selective attention within auditory scenes containing multiple simultaneous stimuli, just as the N2pc has been used to study the operation of attention within visual scenes.

A5

TIME-FREQUENCY ANALYSIS OF MEDITATION DURING AUDITORY ODDBALL PROCESSING: THETA, ALPHA, AND GAMMA FINDINGS *B. Rael Cahn[1,2,3], Arnaud Delorme[4,5], Mark Geyer[1], Franz Vollenweider[6], John Polich[3]; [1]UCSD, Psychiatry, [2]UCSD Stein Institute for Research on Aging, [3]The Scripps Research Institute, [4]UCSD Institute for Neural Computation, [5]UCSD Swartz Center for Computational Neuroscience, [6]University of Zurich, Psychiatry* – A three-stimulus auditory oddball series was presented to experienced Vipassana (mindfulness) meditators during meditation and a control thought period to elicit event-related brain potentials (ERPs) in the two different mental states. The stimuli consisted of a frequent standard, an infrequent oddball, and an infrequent distracter, with all stimuli passively presented. We have previously reported on the ERP findings wherein meditation compared to control state effects occurred most strongly for the distracter stimuli with frontal N1 amplitude, P2 amplitude, and P3a amplitude all decreased during meditation. We now report on the time frequency analysis of these data. We again found the greatest change in attention-related activity for the distracter stimuli with decreased stimulus-induced theta power induction. We also found a significant alpha desynchronization to the standard stimuli during the thought condition, but not the meditation condition, indicating less processing demands on the brain imposed to the frequent standards during meditation. We also found greater differential gamma activity in meditation compared to control period during the first 100 msec post-stimulus across stimuli, suggesting that the meditation state may involve greater sensitivity to the sensory surround at the early pre-attentive level of processing but decreased engagement of attentional circuits to such stimuli. Finally, meditation also increased broadband inter-trial coherence to the standards implying more stable entrainment of brain activity to the frequent standards. We discuss the relevance of such findings to the reported outcomes of meditation including enhanced self awareness and decreased distractibility and emotional reactivity.

A6

SYNCHRONOUS INTERACTIONS AND FUNCTIONAL ORGANIZATION OF AUDITORY CHANGE DETECTION *Shannon MacLean[1], Lawrence Ward[1]; [1]University of British Columbia* – The cortical dynamics underlying the process of auditory change detection are poorly understood. This high density electroencephalography (EEG) study comparing two auditory oddball tasks (passive listening/active identification) revealed the spatiotemporal interactions of active cortical sources through a modern approach of EEG analysis using independent component analysis. Our results establish active regions in the superior temporal gyrus (STG), inferior frontal gyrus (IFG), precentral gyrus (PCG) and cingulate cortex (CC) for both listening conditions. This demonstration of oscillatory dynamics between sources provides a measure of functional organization for change detection in the human auditory system. Synchronization in the beta-band between the CC and generators in the frontal and temporal regions was significantly enhanced for the identification task requiring attention compared to passive listening. Change detection processing appears to consist of initial detection in the primary auditory cortex, detailed analysis in the STG, and monitoring of task performance in the CC for the allocation of attentional resources in the IFG.

A7

OSCILLATORY BRAIN NETWORKS FOR THE ATTENTIONAL CONTROL OF COMPLEX AUDITORY PROCESSING MEASURED WITH MEG *Anthony Kaveh[1,2], Corby Dale[1], Felix Darvas[3], Tracy Luks[1], Darren Weber[4], Robert Zatorre[5,6], Gregory Simpson[1]; [1]University of California, San Francisco, [2]University of California, Berkeley, [3]University of Washington, [4]Buck Institute, [5]Montreal Neurological Institute, [6]McGill University* – Neural mechanisms of auditory attention hypothesize coordinated activity between frontal and parietal control regions and auditory sensory regions, orchestrated in a cortical network. We recorded whole-head magnetoencephalography (MEG) from 9 healthy volunteers while performing a discrimination task that required processing linguistic information with simultaneous suppression of tonal pattern information, and vice versa. To examine oscillatory activity in control and sensory regions of interest, we utilized cortically-constrained minimum norm methods (Brainstorm) to reconstruct images of the neuronal currents specific to the anatomy of each subject (Freesurfer), applied wavelet transforms, and analyzed spectral data in six frequency bands. Synchronization of oscillatory activity within (spectral power) and between (phase locking) brain regions was calculated to determine involvement in auditory attention and selective processing of complex auditory stimuli. Results revealed statistically significant increases in local neural synchronization in frontal, parietal and sensory regions, showing dynamic asymmetries indicative of increased right hemisphere activity. Frequency-specific asymmetries in high alpha (12-14 hz) and theta (3-7 hz) bands also occurred in control and sensory regions. Increased communication between regions, measured by phase locking, was found both between frontal and parietal control regions and between control regions and auditory sensory cortex. Analysis of the relation between performance and synchronization between control and sensory regions revealed statistically significant correspondence between performance and phase locking values. The results support a critical role for oscillatory brain activity in auditory processing, and for functionally interconnected control and sensory regions that form networks to produce successful auditory attention.

Attentional processes: Other

A8

CROSS-MODAL CUEING OF ATTENTION ALTERS VISUAL APPEARANCE AND EARLY CORTICAL PROCESSING *Viola Störmer[1], John McDonald[2], Steven Hillyard[3]; [1]International Max Planck Research School "The Life Course: Evolutionary and Ontogenetic Dynamics" (LIFE) School MPI Berlin, [2]Simon Fraser University, [3]University of California San Diego* – Recent psychophysical evidence suggests that visual cues can alter the appearance of subsequent visual objects (e.g. Carrasco, Ling, & Read, 2004). Here, we investigated whether cross-modal cueing can also alter the appearance of visual objects. We found that a reflexive shift of attention to a lateralized sound enhances the perceived contrast of a spatially co-incident visual object. Following the general design used by Carrasco et al., (2004), a bilateral pair of Gabor patches (8°x 8°1cpd) presented to the left and right of fixation was preceded by a spatially non-predictive sound on either the left or right side at one of the target locations. Target stimuli varied in relative contrast, orientation and phase and observers reported the orientation of the target that appeared to be higher in contrast. Target stimuli that were presented on the cued side appeared to be higher in contrast on the majority of the trials. To determine whether this apparent boost in perceived stimulus contrast was due to an effect of cross-modal cueing on early sensory processing, we recorded event-related potentials (ERPs) to equal-contrast targets (50% of trials). Cross-modal attention cueing led to enhancement of ERP activity over the occipital scalp beginning 90 ms after target onset, and the magnitude of this enhancement was predictive of the degree to which the cued-side target appeared higher in contrast. We conclude that the boost in perceived stimulus contrast by the cross-modal cueing of attention arises from increased signal strength in the early visual pathways.

A9

SPECIFIC ATTENTIONAL PROFILE IN PURE DEVELOPMENTAL DYSCALCULIA *Sarit Ashkenazi[1], Avishai Henik[1]; [1]Ben Gurion University, Beer Sheva, Israel* – Fourteen university students diagnosed as suffering from Developmental Dyscalculia (DD) [IQ and reading abilities in the normal range and no indication for ADHD (Attention-Deficit Hyperactivity Disorder) [and 14 matched controls were examined with the ANT-I (Attentional Network Test - Interactions). This test was

designed to investigate three different attentional networksóexecutive, orienting, alertingóand the interactions between them. The results revealed deficits in those with DD in the alerting network (DD participants showed a larger alerting effect than controls) and the executive function network (DD participants showed a larger congruity effect). The interaction between these networks (alerting and executive function) was also modulated by group. These results imply specific attentional deficits in the executive function and alertness network in those with pure DD. This indicates that people having DD suffer from difficulties in recruiting attention, in addition to the deficits in numerical processing. Moreover, this suggests that DD is a non-unitary deficit.

A10

CROSS-MODAL AND ATTENTIONAL MODULATION EFFECTS IN THE THALAMUS AND EARLY SENSORY CORTICES *David Fegen[1,2], Taraz Lee[1,3], Jesse Rissman[4], Bradley Buchsbaum[1,3], David Badre[5], Mark D.Esposito[1,2,3]; [1]Henry H. Wheeler Jr. Brain Imaging Center, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley, [3]University of California, Berkeley, [4]Stanford University, [5]Brown University* – Previous studies have found that attention can modulate activity in the lateral geniculate nucleus (LGN) of the thalamus. However, almost no studies have examined how different perceptual modalities interact in the thalamus as a function of one's attentional goals. We aimed to examine the effects of modality-specific attention and cross-modal conflict within the thalamus using high-resolution fMRI. Eighteen participants viewed a moving Gabor patch that was presented simultaneously with the sound of a musical instrument. In high-conflict blocks, participants were instructed to make either an auditory or visual speed judgment, which often were mapped to competing response alternatives. In low-conflict blocks, subjects had to make a visual width discrimination or an auditory instrument discrimination. In these blocks, the semantic decision space did not overlap between sensory channels. fMRI analyses revealed trend-level attentional modulation in LGN, as well as significant modulation of early visual areas, when visual stimuli were relevant targets versus irrelevant distractors. In contrast, a conflict-dependent suppression was only revealed in LGN and not other early visual areas. This suppression effect is difficult to explain through a simple attentional vigilance account, since LGN showed the lowest activity in the most difficult condition (as confirmed by behavior). This effect may be due to cross-modal interactions between thalamic nuclei, as predicted by single-unit studies. In conclusion, these findings confirm that modality-specific attentional modulation occurs at multiple levels of early sensory processing and further suggest that the thalamus may serve as a gatekeeper to help mitigate cross-modal conflict.

A11

NEUROFEEDBACK TRAINING ENHANCES THE EFFICIENCY OF CORTICAL PROCESSING IN NORMAL AGING *Elena K. Festa[1], William C. Heindel[1], Nina C. Connors[1], Lawrence Hirshberg[1], Brian R. Ott[1]; [1]Brown University* – The goal of the present study was to examine the efficacy of neurofeedback training (NFT) in improving selective neurocognitive measures of attention and sensory processing in normal aging. Healthy elderly subjects received either: a) real-time feedback linked to their individual brain activity (real-NFT group); or b) playback recordings of the actual feedback obtained from demographically-matched participants in the real-NFT group (mock-NFT group). Neurofeedback was based on a global z-score protocol in which participants trained to normalize quantitative brainwave parameters across four central posterior sites (C3, C4, P3, P4) that existed outside of a threshold as determined by a normative database. All participants were administered eight NFT sessions across four to six weeks, with mood and arousal measures and EEG recordings of resting brain activity obtained both immediately before and after each training session. To evaluate the effect of NFT on cognitive functioning, a battery of neuropsychological tests, neurocognitive tests of attention and sensory integration, and EEG recordings of resting brain activity were obtained both prior to and after the eight training sessions. For the real-NFT participants, neurofeedback produced a selective improvement in the efficiency of processing within the posterior sensory cortical network, but not in those selective attention and executive control processes associated with more anterior cortical networks. The mock-NFT participants showed either no change or a selective impairment on all outcome measures. Taken together, these results indicate that neurofeedback training can be effective in inducing changes in cortical processing associated with improvements in specific aspects of cognitive functioning.

A12

THE EFFECT OF AROUSAL ON HEMISPHERIC ATTENTION *Michael Minnema[1], Eran Zaidel[1]; [1]University of California, Los Angeles* – INTRODUCTION: The two normal cerebral hemispheres constitute two independent cognitive systems, each orchestrated by its own attentional networks. We explored the effect of arousal on the attentional networks of the two hemispheres. We used a truncated, lateralized version of Posner's Attention Network Test. Our test measures three networks of attention in each hemisphere: (1) executive attention/Conflict Resolution, (2) spatial Orienting Cost and (3) spatial Orienting Benefit. METHOD: Forty-five undergraduates completed the task under conditions of high, mild, and no social arousal. Arrow targets pointing up or down were presented tachistoscopically up or down to only one hemisphere. Targets were flanked by congruent or incongruent arrows (Conflict) and preceded by valid, invalid, or central/neutral cues. The advantage of valid relative to neutral cues defines Orienting Benefit and the cost of invalid relative to neutral cues defines Orienting Cost. Subjects had to indicate unimanually the direction of the target arrow. RESULTS. There was a significant interaction of Arousal x Conflict, showing that Conflict decreased (improved) under mild arousal, but increased under high arousal. There was also a significant interaction of Arousal x target Visual Field (left, right) x spatial Orienting, showing a larger Orienting Benefit and a lower Orienting Cost in the right than the left hemisphere. CONCLUSION: Arousal followed the Yerkes-Dodson law for Conflict in both hemispheres. However, arousal affected selectively spatial Orienting in the right hemisphere. This conforms with the differential deficits in spatial attention observed in patients with left or right parietal lesions.

A13

VISUAL ATTENTION INTERACTS WITH CONGRUENCY OF LETTER/SOUND COMBINATIONS IN LATE AUDITORY ERPS *Ulrike Zimmer[1], Suksun Itthipanyanan[1], Marty Woldorff[1]; [1]Center of Cognitive Neuroscience, Duke University, Durham, NC* – Reading of written letters can be slowed by incongruent, but speeded up by congruent, letter-sound combinations. Neuroimaging studies, using attended task-relevant stimuli, have revealed higher brain activity for incongruent than congruent stimulation in auditory cortex. In contrast, studies using passive (i.e., "unattended") stimulation have found the opposite pattern. However, these studies have all examined congruency effects for exclusively attended or unattended stimuli. Here, we specifically asked how selectively focused visual-spatial attention modulates ERP brain-activity patterns for congruent versus incongruent letter-sound pairs. Subjects attended to one of two concurrent streams of visual letters presented to the left and right fields. On some stimulus trials, a task-irrelevant letter sound was presented centrally, the responses to which were extracted by a series of subtractions for the different conditions. The modulation of the central-auditory letter-sound responses due to visual attention (i.e., being presented with an attended versus unattended lateral visual letter) differed as a function of congruence, but only at later latencies. First, at ~250-300ms, a frontal negativity was elicited only by incongruent auditory-letter sounds concurrent with attended visual-letter stimuli, consistent with an anterior-cingulate conflict response. Second, at ~500-550ms, another frontal negativity was observed revealing an attentional modulation interaction for incongruent versus congruent auditory ERPs. More specifically, the pattern suggests that if a visual letter is attended, a synchronous incongruent letter sound seems to act as a distracter that cap-

tures attention, evoking conflict detection in the ACC, followed by other cortical increases of activity that may reflect suppression of the distracting sound input.

A14

INHIBITION OF RETURN ACROSS MODALITIES: ELECTROPHYSIOLOGICAL EVIDENCE FOR CROSSMODAL BIASING OF ATTENTION *Jessica Green[1], John McDonald[1]; [1]Simon Fraser University* – Recent work in our lab has associated inhibition of return (IOR) - the slowing of responses to stimuli that appear at previously attended spatial locations - with a reduction of the N2pc component of the visual event-related potential (ERP). The N2pc, which reflects attentional processing of a visual stimulus, was reduced in amplitude when the target appeared at the same location across successive trials compared to when the target appeared at a new location. Here we adapted our paradigm to investigate audiovisual IOR. We used a target-target paradigm in which visual (V) and auditory (A) target trials were intermixed, resulting in consecutive targets in the same (VV and AA) or opposite (AV and VA) modality. Within each of these conditions the target could appear at the same or opposite location on successive trials. Both the N2pc to visual targets and a contralateral negativity to auditory targets were reduced for same location trials, regardless of the modality of the preceding target, highlighting the role of a location-based attentional bias in IOR. We then used distributed source modeling to estimate which brain areas were activated in each condition. We observed attention-related activities in regions of medial and lateral prefrontal cortex that were common to all conditions, suggesting the involvement of a supramodal attention system in producing IOR. In addition, in sensory-specific auditory and visual cortices we observed activities that reflected attentional processing of the current target as well as activities that reflected the suppression of the previous target location and modality.

A15

MIND WANDERING AND EARLY ATTENTIONAL SELECTION: ERP EVIDENCE FOR CROSS-MODAL EFFECTS *Julia W. Y. Kam[1], Todd C. Handy[1]; [1]University of British Columbia* – Mind wandering has been associated with reduced cognitive and sensory analysis of external visual events. However it is unclear whether the attenuation of sensory responses is restricted to the visual modality. This study examined whether mind wandering is associated with reduced early attentional sensory responses in both the visual and auditory modality. Participants performed a target detection task at fixation while event-related potentials (ERPs) were recorded. Interspersed with each target were a task-irrelevant probe in the visual periphery, and a task-irrelevant tone, presented in a randomized order. At the end of each trial block, participants self-reported on whether or not they had been mind wandering at the conclusion of the trial block. The ERPs to the visual and auditory probes were then examined as a function of whether or not they immediately preceded a report of mind wandering versus on task. Data analysis found that the visual sensory-evoked P1 and auditory sensory-evoked N1 ERP components both showed decreased amplitude during periods of mind wandering relative to being on-task. Our data thus suggests that the effect of mind wandering on early attentional selection is cross-modal in nature, equally affecting both visual and auditory inputs.

A16

THE IMPACT OF AGING ON SLIPS OF ACTION IN EVERYDAY LIFE *Amanda Clark[1], Eric Roy[1], Daniel Smilek[1], James Lyons[2]; [1]University of Waterloo, [2]McMaster University* – Many of our daily activities are successfully achieved through goal-oriented routines. This is an illustration of the adaptability and efficiency of information processing but nevertheless, slips of attention and action do occur. This study was designed to determine if slips of action can be induced in a well learned task and if so, how these slips are impacted by aging. We induced action errors in both younger and older adults by occasionally altering a routine action sequence and measured the frequency of errors in addition to reaction (RT) and movement times (MT). Participants also completed the Attention-Related Cognitive Errors Scale (ARCES), a measure of attention failures in daily life and the Sustained Attention to Response Task (SART). Numerous slips were committed by both participant groups but the older adults were surprising more accurate in the face of alterations to the routine. Also, while errors on the SART were highly predictive of slips, the ARCES only predicted errors on trials that did not require a change in the routine action sequence. By understanding the mechanisms through which slips are induced and how they relate to both errors in everyday life and aging, we hope to be able to use our slip induction task to identify individuals who are prone to attention failures and equip them with strategies to protect themselves in activities of daily living.

A17

THE DECOUPLED MIND: PHYSIOLOGICAL AROUSAL AND THE FOCUS OF ATTENTION DURING VIGILANCE *Jonathan Smallwood[1], Michael Franklin[1], Jonathan Schooler[1]; [1]University of California, Santa Barbara* – States of imaginative thought occupy a large proportion of our waking life and yet little is known about how different foci of attention are associated with physiological changes. This study employs novel statistical techniques to examine how different physiological measures (including skin conductance and heart rate) relate to the effectiveness of external attention. The results demonstrate how components of physiological arousal differentially relate to the focus of attention and suggests that physiological changes could be critical in understanding how internal and external focus of attention emerge.

Attentional processes: Visual

A18

SUPPORTING THE LINK BETWEEN THE LOCUS COERULEUS - NOREPINEPHRINE SYSTEM, THE P300, AND THE ATTENTIONAL BLINK *Christopher Warren[1]; [1]University of Victoria* – This poster presents evidence in support of the hypothesis that the locus coeruleus - norephinephrine (LC-NE) system is the neurophysiological basis of both the attentional blink (AB) and the event related potential (ERP) component known as the P300. The LC-NE system is thought to provide a brief burst of processing facilitation in response to motivationally salient events. The AB refers to decreased accuracy for reporting the second of two targets (T1 and T2) inserted into a rapid serial visual presentation (RSVP). The LC-NE account of the AB holds that the AB is the result of a refractory-like period in LC-NE activity. The LC-NE account of the P300 suggests the P300 is the electrophysiological manifestation of the activity of the LC-NE system. The proposed three-way link between these different aspects of brain activity is supported by work showing that subjects who show a larger amplitude P300 response to T1 (T1-P300) in the AB paradigm demonstrate a greater deficit for reporting T2 (Shapiro et al., 2006). Until the work reported here, this relationship has not been shown within subjects, across trials. I ran a typical AB experiment and used single trial analysis of the P300 in response to T1 (T1-P300) to categorize trials into low- and high-amplitude trials. The high-amplitude T1-P300 condition showed a greater T2 deficit. Consistent with the LC-NE theory of the AB, I conclude that T1-P300 amplitude indexes the investment of NE facilitated processing to T1, with resulting cost to T2.

A19

THE ROLE OF THE LEFT AND RIGHT FEF IN VOLUNTARY CONTROL OVER OCULOMOTOR REFLEXES; A TMS STUDY *Martijn G. van Koningsbruggen[1], Alex List[1], Robert D. Rafal[1]; [1]School of Psychology, Bangor University* – TMS was used to investigate the role of the left and right FEF in the voluntary control over oculomotor reflexes. TMS was used to investigate the role of the FEF in the cognitive control of oculomotor reflexes. The FOE, which is the difference in saccadic reaction time between overlap and offset trials, is a measure of the amount of influence an external fixation point has over oculomotor behaviour. For example, the FOE is larger when executing pro-saccades, than anti-sac-

cades. The reduced FOE during anti-saccades reflects an increase in voluntary control over the fixation reflex. It has been shown in monkeys that, in order to suppress reflexive saccades when anti-saccades are required, the preparatory set increases fixation related activity. Due to this increase in activity of fixation related process, the oculomotor system is less influenced by the presence or absence of an external fixation point, i.e. reducing the size of the FOE. Patients with unilateral lesions in the Frontal Eye Fields are impaired in controlling their oculomotor reflexes as measured by the FOE. In the present study, we investigated whether TMS over either the left or right FEF has the same effect in healthy controls. We measured the size of the Fixation Offset Effect (FOE) during both a block of Pro-saccades and Anti-saccades, while TMS was applied over either the left, or right FEF, or a sham control side. So far (N=4), results suggest that TMS over the FEF results in a loss of voluntary control over oculomotor reflexes.

A20

LINKING THE OCULAR MOTOR SYSTEM AND REFLEXIVE ALLOCATION OF ATTENTION: AN FMRI INVESTIGATION *Shai Gabay[1], Yoni Pertzov[2], Libe Gradstein[3], Avishai Henik[1], Galia Avidan[1]; [1]Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Beer-Sheva, Israel, [2]Interdisciplinary Center For Neural Computation, The Hebrew University, Jerusalem, Israel, [3]Soroka Medical Center, Beer-Sheva, Israel* – It is generally accepted that eye movements and covert attention are closely related but the exact association between these two processes is still under debate. We addressed this issue by investigating a patient (GS) with Duane Retraction Syndromeóa congenital impairment in executing horizontal eye movements affecting only the left visual field in her left eye. GS and control participants performed Posner's exogenous cuing task during an fMRI scan. The experiment was repeated twice, each time with only one eye open. Behavioural results revealed an exogenous validity effect for controls in both eyes and both visual fields. Importantly however, a reversed pattern was found in GS's restricted visual field, even though no eye movements were required or preformed during the task. fMRI data revealed lower activation for GS in the left intraparietal sulcus (IPS), known to be involved in orienting of attention, when cues were presented in the restricted visual field. That is, GS presented intact behavioural performance and brain activation when viewing stimuli in the healthy visual fieldóevidence for normal development of attention. In spite of this, covert orienting depended on the ability to execute appropriate eye movements even when they were not explicitly required. This result provides evidence for a strong linkage between the reflexive orienting system and the ocular motor system.

A21

THE CAUSAL ROLE OF THE DORSOLATERAL FRONTAL CORTEX IN THE STROOP COLOR-NAMING TASK *Eishi Asano[1], Shin-ichiro Koga[1], Robert Rothermel[1], Csaba Juhasz[1], Miho Fukuda[1], Masaaki Nishida[1], Sandeep Sood[1]; [1]Children's Hospital of Michigan, Wayne State University* – Previous human studies using functional MRI demonstrated that a Stroop color-naming task induced greater cortical activation in the left dorsolateral-frontal region, compared to a word-reading task. In the present study, we evaluated event-related gamma-oscillations (80 - 100 Hz) during the Stroop color-naming and word-reading tasks in two epileptic patients who underwent intracranial electrocorticography. Using our in-vivo animation technique (Brown et al, NeuroImage 2008; Fukuda et al, Brain 2008), we delineated 'how' color-naming-specific gamma-augmentation involved the left dorsolateral-frontal region. Both Stroop color-naming and word-reading tasks commonly induced gamma-augmentation in the posterior-inferior temporal region immediately following presentation of colored-word stimuli. Both Stroop color-naming and word-reading tasks also commonly induced gamma-augmentation in the inferior Rolandic region immediately prior to and during overt responses. In addition, the Stroop color-naming task specifically induced gamma-augmentation in the left dorsolateral-frontal region approximately 500 - 300 msec prior to overt responses. Electrical stimulation of the site showing color-naming-specific gamma-augmentation resulted in temporary naming impairment in both patients. The present study has provided further evidence that the left dorsolateral frontal region plays a causal role in the Stroop color-naming task.

A22

PRISM ADAPTATION REVERSES THE LOCAL PROCESSING BIAS IN PATIENTS WITH RIGHT TEMPORO-PARIETAL JUNCTION LESIONS *Janet Bultitude[1], Robert Rafal[1,2], Alexandra List[1]; [1]School of Psychology, Bangor University, [2]Wolfson Centre for Clinical and Cognitive Neuroscience* – Lesions to the right temporo-parietal cortex commonly result in hemispatial neglect. Lesions to the same area are also associated with hyperattention to local details of a scene and difficulty perceiving the global structure. This local processing bias is an important factor contributing to neglect and may contribute to the higher prevalence of the disorder following right compared to left hemisphere strokes. In recent years promising evidence has emerged for improvements in neglect symptoms following adaptation to rightward-shifting prisms. Explanations for these improvements have generally described a leftward realignment of attention, however the present investigation provides evidence that prism adaptation reduces the local processing bias. Five patients with right temporal-parietal junction lesions were asked to identify the global or local components of hierarchical figures before and after undergoing visuo-motor adaptation to rightward-shifting prisms. Prior to prism adaptation the patients had difficulties inhibiting the local elements when identifying the global component compared to ten age- and gender-matched controls. Following prism adaptation, however, this pattern was reversed, with greater global interference during local identification. The results suggest that prism adaptation may improve non-spatially lateralised deficits that contribute to the neglect syndrome.

A23

HOW DO WE LOOK AT FACES? *Aurelie Porcheron[1], Walter Jenner[2], Juergen Pripfl[2], Maja Pivec[2], Michael Binder[3], Erwin Tschachler[1,3], Frederique Morizot[1]; [1]CE.R.I.E.S, Neuilly sur Seine, France, [2]University of Applied Sciences FH JOANNEUM, Information Design, Graz, Austria, [3]Medical University of Vienna, Dermatology, Vienna, Austria* – Facial appearance is an important source of social affective information. Face perception and visual attention play an important role in the judgement of social characteristics. The analysis of gaze behaviour provides information on how we are looking at faces. The objective of the present study was to determine the facial areas used for age estimation. The eye movements of women exposed to faces demonstrating different signs of aging was tracked. Twenty two women aged between 39 and 45 were exposed twice to 48 female facial pictures: a first time without any instruction, and a second time with the instruction to estimate the age of the faces shown. Images of the faces showing different signs of aging were from women of three age groups: young (30 to 39), middle (40 to 49) and old (50 to 59). We observed a common behaviour in the group of viewers exposed to female faces whatever the instructions. When subjects were instructed to rate the age of a face, their eyes remained fixated within an area which covers the eyes, the nose and the middle upper part of the mouth. More than 75,5% of all fixations fall within this area, whereas when subjects were instructed to just look at the faces, this area demanded only 64,7% of all fixations. Our results suggest that we mainly look at internal features when estimating the age of a face and we strongly focus on the eyes.

A24

PARIETAL CORTEX REPRESENTATION OF VISUAL PRIORITY: EVIDENCE FROM SPATIAL NEGLECT *Masud Husain[1,2], Victoria Singh-Curry[1,2], Jon Driver[1], Paul Bays[1,2]; [1]Institute of Cognitive Neuroscience, University College London, UK, [2]Institute of Neurology, University College London, UK* – Where we look is determined both by our current intentions and by the tendency of visually salient items to 'catch our eye'. This normal process of directing attention can be profoundly impaired by damage to parietal cortex, resulting in visual neglect of the contralesional hemispace. Here we use neglect patients' (n=5) eye movements in a

visual search task to separately evaluate impairments in goal-directed orienting to targets and in stimulus-driven orienting to salient distractors. These deficits are shown to be identical in both magnitude and spatial distribution. The findings appear consistent with damage to a single topographically-organized 'priority map' in posterior parietal cortex, representing both the goal-relevance and the visual salience of items in the visual scene. According to this hypothesis, left neglect occurs when right-hemisphere damage leaves left hemispace under-represented in the priority map, resulting in a pathological bias of attention towards ipsilesional space. However, because targets of attention are chosen by competition within the map, shifts of attention to left hemispace should still be possible if the leftward input is strong enough to overcome the over-representation of right space. We used an adaptive algorithm to systematically vary the distribution of distractor luminance in a search array, searching for a display that will normalize a patient's exploratory behaviour. Consistent with the priority-map hypothesis, we demonstrate that the rightward bias in neglect can indeed be eliminated and even reversed by biasing the distribution of visual salience towards the left.

A25

DISTRIBUTION OF GAZE AND ATTENTION DURING FACIAL IDENTITY AND EXPRESSION TASKS *Susan M. Letourneau[1], Teresa V. Mitchell[2]; [1]Brandeis University, [2]E.K. Shriver Center, University of Massachusetts Medical School* – Two studies compared the distribution of gaze and attention during emotion and identity judgments. We hypothesized that the top and the bottom of the face would vary in salience depending on the type of judgment being made. Subjects learned names for a set of faces, and then were asked to make identity or emotion judgments of whole faces, isolated top halves, and isolated bottom halves of faces. Eye-tracking data was gathered and accuracy was measured. Subjects were more accurate in both tasks when whole faces, rather than isolated top or bottom halves, were presented. Emotion was recognized more accurately from the bottom of the face than the top, while the opposite was observed for identity judgments. Despite this difference, the top of the face immediately captured subjects' gaze in both tasks. Saccades were made to the bottom half of the face only during the emotion task, specifically from 500-1000ms after stimulus onset. In the second study, subjects were asked to identify the name or emotional expression in the top or bottom half of briefly presented composite faces (combining the top of one identity or emotion with the bottom of another). Subjects more accurate when judging emotion from the bottom halves of the stimuli, and when judging identity from the top halves. In sum, while early gaze fixations tend to fall on the top half of the face regardless of the task, later fixations and attention patterns are highly dependent upon the task and stimulus characteristics.

A26

DOES POWER SHIFT ATTENTION ON A VERTICAL DIMENSION? AN EVENT RELATED POTENTIAL STUDY *Kiki Zanolie[1], Jasper Wijnen[2], Saskia van Dantzig[1,3], Inge Boot[1], Diane Pecher[1]; [1]Erasmus University Rotterdam - Institute for Psychology, [2]University of Amsterdam, [3]Leiden University Institute for Psychological Research* – People often use the spatial dimension up-down metaphorically when speaking and thinking of power. Studies show that thinking of power automatically activates the 'power is up' metaphor. This raises the question whether power stimuli can induce a shift of attention to the upper or lower visual field. To address this question, Event Related Potentials were recorded during a dual-task. Participants made power judgments to words denoting powerful or powerless people (e.g. 'king' or 'servant'), presented centrally. Following each judgment, a target letter was presented in the upper or lower visual field. Findings of 15 participants show an enhanced P1 and N1 amplitude when the spatial position of the target is congruent with the metaphorical direction of the preceding word (powerful-up, powerless-down). This result suggests that power stimuli induce a spatial shift of attention corresponding to their implied direction, providing further evidence that metaphors play a role in grounding abstract concepts in sensorimotor processing.

A27

DIFFERENTIAL EFFECTS OF EXOGENOUS AND ENDOGENOUS ATTENTION ON PERCEPTUAL LEARNING *Ikuko Mukai[1], Kandy Bahadur[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, NIMH, NIH* – Perceptual learning is a phenomenon in which one's visual perception improves after repeated exposure to a visual stimulus. However, large differences in the rate and extent of perceptual learning are often observed among subjects, for unknown reasons. Based on results from our previous study (Mukat et al., J. Neurosci 2007), we hypothesized that attention plays a key role in facilitating perceptual learning. To manipulate spatial attention at different locations during training, we used exogenous and endogenous attention cues. Training stimuli (tilted Gabor patches) were placed within four quadrants of the visual field. Subjects decided if the Gabor patch at a task location was tilted to the right or left from the vertical meridian. The contrasts of the stimuli were set at an accuracy level of 75% correct, based on threshold measurements conducted before training. When we manipulated attention by exogenous attention cues, we found a large improvement in accuracy and reaction times at the cued location but no significant improvement at the uncued location. On the other hand, when we manipulated attention by endogenous cues, improvements were observed at both cued and uncued locations, though accuracy was better and reaction times were shorter for the cued location. One possible explanation for these results is that exogenous, but not endogenous, attention facilitates perceptual learning. Another possibility is that our endogenous manipulation, specifically the number of valid task trials, did not sufficiently control subjects' attention during training. We will investigate this further by increasing this number and seeing its effect on learning.

A28

DISCRIMINATING DIFFERENT ATTENTION LEVELS BY THE ELECTROPHYSIOLOGICAL AND BEHAVIORAL MEASURES *Yu-Chieh Chang[1], Shwu-Lih Huang[1,2], Ai-Ru Lee[1], Huan-Chun Sun[1]; [1]National Chengchi University, [2]Research Center for Mind, Brain & Learning, National Chengchi University* – The purpose of present study is to find out indices which can discriminate different attention levels. Most of the previous studies could hardly control perceptual content well while manipulating attention levels. Thus the indices found may reflect a mixed effect from perceptual content and attention levels. Therefore, the task was revised in present study by equalizing perceptual content in different attention levels. A lot of measures such as electroencephalography (EEG), electrooculography (EOG), respiration and temperature were recorded simultaneously while doing the task. Four conditions were manipulated to induce different attention levels. In baseline condition, participants took a rest, opened their eyes and being motionless. In control condition, participants observed movie clips only. In low attention condition, participants observed the same clips and counted the easy target events defined by one feature dimension only. In high attention condition, participants counted the difficult target events defined by two feature dimensions conjointly. Based on the Feature Integration Theory, our high attention condition consumes more attention resources than the low attention condition. In order to equalize perceptual content in different attention levels, movie clips used in our conditions of control, low attention, and high attention were totally identical. A MANOVA analysis (N=24) of the data revealed that only power value of alpha band (8.2~12.9Hz) and delta band (1~2Hz) of EEG and blink duration may potentially discriminate different attention levels. The implications of present findings in psychophysiology and cognitive neuroscience could lead more explorative investigations in the future.

A29

PRISMS IMPROVE BOTH ACTION AND PERCEPTION IN AN ARTIST WITH NEGLECT *James Danckert[1], Nadine Quehl[1], Colleen Merrifield[1]; [1]University of Waterloo* – We recently tested the hypothesis that prisms will influence dorsal but not ventral stream processing in patients with neglect using the line bisection and landmark tasks. In two patients with neglect we showed improvement in the line bisection task but no change in the landmark task, which represents a perceptual variant of line bisection. Here we tested a patient who had been a graphic artist prior to suffering a right fronto-parietal stroke leading to dense unilateral neglect. Prior to prisms he showed only a minor rightward bias on the line bisection task and a marked leftward bias on the landmark task (note: leftward biases on this task indicates that the patient perceives the left half of the line to be shorter than the right even when they are of equivalent lengths). After prisms the patient showed a significant leftward shift in line bisection mirroring the same effects observed in other neglect patients. In contrast to our previous work, this patient also showed a marked change in the landmark task such that he was no longer biased toward perceiving the left end of the line as shorter (his responses were more equally distributed towards left and right responses). It may be the case that accomplished artists have far stronger linkages between perception and action than do non-artists. Prisms may have restored such linkages for our patient leading to improved perception and action.

A30

HIGH-FIELD FMRI REVEALS CONTRALATERAL AND EGOCENTRIC-REFERENCE-FRAME PROPERTIES OF THE SUPERIOR COLLICULUS DURING SACCADE EXECUTION IN HUMANS *Ruth Krebs[1,3], Marty Woldorff[3], Claus Tempelmann[1], Nils Bodammer[1], Toemme Neosselt[1], Carsten Boehler[2,3], Jens-Max Hopf[1,2], Emrah Duzel[1], Hans-Jochen Heinze[1,2], Ariel Schoenfeld[1,2]; [1]Clinic for Neurology, University of Magdeburg, Germany, [2]Leibniz-Institute for Neurobiology Magdeburg, Germany , [3]Center for Cognitive Neuroscience, Duke University, United States* – Neural correlates of saccade execution in humans were mapped using 7T high-field fMRI. Subjects performed centrally cued saccades to a left or right lateral target square (centrifugal saccade) and maintained the new position until a second cue at that location indicated to return back to the center (centripetal saccade). Activity in the superior colliculus (SC) was significantly larger contralateral to the direction of the saccade, providing direct evidence for the contralateral functional anatomy of the SC in humans. Additionally, the SC exhibited higher activity for centrifugal compared to centripetal saccades, presumably reflecting higher processing demands. Correspondingly, centrifugal saccades were also associated with substantially greater deactivations in the default-mode network than were centripetal saccades, further supporting the notion that the return to the center of egocentric reference space is less effortful. These differential reference-frame effects may be due to reduced requirements for calculating the reference coordinates and thus for attentional allocation during saccades that return to the center of egocentric space. More generally, the present data support the view that the center of straight gaze, in which retinotopic and the egocentric frame are aligned, might represent the natural default baseline value for eye movements from which the visual world can be explored.

A31

NEURAL MODULATION OF RHYTHM INDUCED TEMPORAL EXPECTATIONS *Gustavo Rohenkohl[1], Anna Dal Molin[1,2], Anna Christina Nobre[1]; [1]University of Oxford, [2]University of Verona* – Time is an essential dimension of our experience, framing human behaviour at scales ranging from the millisecond organization of motor actions to circadian rhythms cycle, and beyond. Nevertheless, the mechanisms by which the brain keeps time and uses temporal information to organise behaviour remain unknown. Whereas the principles of the organisation of spatial cognition in the human brain are emerging, the same is not true for temporal cognition. The current study tested the influence of temporal expectations on attentional orienting to moving targets. In this task, a ball appeared at the left side of a screen and moved across the screen in steps following either a regular or irregular rhythm. After reaching an occluding band, the ball was temporarily occluded. When the ball reappeared, it contained either an upright (50%) or tilted (50%) cross. The task involved making a speeded perceptual discrimination about the target stimulus that reappears after the occlusion. The results indicated a strong behaviour benefit from temporal orienting. We recorded ERPs elicited by reappearance of the target stimulus, and investigated how temporal expectations influenced perceptual (e.g., visual P1 potential) and motor (lateralised readiness potential) stages of neural processing. The results showed that temporal expectations facilitated both early visual (P1) as well as motor (LRP) potentials. We are currently comparing induced frequency activity during the pre-occlusion and occlusion periods to look for modulation of rhythmic activity in lower frequency bands related to visual (alpha) and motor (mu) processing.

A32

DISTRACTIBILITY WITH ADVANCING AGE AND PARKINSON'S DISEASE: EVIDENCE OF DYSFUNCTIONAL REACTIVE INHIBITION *Liana Machado[1], Amy Devine[1], Natalie Wyatt[1]; [1]University of Otago* – Focused attention can be compromised by the neurodegenerative processes associated with both healthy aging and Parkinson's disease (PD). Deficits in ignoring distractors with reflexive or overlearned response links have been attributed to impaired inhibition. The current research assessed whether similar deficits occur for distractors with recently learned arbitrary response associations, for which sensorimotor transformations are far less automatic and therefore considerably easier to resist. We used a selective attention task that evaluated distractibility and the use of distractor inhibition within the same context. The task involved stimuli that were arbitrarily assigned to responses based on a rule learned during the testing session. Performance showed that distraction increased with both healthy aging and PD. Moreover, these increases in distraction were accompanied by decreases in overt evidence of distractor inhibition, which appear to reflect at least in part a failure of reactive inhibition. Removing the distractor prior to the appearance of the target eliminated the age- and PD-specific increases in distractibility; however, inhibitory deficits remained evident. Comparison of the two groups indicates that the key differences reflect severity of symptoms, rather than distinct symptoms, suggesting that the deficits stem from neural changes associated with both advancing age and PD. These results demonstrate that age- and PD-related hyper-distractibility and impaired inhibition during focused attention affect stimuli without prepotent response links, suggesting a critical role for dopaminergic networks in the strategic control of arbitrary visuomotor transformations.

Emotion

A33

EMOTIONAL MEMORY CONSOLIDATION IN A CONDITIONAL DISCRIMINATION PARADIGM USING FMRI IN HUMANS *Amal Achaibou[1,2,3], Irina Constantinescu[1,2], David Sander[2,3,1], Patrik Vuilleumier[1,2,3], Sophie Schwartz[1,2,3]; [1]University of Geneva, [2]Center for Neuroscience, University of Geneva, [3]Swiss Center for Affective Sciences, University of Geneva* – In classical aversive conditioning paradigms, a neutral stimulus (conditioned stimulus, CS) is paired with an aversive stimulus (unconditioned stimulus, US) and acquires an emotional valence. A conditioned response (CR) is then observable after presentation of the CS alone. Extinction of the CR occurs when the CS is presented alone for several trials, corresponding to a new safety-related memory rather than to the forgetting the conditioning phase. While this has been commonly used to assess fear inhibition, it remains difficult to disentangle between the "aversive" and "safety" signals associated with the CS. We used a conditional discrimination paradigm, in 21 participants while

they viewed pairs of faces during fMRI. One pair (AX, excitatory) was associated with an aversive noise (US) whereas another pair (BX, inhibitory) was never associated with the US. During a subsequent testing phase, subjects viewed the same pairs and 2 additional pairs to test the transfer of inhibition (AB) and of excitation (AC). Between sessions, participants took a 45-minutes nap while their EEG was recorded, allowing us to assess any influence of sleep on emotional memory. Behaviorally, preliminary results show increased pupil responses to AX as compared to BX during testing, indicating efficient conditioning. In fMRI, we found increased activity in the Insula for AX as compared to BX and in prefrontal, hippocampal and retrosplenial regions for BX as compared to AX, suggesting a role of contextual memory systems for acquisition of safety signals. Further analysis will focus on sleep influence on emotional learning and associated brain activity.

A34

EEG MEASURES OF ADULT RESPONSE TO INFANT EMOTION *Jeffrey K. Erbe[1], Nicole Landi[1,2,3], Julia R. Irwin[2], W. Einar Mencl[2], Jocelyn L. Topf[4], Mark N. Potenza[4], Linda C. Mayes[1]; [1]Yale Child Study Center, New Haven, CT, [2]Haskins Laboratories, New Haven, CT, [3]University of Minnesota, [4]Yale School of Medicine, New Haven, CT* – At the earliest stages of infant development, the primary way in which infants communicate with caregivers is through facial expression and vocalizations such as cries. Thus, it is of great importance to understand how and when human caregivers process this information. Two experiments were conducted to examine EEG response to infant emotion in female adults. The first study compared processing of infant faces expressing happy, neutral or sad affect; the second study compared processing of low distress and high distress infant cries. We conducted temporal principle components analyses (PCA) for each of a set of a priori defined scalp regions for each experiment, followed by a series of repeated measures ANOVAs. In the face study we observed a large N170 effect in the right hemisphere occipital parietal scalp region that was modulated by valence such that both happy and sad faces produced more negative deflections than neutral faces, consistent with theories that postulate that the N170 and not just later components are sensitive to emotion (e.g., Blau et al, 2007). The cry analyses revealed more negative N1 responses to high distress cries relative to low distress cries. Critically, this EEG response demonstrates that the N1 is modulated by perceived distress level (previous research on cries has shown that the N1 is more negative for cries relative to a neutral sound, but has not examined distress level). Taken together these findings reveal that information about infant emotional valence is processed at very early stages of visual face and auditory cry perception.

A35

FUNCTIONAL CORTICAL ACTIVATION ASSOCIATED WITH PROCESSING OF INFANT EMOTIONAL STATES *Nicole Landi[1,2,3], W. Einar Mencl[2], Jeff Erbe[3], Mark Potenza[4], Julia Irwin[2], Jocelyn Topf[4], Linda Mayes[3]; [1]University of Minnesota, Minneapolis, MN, [2]Haskins Laboratories, New Haven, CT, [3]Yale Child Study Center, New Haven, CT, [4]Yale School of Medicine, New Haven, CT* – The nature of the bond between infant and caregiver has important effects on children's developmental trajectories. Because this bond is formed very early in development, during a time when the primary communication from the infant to the care-giver is expressed via facial expression and vocalizations such as coos and cries, it is of great interest to understand how care-givers process the emotional content of these basic visual and pre-verbal communications. We used event-related fMRI to examine the underlying neurocircuitry associated with this process. Twenty adult females viewed infant faces expressing happy, sad, or neutral emotion, and cries expressing high or low distress. The comparisons of infant face processing revealed modulation of the anterior cingulate (an area previously implicated in processing of infant facial affect), with greater activation for sad relative to neutral faces. We also observed differential processing for sad and happy faces in the globus pallidus, an area thought to be involved in integration of emotion and body location. These findings reveal a circuit for processing of infant facial emotion involving both cortical and subcortical regions. For auditory cries, more distressed/sad cries again produced greater activation in the anterior cingulate, as well as the insula, another area implicated in infant facial emotion processing. Together these findings indicate that processing of infant facial emotion and cries reveals a partially overlapping network of regions that have been implicated previously in emotion processing.

A36

ACTIVE SUPPRESSION OF FACIAL MOVEMENT DIMINISHES BUT DOES NOT ABOLISH AUTOMATIC FACIAL MIMICRY *Sebastian Korb[1,2], Didier Grandjean[1,2], Klaus Scherer[1]; [1]Swiss Center for Affective Sciences, Geneva, Switzerland, [2]University of Geneva, Switzerland* – Automatic facial mimicry is a well described phenomenon involving people's reflexive tendency to display facial expressions they perceive in others. It has also been proposed to be the main process underlying emotion recognition, emotional contagion, and empathy. In order to address the question whether automatic facial mimicry persists despite voluntary, active inhibition of facial movements, we recorded facial electromyography (EMG) in healthy participants during an emotional Go/NoGo task. In a within-subjects design, participants were instructed to smile quickly to smiling faces and to keep a neutral expression to neutral faces (congruent condition), or the reverse (incongruent condition). Activity of the left corrugator and zygomaticus muscles was measured with EMG. Results showed significantly earlier activity of the zygomaticus for smiling in congruent compared to incongruent Go trials, and a higher false-alarm rate for incongruent compared to congruent NoGo trials. Moreover, activity of the zygomaticus was significantly higher during response-free incongruent than congruent NoGo trials. These results suggest that facial mimicry effects are present even at short intertrial intervals, and that they can survive participants' active suppression of facial movement.

A37

REWARDS EARNED FOR OTHERS - AN FMRI STUDY OF THE NEURAL CORRELATES OF ALTRUISM *Jeff MacInnes[1,2], R. McKell Carter[1,2], R. Alison Adcock[1,2,3], Scott Huettel[1,2,4]; [1]Center for Cognitive Neuroscience, Duke University, Durham NC, [2]Brain Imaging and Analysis Center, Duke University, Durham NC, [3]Duke University Medical Center, Durham NC, [4]Duke University, Durham NC* – The anticipation of reward has been reliably shown to elicit fMRI activations in the ventral tegmental area (VTA) and nucleus accumbens (NAcc). However, previous research has focused predominantly on rewards directly earned for oneself. Humans often exhibit altruistic behavior engaging in actions that lead to a reward for others, leaving an open question of whether these types of rewards are processed by mirroring self-directed rewards. We compared fMRI activations in 18 participants during a modified monetary incentive delay (MID) task in which participants played to earn money for a charity of their choosing. The experiment was divided into 2 block types, reward and punishment, where participants played to earn money or avoid losing money, respectively. Within each block participants were cued on a trial-by-trial basis whether they would be playing for themselves or for the charity. Trial outcomes were based on reaction times to targets presented following the cue. Participants received feedback on each trial. GLM analyses conducted in FSL examined fMRI activations during the anticipation period between cue and target across the different test conditions. We find strong striatal activations for both charity and self conditions. Consistent with past research examining the representation of self and other, an analysis comparing charity trial anticipation to self trial anticipation revealed significant activation in the posterior cingulate cortex (PCC) during both the reward and punishment blocks.

A38

REGULATING CRAVING FOR CIGARETTES AND FOOD: AN FMRI STUDY OF CIGARETTE SMOKERS *Hedy Kober[1], Ethan Kross[2], Peter Mende-Siedlecki[1], Kevin Ochsner[1]; [1]Columbia University, [2]University of Michigan, Ann Arbor* – A failure to regulate craving has been implicated in substance abuse disorders and in post-treatment relapse. This under-

scores the urgent need to understand the neural correlates of craving and its regulation in substance abusing populations. Therefore, this study used fMRI to examine the neural bases of craving for cigarettes and food, as well as the regulation of craving using cognitive strategies in a nicotine-dependent population. Twenty-one cigarette smokers viewed images of cigarettes and of delicious looking, unhealthy foods, and were instructed to think about either the (a) immediate sensory experience (e.g. increase craving), or (b) the long-term negative physical health implications associated with consuming each item (e.g. regulate craving). Subjective ratings indicated that participants experienced significantly less craving for both cigarettes and food when considering the long-term consequences associated with consumption, suggesting that cognitive strategies can be used to effectively regulate craving for both food and cigarettes (consistent with clinical data). On "increase craving" compared to "regulate craving" trials, we observed activation in "reward" regions including subgenual cingulate, ventral striatum, and ventral tegmental area. This pattern was stronger for cigarettes compared to food, consistent with participants' reports of greater craving for cigarettes compared to food. Conversely, on "regulate craving" trials we observed activity in "control" regions including the dorsomedial prefrontal cortex and inferior frontal gyrus. This pattern was stronger for food compared to cigarettes, suggesting a possible mechanism for the impaired regulation of cigarette craving (compared to food craving) exhibited by these cigarette smokers in everyday life.

A40

COULD THE CONTEXT BECOME A PREDICTOR OF AN AVERSIVE STIMULUS? *Marta Andreatta[1], Andreas Muelberger[1], Cornelius Gross[2], Peter Weyers[1], Paul Pauli[1]; [1]University of Wuerzburg, [2]European Molecular Biology Laboratory (EMBL)* – After learning, a stimulus can signal that an expected aversive unconditioned stimulus (US) will not occur and it induces inhibition of defensive responses. Urcelay et al. (2006) in a study with rats found that context became a good predictor of US when it was presented for short periods of time in the absence of US. Thus, Pavlovian conditioned inhibition was disrupted because context competed with the stimulus predicting US (i.e. excitor) and it decreases inhibitory potential of the stimulus signaling the absence of US (i.e. inhibitor). Goal of the study is to investigate the conditions in which context becomes a predictor of US in humans. In a between-subject design, we compared Pavlovian inhibition with relatively spaced-trials (intertrial interval - ITI - 25 s) to Pavlovian inhibition with relatively massed-trials (ITI 7 s). A geometrical shape was associated with an aversive electrical shock (US) and functioned as excitor (A+), whereas a compound shape (AX-), which functioned as inhibitor, not. As index of inhibition startle reflex, skin conduction and subjective ratings were assessed during a summation test. According to animal data, we did not find conditioned inhibition modulation, when participants underwent massed-trials training. However, we would expect a conditioned inhibitory response to AX- compared to control compound shape (AY) when participants undergo a spaced-trials training. We conclude that context could work as predictor of US in rats as well as in humans. In fact, context seems to compete with the excitor and to down-modulate inhibitory effectiveness of AX-, when ITIs were short.

A41

EYE GAZE AND PUPIL RESPONSE AS INDICES OF EMOTIONAL RECOGNITION MEMORY *Daniel Younglove[1], Sara Bagley[1], Tony Buchanan[1]; [1]Saint Louis University* – Eye gaze and pupillometry have been used to index both emotion and memory. There is not, however, a reliable signature of gaze or pupil response patterns that predict recognition of emotional stimuli. Fifteen participants were shown 6 pleasant, 6 unpleasant, and 6 neutral pictures. Twenty-four hours later they saw each of these pictures again along with a new picture matched for content and valence in a two-alternative forced choice recognition memory task. Eye tracking methodology was implemented to examine the latency of the initial shift of gaze, duration of gaze on the initial fixation, and pupil dilation. Participants were quicker to make their initial fixation to emotional compared to neutral picture pairs, with fixations to unpleasant pictures made the quickest, $F(2,13) = 4.98$, $p = 0.025$, eta-squared = 0.43. There was no effect of prior viewing, as the latency of the first fixation did not differ between new and old pictures. Participants fixated longer on the 'old' neutral and pleasant pictures compared with the 'new' neutral and pleasant pictures, but were quicker to avert their gaze from the 'old' unpleasant pictures than from the 'new' ones, $F(2,13) = 9.1$, $p = 0.003$, eta-squared = 0.5. A similar pattern was found with pupil diameter, such that 'new' unpleasant pictures elicited the greatest pupil dilation, $F(2,13) = 6.68$, $p = 0.01$, eta-squared = 0.51. These results suggest that gaze pattern and pupil diameter may be useful implicit indicators of recognition memory for emotional stimuli.

A42

EMPATHIC NEURAL RESPONSE TO LIVING THINGS AS A FUNCTION OF AGENCY AND EXPERIENCE *Vani A. Mathur[1], Tokiko Harada[1], Bobby K. Cheon[1], Jason Scimeca[1], Joan Y. Chiao[1,2]; [1]Northwestern University, [2]Northwestern Interdepartmental Neuroscience Program* – Living things in the natural world vary on their degree of agency (e.g., how much control they have over their world) and experience (e.g., their capacity to feel). Prior research has shown that these dimensions predict the extent to which humans infer that a living thing is capable of internal states, such as suffering. Though empathy may be defined as the human capacity to share and understand the internal states of other humans, people also display empathic feelings for other living things that vary in agency and experience such as animals and elements in the natural world. Additionally, people exhibit prosocial intentions and behaviors towards other biological entities, such as refusing to eat meat or recycling trash. Although it is well-established that neural regions within the pain matrix, such as anterior cingulate cortex (ACC) and bilateral anterior insula (AI) underlie empathy for other humans, here we examined the possibility that distinct or shared neural circuitry underlie empathic responses for biological entities in the world that vary on agency and experience. Using functional magnetic resonance imaging (fMRI), we measured neural activity while participants viewed images of humans, animals or nature in either egregiously negative (painful) or neutral situations. Results indicate that empathic neural response within the right AI varies as a function of agency and experience. Here we show for the first time that empathy for the suffering of humans, animals and nature relies on shared neural circuitry within the pain matrix.

A43

EMOTION-MODULATED VIEWING OF NEUTRAL FACES *Lily Riggs[1,2], Douglas A. McQuiggan[1,2], Jessica Chan[2], Ella Pan[1], Adam K. Anderson[2], Jennifer D. Ryan[1,2]; [1]Rotman Research Institute, [2]University of Toronto* – We examined whether memory for faces, as indexed via changes in eye movement sampling behavior, could be modulated as a consequence of the type of emotional information that is associated with the face. During a study period, participants saw neutral faces presented alone, and then paired with either a negative or neutral sentence, followed by a repeated presentation of the face alone. This procedure was repeated across 5 study blocks. Viewing to particular face regions was modulated by whether the face had been associated with neutral vs. negative information. Participants spent more time viewing the eyes, and less time viewing the mouth, if the face had been associated with a negative sentence. During the test session, participants viewed displays of 3 faces presented simultaneously. The 3-face displays contained either 0, 1 or 2 faces previously paired with a negative sentence. Under free viewing conditions, memory for the emotional valence of associated information was assessed indirectly via eye movement monitoring. Sampling of the 3-face displays was related to the number of faces present within the display that had been previously associated with emotional information. For instance, the average fixation duration directed to the three faces increased with an increasing number of faces that had been previously paired with negative information; suggesting that associated emotional

information had been accessed during viewing of the faces. Altogether, these findings suggest that the retrieval of associated emotional information can alter the manner by which a perceptually neutral item is processed, even when presented in isolation.

A44

INCREASED AMYGDALA RESPONSE TO EMOTIONAL STIMULI DURING THE MID-LUTEAL PHASE OF THE MENSTRUAL CYCLE *Joseph Andreano[1,2], Larry Cahill[1,2]; [1]University of California, Irvine, [2]Center for the Neurobiology of Learning and Memory* – Previous studies of emotional encoding have indicated opposing effects of the ovarian hormones estrogen and progesterone on arousal-related activity in the amygdala, with emotional responses reduced during cycle phases when estrogen levels are high (Goldstein et al., 2005), but increased by progesterone treatments (Van Wingen et al., 2008). However, no study to date has assessed the effects of endogenous progesterone on amygdala activity in the context of a natural cycle, where progesterone release is coincident with the release of estrogen. To address this question, 17 naturally cycling women were scanned using fMRI during 2 hormonally distinct phases of their cycles: the early follicular phase, when both estrogen and progesterone are low, and the mid-luteal phase, when progesterone is at peak levels, and estrogen levels are also relatively increased. During both scans, participants viewed blocks of arousing negative images and blocks of low-arousal neutral images, drawn from the IAPS set. The results indicated significantly greater emotion-induced activity in the mid-luteal phase compared to early follicular phase in both the right amygdala and left hippocampus. These findings provide further support for the view that the activity of regions involved in emotional memory vary in women across the menstrual cycle due to modulatory influences of ovarian hormones.

A45

HEIGHTENED FUSIFORM GYRUS AND AMYGDALA FUNCTIONAL CONNECTIVITY DURING EMOTIONAL FACE PROCESSING IN WILLIAMS SYNDROME *Brian W. Haas[1], Fumiko Hoeft[1], Ursula Bellugi[2], Allan L. Reiss[1]; [1]Stanford University, Stanford, CA, [2]Laboratory for Cognitive Neuroscience, Salk Institute for Biological Studies, San Diego CA* – Williams syndrome (WS) is a genetic disorder caused by a hemizygous microdeletion on chromosome 7q11.23. WS is associated with a compelling symptom profile characterized by relative deficits in visiospatial function and relative strengths in face and language processing. Interestingly, WS is also characterized as being associated with a heightened drive towards social engagement. Recent brain imaging studies have demonstrated atypical fusiform gryus and amygdala response to emotional stimuli in WS. However, emotional processing is extremely complex and involves a large neural network including the functional connections between the fusiform gyrus, amygdala and other brain structures. Based on the established social/emotional phenotype of WS, we predicted that the functional connectivity within this network would be aberrant in WS during emotional face processing. We used fMRI to study a sample of WS and typically developing (TD) participants who performed a gender discrimination task of emotional facial expressions (happy, fearful and neutral). The WS sample exhibited greater functional connectivity between the fusiform gyrus and medial prefrontal cortex compared to the TD sample during emotional face processing (both happy and fearful). The WS sample also exhibited greater functional connectivity between the amygdala and prefrontal cortex during happy face processing compared to the TD sample. These findings provide evidence that abnormal social/emotional processing in WS is in part due to atypical functional connectivity between a network of brain structures.

A46

CULTURAL VARIATION IN PERCEPTUAL STRATEGIES UNDERLYING EMOTION REGULATION *Genna Bebko[1,2], Steven Franconeri[2], Kevin Ochsner[3], Joan Chiao[1,2]; [1]Northwestern University Interdepartmental Neuroscience Program, [2]Northwestern University, [3]Columbia University* – Norms for the experience, expression, and regulation of emotion vary widely between individualistic and collectivistic cultures. Collectivistic cultures value conformity, social harmony, and social status hierarchies, so attention is directed to contextual emotion information and disruptive emotions may be suppressed. By contrast, individualistic cultures valuing autonomy and the pursuit of happiness are more likely to attend to central emotion information and to reappraise emotions to promote positive emotional experience. Here we examined how culture affects perceptual strategies employed during emotion regulation, particularly during cognitive reappraisal and emotional suppression. Eye movements were measured while healthy young adult participants viewed negative IAPS images and regulated emotions by using either reappraisal (19 Asian-American, 21 Caucasian-American) or suppression (21 Asian-American, 23 Caucasian-American). After image viewing, participants rated how negative they felt as a measure of subjective emotional experience. Consistent with prior studies, reappraisers made lower negative valence ratings after regulating emotions than suppressers across both Asian-American and Caucasian-American groups. Although no cultural variation was observed in subjective emotional experience during emotion regulation, we found evidence of cultural variation in perceptual strategies used during emotion regulation. During middle and late time periods, Asian suppressers made significantly fewer fixations to emotionally salient areas than Caucasian suppressers. These results indicate cultural variation in perceptual differences underlying emotional suppression, but not cognitive reappraisal.

A47

THE NEURAL CORRELATES OF GUILT AND SHAME - AN FMRI STUDY *Ullrich Wagner[1,2,3], Karim N'Diaye[1,2,3], Thomas Ethofer[1], Patrik Vuilleumier[1,2,3]; [1]University Medical School, University of Geneva, Switzerland, [2]Center for Neuroscience, University of Geneva, Switzerland, [3]Swiss Center for Affective Sciences, University of Geneva, Switzerland* – Within the relatively new research field of "affective neuroscience" much progress has been achieved in understanding the neural bases of fundamental emotions like fear and disgust, but little research has been devoted so far to the more complex "self-conscious" emotions like guilt, shame, and pride. These emotions typically occur in interpersonal contexts and can constitute important psychological factors guiding social behavior. Here, we use an autobiographical memory paradigm to investigate the specific neural networks associated with the negative self-conscious emotions guilt and shame by functional magnetic resonance imaging (fMRI). In a pre-scanning questionnaire, subjects defined situations from their personal life that were associated with strong personal feelings of guilt or shame, as well as situations of sadness (negative basic control emotion) and neutral situations. For each situation, subjects provided general context information (place, time, other persons present) and four specific keywords. These were later used as reminder cues in the scanner, where subjects were asked to relive the personal situations and the associated feelings in their mind as vividly as possible (block design: 4 blocks of 20s mental imagery for each emotion condition). This is the first study that directly compares the neural correlates of the closely related self-conscious emotions guilt and shame. Results point to distinct patterns of brain activation associated with these emotions mostly in prefrontal and temporal areas. In particular, guilt more strongly than shame activated medial prefrontal brain areas related to self-referential processing, suggesting higher self-relevance for guilt than shame.

A48

EMPATHIC NEURAL RESPONSES TO OTHERS' PAIN ARE MODULATED BY EMOTIONAL CONTEXTS *Shihui Han[1]; [1]Peking University, China* – Recent brain imaging studies indicate that empathy for pain relies upon both the affective and/or the sensorimotor nodes of the pain matrix. In addition, empathic neural responses are modulated by stimulus reality [Gu and Han, 2007; Fan and Han, 2008], personal experience [Cheng et al., 2007], and perceived fairness of others [Singer et al.,

2006]. The current work investigated whether and how empathic neural responses are modulated by social emotional contexts. Using functional magnetic resonance imaging (fMRI), we first showed that perceiving a painful stimulation (needle penetration) applied to a face with neutral expression induced activation in the anterior cingulated cortex (ACC) relative to non-painful stimulation. However, when observing the painful stimulus delivered to a neutral face was intermixed with observation of painful or happy faces, the ACC activity decreased whereas the activity in the face area of the secondary somatosensory cortex increased to the painful stimulation. Moreover, the secondary somatosensory activity associated with the painful stimulation was decreased when the painful stimulation was applied to faces with happy and painful expressions. The findings suggest that observing painful stimuli in an emotional context weakened affective responses but increased sensory responses to perceived pain and imply possible interactions between the affective and sensory components of the pain matrix during empathy for pain.

A49

BRAIN REGIONS INVOLVED IN RESISTING EMOTIONAL DISTRACTION *Alan Anticevic[1], Grega Repovs[1], Jennifer Staplins[1], Tara Benesch[1], Todd Braver[1], Deanna Barch[1]; [1]Washington University in St. Louis* – Emotional stimuli that communicate survival relevance often demand immediate attention re-allocation. However, there are times when emotional distractions need to be suppressed in the service of ongoing goals. Human have the unique ability to resist distraction and orient attention in a goal directed fashion. This ability involves a dorsal frontal-parietal network that is engaged in a wide range of cognitive operations. One such process is maintenance and manipulation of information in working memory (WM). In the context of WM function, previous work has shown that emotional distracters have a different effect on dorsal and ventral prefrontal regions. However, one question not fully explored is the relationship between signals in these cortical regions during emotional interference and behavioral performance. Here we examine these relationships using slow event-related fMRI at 3T allowing us to discern signals at different phases of a WM task. First, we show that frontal, but not parietal nodes of the dorsal network show a within subject, trial-by-trial relationship with performance during emotional distraction. Specifically, less deactivation was associated with better performance. Conversely, in ventral frontal regions more activation was associated with better performance. Also, we demonstrate that, across-subjects, less amygdala signal correlates with better performance during emotional distraction. Lastly, using trial-based functional connectivity, we show that amygdala signal is negatively correlated with frontal, but not parietal nodes of the dorsal network during emotional distraction. Together, these finding suggest that the source of emotional regulation may originate from dorsal and ventral frontal, but not parietal cortical regions.

A50

REPETITION EFFECTS OF AFFECTIVE VISUAL STIMULI (IAPS) ON ERPS *Ryan Yee[1], Bella Rozenkrants[2], John Polich[1]; [1]The Scripps Research Institute, [2]University of Southern California* – Visual stimuli from the International Affective Pictures System (IAPS) were presented as target stimuli in an oddball discrimination task, with a geometric figure as the standard stimulus (n=16). Three repetitions of each picture occurred sequentially, with varying numbers of standards between these target stimuli. Stimulus pictures were chosen purposefully to reflect extreme arousal (low, high) and valence (negative, positive). Participants were instructed to press a button when a target occurred and to ignore standards. ERP waveforms were assessed systematically from early (N1, P2, N2) and later (P3, SW1, SW2) components. Component amplitudes increased across repetitions from P2 to SW1; amplitudes were larger for high compared to low arousal stimuli for N2 through SW1; amplitudes were larger for positive compared to negative valence stimuli only for SW1, although arousal and valence demonstrated reliable statistical interactions for N2, P3, and SW2. These effects were generally consistent across stimulus repetitions. Taken together, the visual affective stimuli used in a simple discrimination task in which target stimuli are repeated produce ERPs in which (1) stimulus repetition changes component magnitude, (2) arousal and valence characteristics differentially modulate specific component amplitudes, and (3) stimulus repetition affects ERP component amplitudes generally independent of affective condition.

A51

WHERE YOU LOOK AFFECTS VISUALLY-SPECIFIC MEMORY *Michael P. Blank[1], Richard E. Biga[1], Chad J. Marsolek; [1]University of Minnesota* – Visual attention is more restricted when viewing emotional scenes than when viewing non-emotional scenes (the "weapon focus" effect; Loftus, 1979). Recently, we showed that this difference in attentional allocation during encoding affects visually-specific memory (VSM) for both high-arousal, emotional scenes and low-arousal, less emotional scenes (Blank & Marsolek, 2006). Specifically, when participants rated the emotionality of scenes during encoding, broadening of attention (more fixations of shorter duration) predicted subsequent VSM for low-arousal scenes, whereas restriction of attention to emotionally salient parts predicted subsequent VSM for high-arousal scenes. In this study, we examined whether those results would be observed when participants freely view the scenes during encoding rather than rate their emotionality. We recorded eye movements while participants freely viewed high-arousal and low-arousal scenes for two seconds each. Then, we measured VSM in a recognition test by asking participants to decide whether briefly presented scenes were in the same orientation or mirror-reversed compared with encoding. In contrast with the results from the previous study, a relative broadening of attention during encoding - more fixations of shorter duration - predicted subsequent VSM for both low- and high-arousal scenes (this pattern was previously observed only for low-arousal scenes). Thus, an interesting difference in subsequent memory for low- and high-arousal scenes, previously observed when participants explicitly rated the emotionality of scenes during encoding, is not found under more typical, everyday free-viewing conditions. If so, particular viewing conditions and goals during encoding may alter the information stored in memory representations of low- and high-arousal scenes.

A52

NEURAL CORRELATES OF EMOTIONAL INFLUENCES ON ATTENTION *Jamil Bhanji[1], Jennifer Beer[1]; [1]University of Texas at Austin* – Emotion may influence judgments by directing attention to information that is the same valence as the emotional state experienced by an individual. The current study examines neural activity associated with the mood-congruent influence of emotion on attention. Participants made judgments of ambiguously valenced pictorial compositions of facial expressions after viewing negative or neutral word primes. Each ambiguously valenced composition contained both a 'happy' and an 'angry' facial emotion expression overlayed on top of each other. These stimuli were presented rapidly so that participants only had time to see one of the facial expressions clearly. The participants indicated which emotion they saw in the picture, thus revealing which emotion they preferentially attended to while viewing the picture. Behavioral data showed that participants attended to 'angry' expressions more frequently when the pictures were preceded by negative word primes compared to neutral word primes. Functional Magnetic Resonance Imaging data revealed regional neural activity that was associated with this mood congruent influence of the negative primes on the ambiguous judgments. Activity in ventromedial prefrontal cortex and insular cortex was associated with mood-congruent attention to the ambiguously valenced composition. Discussion focuses on how regional neural activity associated with the word primes may modulate neural activity associated with the subsequent viewing of the ambiguously valenced composition.

A53

SEROTONIN TRANSPORTER GENE VARIATION MODERATES ACTIVITY IN REGIONS INVOLVED IN THE COGNITIVE CONTROL OF EMOTION *Peter C. Clasen[1], Christopher G. Beevers[1], Cristina Benavides[1], John E. McGeary[3,4], David M. Schnyer[1,2]; [1]The University*

of Texas at Austin, [2]Imaging Research Center, The University of Texas at Austin, [3]Research Service, Providence VA Medical Center, [4]Center for Alcohol and Addiction Studies, Brown University – Evidence suggests that genetic variation in the serotonin transporter-linked polymorphic region (5-HTTLPR) is associated with individual differences in the activity of brain regions underlying emotional regulation (Hariri & Holmes, 2006). A common polymorphism of this gene results in long or short alleles and it has been shown that short allele carriers demonstrate hyper-reactive amygdala response to negative faces (e.g. Hariri et al., 2005). However, this evidence relies on tasks that elicit emotional reactivity incidentally. Therefore, it is unclear whether genetic status also moderates activity in regions associated with the conscious regulation of emotion. Using a task where participants actively regulate emotional appraisal (Ochsner et al., 2002), we tested whether 5-HTTLPR variation moderates functional patterns of activation in brain regions previously associated with the cognitive control of emotion. Participants genotyped for the 5-HTTLPR polymorphism (N = 12) were asked to either "decrease" their emotional response to a series of negative pictures or simply "look" at the pictures while undergoing fMRI scanning. Examining activity in lateral prefrontal cortex regions associated with the cognitive control of emotion indicated the expected finding of greater activity when participants were asked to "decrease" their emotional response. Short allele carriers (N = 6) demonstrated higher levels of activity in these regions compared to long allele homozygotes (N = 6). These preliminary findings indicate that genetic variability associated with the serotonin transporter gene alters activity in brain regions associated with the cognitive control of emotion.

A54

EFFECTS OF REGULATION ON POSITIVE AND NEGATIVE EMOTIONS: A STUDY OF ELECTROPHYSIOLOGICAL RESPONSES *Chun-Yu Chen[1], Nai-Shing Yen[1,2], Hsuan-Yu Lin[1]; [1]National Chengchi University, Taipei, Taiwan, [2]Research Center for Mind, Brain, and Learning, National Chengchi University, Taipei, Taiwan* – The aim of the current study is to investigate the effects of emotion regulation on the electrophysiological responses. In the present study, subjects' emotion was elicited by presenting affective pictures (positive, negative, and neutral), and emotion regulation was manipulated by providing instructions (attend, enhance, and reappraisal). In both "enhance" and "reappraisal" conditions, subjects were instructed to imagine the events or images which related to the presenting pictures. In the behavioral results, the subjective valence rating changed differently according to the instructions which delivered to subjects. The facial electromyogram (EMG) showed that the activity of corrugator, which correlates negatively with the valence of the subjects' emotional response, reduced when subjects were instructed to reappraise the emotion after the presenting of negative pictures. For the heart rate data, the heart rate change reduced during 3.5 to 4 second after presenting the instruction under the reappraisal conditions. For skin conductance response (SCR), the differences of SCRs before and after the presenting of the emotion regulation instruction were larger under the reappraisal conditions. Event-related potential (ERP) showed that, at site Pz, the amplitude at 400ms after the instruction was more positive going under the "enhance" condition than under the "attend" condition. In summary, behavioral and electrophysiological data showed different effects of emotion regulation, and the subjective valence rating went with the electrophysiological responses consistently.

A55

WHAT'S LOVE GOT TO DO WITH IT? NEURAL CORRELATES OF LONG-TERM PAIR-BONDING IN HUMANS *Bianca Acevedo[1,3], Arthur Aron[1], Helen Fisher[2], Lucy Brown[3]; [1]State University of New York at Stony Brook, [2]Rutgers University, [3]Albert Einstein College of Medicine* – This study investigated the neural correlates of romantic love among individuals in long-term marriages (> 10 years) using functional magnetic resonance imaging (fMRI; BOLD response). Ten females and seven males (mean ages: 51 and 55 years, respectively) who reported being intensely in love with a long-term spouse (married mean of 21.4 years) underwent fMRI scanning while they viewed headshots of their partner and a highly-familiar neutral person (HFN), interspersed with a distraction-attention task. Group activation specific to the long-term partner compared to the HFN occurred in dopamine-rich mesolimbic areas involved in early-stage romantic love (1-17 mos.; Aron et al., 2005; Bartels & Zeki, 2000) in humans. In addition, consistent with research on monogamous pair-bonding in voles and primates, responses to the long-term partner were displayed in oxytocin and vasopressin-rich regions. Correlations of brain activity with self-report measures of romantic love and passionate love showed significant neural activity in the caudate body and left angular gyrus, replicating findings from previous studies of early-stage romantic love (Aron et al., 2005; Ortigue et al., 2007). Correlating neural activity and marital satisfaction scores displayed significant activations in areas involved in reward processing and decision making; empathy; and social cooperation. We discuss implications of these results and conclude that regions of the mesolimbic reward system—rich in dopamine, oxytocin, and vasopressin—are part of a network that influence the establishment, conservation, and enhancement of pair-bonds in humans.

A56

IS SELF-FACE RECOGNITION SPECIAL? EVIDENCE FROM THE RECOGNITION OF FACIAL EMOTIONS *Yuan Hang Li[1], Shu-wen Wang[1], Eran Zaidel[1,2]; [1]UCLA, Los Angeles, CA , [2]Brain Research Institute, UCLA, Los Angeles, CA* – INTRODUCTION: Is Self-face recognition different from face recognition in general? The majority of faces we see convey emotion, and the neural mechanisms for processing emotions and faces may partly interact. Consequently, we used emotional face stimuli in a face or emotion identification task in normal participants. METHODS: Forty five undergraduates from the University of California at Los Angeles (UCLA) completed two tasks. The tasks were either to judge the identity of the face or the emotion of the face. Stimuli were presented tachistoscopically to the left or right visual hemifield. RESULTS: An Analysis of Variance (ANOVA) of Task (Face, Emotion) x Face Type (Self, Familiar) x Emotion (Happy, Sad) x Visual Field (VF) (Left, Right) showed significant interactions between Face Type and Emotion in accuracy and latency. Participants were significantly faster and more accurate at identifying their friend's sad face compared to their friend's happy face. At the same time, participants were significantly faster at identifying their own happy face compared to their own sad face. This pattern held true for both tasks and VFs. DISCUSSION: This evidence suggests that Self-face recognition differs from general face recognition in the effect of emotional valence on face processing. Furthermore, the recognition of Self-Happy and Familiar-Sad faces in the left VF correlated most strongly with the Sad General Situations subscale of the Social Anxiety Scale for Adolescents (SASA). This suggests one way in which elevated levels of social anxiety influences processing of emotional faces, both self and familiar other, in normal individuals.

A57

ACTIVITY IN MEDIAL PREFRONTAL AND POSTEROMEDIAL CORTICES CORRELATE WITH PSYCHOPATHIC TRAITS: IMPLICATIONS FOR THE RESTING STATE NETWORK *Tong Sheng[1,2], Anahita Gheytanchi[4], Lisa Aziz-Zadeh[2,3]; [1]Neuroscience Graduate Program, University of Southern California, [2]Brain and Creativity Institute, University of Southern California, [3]Division of Occupational Science and Occupational Therapy, University of Southern California, [4]Pacific Graduate School of Psychology* – The medial prefrontal (mPFC) and posteromedial (PMC) cortices have been implicated in a number of studies investigating executive and emotional functions in both healthy and clinical populations. The mPFC is generally considered to be involved in response control while the PMC is commonly associated with self-referential processes. In the current fMRI study, we investigated whether activity in these regions is functionally distinguishable by correlating them with different interpersonal and behavioral factors of psychopathy. Subjects were instructed to either produce or not produce speech depending on a visual cue. During rest conditions as compared to task conditions, activity was

observed in the mPFC and the PMC, in accordance with previous research on the resting state network. We tested the hypothesis that the mPFC and PMC are functionally dissociable by correlating their hemodynamic responses during rest conditions with different scales of the Psychopathic Personality Inventory-Revised. As predicted, we found that activity in the PMC positively correlates with a scale relating to narcissism and social dominance (Machiavellian Egocentricity; ME). Furthermore, mPFC activity correlated positively with a scale relating to spontaneity (Carefree Non-planfulness, CN). These results offer preliminary support for the idea that different components within the resting state network can be functionally dissociated.

A58

IMPAIRED AVERSIVE LEARNING IN NARCOLEPSY WITH CATAPLEXY PATIENTS - A FMRI STUDY *Aurelie Ponz[1], Ramin Khatami[2], Rositsa Poryazova[2], Esther Werth[2], Peter Boesiger[3], Claudio Bassetti[2], Sophie Schwartz[1]; [1]Neurosciences, Center for Neuroscience, University of Geneva, [2]Neurology, University Hospital Zurich, [3]Biomedical Engineering, University of Zurich & Swiss Federal Institute of Technology* – Narcolepsy with cataplexy (NC) is characterized by excessive daytime sleepiness, cataplexy episodes, caused by a deficiency in hypocretin/orexin (HCRT). Recent animal studies suggest that this hypothalamic neuropeptide may also be involved in incentive motivation. Our previous functional MRI findings (fMRI) demonstrated that NC-patients present an abnormal emotional response to positive stimuli within limbic and reward brain circuits. In the present fMRI study, we tested whether the HCRT system plays a general role in regulating emotional learning. We scanned nine unmedicated NC-patients and nine matched controls while they performed a fear conditioning paradigm. Participants saw visual shapes in two different possible colors: one color (CS+) signaled a possible upcoming aversive unconditioned stimulus (US; painful electrical stimulation); another color was never associated with any emotional stimulation (CS-). Our results reveal that both NC-patients and control activated the pain matrix during the presentation of the CS+/US (anterior cingulate, insula, somatosensory cortex, amygdala). However, while controls showed increased activation in the amygdala for the CS+ alone, as expected in this aversive conditioning paradigm, NC-patients did not show any conditioned response in the amygdala. Our new fMRI results thus provide evidence that the HCRT system can affect amygdala activity related to aversive emotional learning. These findings confirm that the Hcrt system is not only involved in sleep-wake regulation, but also in emotion regulation, thus establishing a close connection between both systems.

A59

COORDINATION OF BRAIN ACTIVITY ACROSS MULTIPLE TIMESCALES BY EXCERPTS OF POPULAR MUSIC *Petr Janata[1]; [1]UC Davis, Center for Mind and Brain* – Tonal structure in music unfolds on multiple timescales. Our perception of it is influenced by local contexts generated by transitions from one chord/harmony to the next as well as more global contexts that provide a sense of key. In this study I examined tonality-tracking responses in the whole-brain BOLD data of 13 subjects, each of whom listened to thirty 30 s excerpts of popular music that was largely familiar and/or autobiographically salient to them. The dynamics of the tonal structure were modeled on three timescales that ranged from the moment-to-moment chord changes to the more stable sense of tonal center that might be used for determining whether a piece is in a major or minor key. A region of the dorsal medial prefrontal cortex (MPFC) that was modulated by the overall degree of autobiographical salience of an excerpt exhibited tonality tracking at every timescale. Other brain areas exhibited preferential sensitivity to different timescales in the tonal structure. Posterior temporal and occipital areas exhibited tonality tracking on the fastest time scale, whereas left VLPFC, DLPFC, and ventral MPFC responded preferentially to the slower timescales, with the most ventral excursion of activity in MPFC on the slowest timescale. Given the role of ventral MPFC in emotional regulation, these results are consistent with the idea that the gross tonal characteristics, e.g. the major or minor quality of a piece, shape mood states across tens of seconds. Multiple timescales in music may serve to bind memories, mental images, and emotion into a cohesive experience.

A60

INDEPENDENT INFLUENCES OF PERCEPTUAL LOAD AND EMOTIONAL STIMULI ON THE AMYGDALA AND MOTION AREA V5/MT+ *Catherine Hindi Attar[1,2], Matthias M. Müller[1], Christian Büchel[2], Michael Rose[2]; [1]Institute of Psychology I, University of Leipzig, Leipzig, Germany, [2]University Medical Center Hamburg-Eppendorf, Hamburg, Germany* – There is an ongoing debate over the extent to which selective attention can impede the processing of task-irrelevant emotional stimuli. In this fMRI study subjects had to attend to a display of moving random dots which were superimposed upon happy, fearful or neutral faces. The attentional task required subjects to detect short intervals of coherent motion under two levels of perceptual load. Faces in the background were always task-irrelevant and were not to be attended. For emotional compared to neutral faces we observed a stronger decrease in activation within motion-sensitive area V5/MT+. Likewise, the amygdala showed significantly stronger responses to fearful relative to neutral faces. Most importantly, these emotion effects were independent of the amount of perceptual load associated with the attentional foreground task. A notable finding was that an effect of load was also observed in the amygdalo-hippocampal region which yielded stronger responses to low relative to high load conditions. Since low load conditions were perceptually more salient than high load conditions this might implicate a broader role of the amygdala as salience detector and challenges the widely held view of its fear specificity. To date, these findings demonstrate for the first time that task-irrelevant emotional stimuli receive prioritized processing independently of varying perceptual load demands of the attentional task at hand. This strongly implies that attentional and emotional modulations originate from distinct neural sources and act in parallel upon specific visual processing areas.

A61

EMOTION IMPROVES AND IMPAIRS EARLY VISION *Bruno R. Bocanegra[1], René Zeelenberg[1]; [1]Erasmus University, Rotterdam* – Recent studies indicate that emotion enhances early vision, but the generality of this finding remains unknown. Do the benefits of emotion extend to all basic aspects of vision or are they limited in scope? Our results show that the brief presentation of a fearful face, compared to a neutral face, enhances sensitivity for the orientation of subsequently presented low-spatial-frequency (LSF) stimuli, but diminishes orientation sensitivity for high-spatial-frequency (HSF) stimuli. This is the first demonstration that emotion not only improves but also impairs low-level vision. The selective LSF benefits are consistent with the idea that emotion enhances magnocellular processing. Additionally, we suggest that the HSF deficits are due to inhibitory interactions between magnocellular and parvocellular pathways. Although not predicted by previous data and models, the observed pattern of benefits and deficits shows that the neural mechanisms underlying emotional vision sacrifice the detection of fine visual details for the processing of coarse information. Our results suggest an emotion-induced trade-off in visual processing rather than a general improvement. The magnocellular pathway plays an important role in the perception of motion, depth, direction, global configuration and allows for faster processing than the parvocellular pathway, all of which are potentially important for the detection of threat in the environment. Thus, this trade-off may benefit perceptual dimensions that are relevant for survival at the expense of those that are less relevant.

A62

SELECTIVE ATTENTION MODULATES THE EMOTIONAL EVALUATION OF FACES *Sonia Doallo[1], Jane E. Raymond[2], Monika Kiss[3], Kimron L. Shapiro[2], Martin Eimer[3], John G. Taylor[4], Anna C. Nobre[1]; [1]University of Oxford, [2]University of Wales, Bangor, [3]Birkbeck College, University of London, [4]King's College London* – Recent evidence indicates that attentional selection of stimuli affects their subsequent emotional

evaluation, such that previously unattended stimuli are valued more negatively than previously attended stimuli ("Distractor Devaluation Effect"). In this study, we used event-related functional magnetic resonance (fMRI) to examine the brain activity associated with this emotional devaluation effect. Participants were asked first to perform a Go/No-Go task involving Asian and Caucasian faces, making a motor response to faces of one race (Go), and refraining from responding to faces of the other race (No-Go). In a subsequent evaluation task, a trustworthiness rating for each face was required. A region-of-interest (ROI) approach was used to measure neural activity during the evaluation task in areas involved in the emotional and perceptual processing of faces (i.e. amygdala and fusiform gyrus). Behavioral data showed that previous No-Go faces were rated as less trustworthy than previous Go faces. Functional imaging data revealed increased activity in the right amygdala along with the left fusiform gyrus for low-rated faces relative to high-rated faces. Furthermore, this emotional response in the amygdala was significantly modulated by attention and race, with greater activity to low-rated (versus high-rated) Asian faces when they were previously presented as No-Go stimuli. These findings indicate that attentional selection has consequences for the social-emotional evaluation of faces, in part by modulating the activity in emotion-related areas, and provide additional evidence that other relevant social signals in faces, such as the race, may play an important role in mediating these effects.

A63

ANTICIPATION OF MONETARY AND SOCIAL REWARD DIFFERENTLY ACTIVATES MESOLIMBIC BRAIN STRUCTURES IN MEN AND WOMEN *Lena Rademacher[1], Sören Krach[1,2], Gregor Kohls[3], Arda Irmak[1], Tilo Kircher[1], Kerstin Konrad[3], Gerhard Gründer[1], Katja Spreckelmeyer[1]; [1]RWTH Aachen University, Germany, [2]Central Service Facility, RWTH Aachen University, Germany, [3]Child Neuropsychology Section, RWTH Aachen University, Germany* – Social reward has been identified as a strong incentive for goal-directed behavior. The aim of the present study was to examine if the neural mechanisms underlying the anticipation of monetary rewards would also apply to the anticipation of social feedback in the form of friendly faces. Based on previous findings indicating a linear relation between reward value and striatal activation for monetary rewards, we expected to find a similar relationship for social incentives. Furthermore, gender was introduced as an additional factor, postulating greater sensitivity to social stimuli in women than men. Sixteen male and 16 female participants performed two tasks on a 1.5 Tesla scanner: the "monetary incentive delay" paradigm (Knutson et al., 2000) and an adaptation of the former, termed "social incentive delay" task, replacing monetary by social rewards (smiling faces). In both conditions a cue indicated potential reward. In order to receive reward a target button had to be pushed within a certain time window. fMRI recording during the anticipation phase revealed proportional activation of neural structures constituting the human reward system for increasing levels of reward, independent of incentive type. However, turning our attention to gender effects showed differences in brain activation between male and female participants: in men activation was strong in the prospect of monetary rewards but weak for social rewards, while in women activation level was intermediate, but equally strong for both incentive types. The results suggest a common neural basis but gender-specific activation intensities for the anticipation of monetary and social rewards.

A64

FACIAL EMOTION RECOGNITION DEFICITS IN PARKINSON'S DISEASE ARE NOT MODULATED BY DOPAMINE REPLACEMENT THERAPY *Alison Simioni[1], Lesley Fellows[1]; [1]McGill University, Montreal, Quebec, Canada* – Although the basal ganglia are thought to play a critical role in the ability to recognize emotions from facial expressions, there is little consensus regarding the contribution of dopamine to this ability. There are conflicting data on the effects of Parkinson's disease (PD) on facial emotion recognition, with some studies suggesting deficits in specific emotions, and others reporting intact performance. Differences in disease severity, and medication status, as well as in the sensitivity of the tasks used across studies, may explain this lack of consensus. Here we examined both the effects of PD, and of dopamine replacement therapy, on facial emotion recognition, using a sensitive and well-validated task. Twenty-one non-demented patients with mild-moderate Parkinson's disease were tested twice, once while taking their usual dopamine replacement therapy, and once after an overnight medication washout, and compared to 18 demographically-matched healthy control participants The task featured morphs between an emotionally neutral face and an emotional expression posed by the same individual and asked participants to rate each face on the degree of all 6 cardinal emotions, one at a time. Patients with PD showed selective impairments in the ability to recognize sadness and anger in these subtle morphs. However, dopamine replacement therapy did not modulate the ability to detect any of the emotions studied. These findings support an effect of PD on emotion recognition from faces, at least for certain emotions. However, the lack of effect of the medication manipulation argues that dopamine depletion is not the basis for this deficit.

A65

TRAIT ANXIETY PREDICTS PULVINAR AND AMYGDALA REACTIVITY TO BACKWARD MASKED FEARFUL FACES *Joshua Carlson[1], Tsafrir Greenberg[1], Lilianne Muijica-Parodi[1]; [1]State University of New York at Stony Brook* – Previous research suggests that backward masked fearful faces are processed through a subcortical fear network consisting of the thalamic pulvinar and amygdala. Additionally, there is evidence that anxiety is associated with heightened amygdala reactivity to masked, but not unmasked, fear stimuli in both clinical and nonclinical populations. However, while amygdala reactivity to masked fear appears to be correlated with anxiety, the relationship between anxiety and pulvinar reactivity to masked threat is unknown. Therefore, the aim of the current study was to examine the extent to which trait anxiety predicts pulvinar and amygdala responses to masked and unmasked fearful faces. Participants completed the Trait Anxiety Inventory and an event-related fMRI passive viewing backward masking task. Each trial began with a fixation cue (1000ms) that was immediately followed by an initial face (33ms)-mask face (167ms) pairing. Trial types included fearful-neutral (masked fear), neutral-fearful (unmasked fear), and neutral-neutral. Amygdala and Pulvinar ROIs were created using MARINA. Results revealed that higher levels of trait anxiety coincided with greater subcortical activity in the pulvinar and amygdala during masked, but not unmasked, fearful face processing. Additionally, masked and unmasked fearful faces appear to differentially influence functional connectivity within a broader neural network. The results are consistent with an amygdala-pulvinar network involved in the processing of crude representations of fearful faces and activity in this network is associated with an individual's level of trait anxiety.

A66

THAT'S ONE ANGRY EYEBROW: SEMANTIC PROCESSING OF EMOTIONAL FACIAL EXPRESSIONS IN EMPATHY *Alicia Hofelich[1], Stephanie Preston[1]; [1]The University of Michigan* – Humans are highly attuned to facial emotions, likely because they provide important information about another's internal state. Prior research has shown that people mimic others' facial emotions, even when subliminally presented (Dimberg et al., 2000). This effect is higher for those with high trait empathy (Sonnby-Borgstrom, 2002). People also spontaneously access semantic emotion categories when viewing facial emotions, even when the face is irrelevant to the task (the Emostroop Effect; Preston & Stansfield, 2008). However, it is unknown whether subliminal face perception also activates semantic knowledge, and if the extent of semantic activation is related to trait empathy. To test this, participants who are high versus low on trait empathy were compared on three different emotional Stroop tasks: 1) A supraliminal Emostroop task where congruent and incongruent emotion adjectives were overlaid on facial expressions (replicating the 2008 study), 2) A subliminal Emostroop where emotional faces were

presented for 13ms, then masked by an emotion adjective overlaid on a neutral face, and 3) An intrusive cognitions task (McKenna & Sharma, 1995). Participants were instructed to categorize the emotion adjective into the corresponding basic emotion. The supraliminal task replicated the Emostroop Effect with slowed responses on incongruent trials. Results in all three emotional Stroop tasks suggest that highly empathic participants process emotional adjectives faster than low empathy participants, and may be more affected by subliminal perception of emotional faces. These findings suggest that individual differences in empathy may emanate from differences in the tendency to access semantic information when perceiving other's states.

A67

WHAT? AND HOW GOOD?: DISTINCT NEURAL MECHANISMS ENCODE REWARD AND IDENTITY PREDICTION *Cendri Hutcherson[1], Antonio Rangel[1]; [1]California Institute of Technology* – In order to adaptively respond to its environment, an organism needs to learn which cues are associated with the most reward. A considerable amount of evidence has shown that such learning can be accomplished through the computation of reward prediction errors, which respond to the unexpected delivery or omission of reward, and that BOLD response in the ventral striatum is correlated with this type of signal. However, because the value of a particular outcome can vary with context, organisms need to learn not only stimulus-reward associations (how good?), but also stimulus-outcome associations, in which the organism learns to predict reward indirectly by first representing the identity of an outcome (what?). In most previous learning studies, prediction errors of reward and identity are perfectly correlated, making it impossible to identify their unique or overlapping neural basis. We present the results of a novel experimental setting designed to dissociate the neural representation of these two types of signals using human functional magnetic resonance imaging. Our results suggest that the two learning signals have common and dissociable components in regions of the ventral striatum and orbitofrontal cortex.

Memory: Memory systems

A68

PARIETAL LOBE MEMORY RETRIEVAL MECHANISM: IS THE EPISODIC BUFFER HYPOTHESIS A FEASIBLE ACCOUNT? *Marian E. Berryhill[1, 2], Ingrid R. Olson[1, 2]; [1]Temple University, [2]University of Pennsylvania* – A current question of interest in the memory field is the role of posterior parietal cortex (PPC) in memory. PPC damage does not cause severe memory deficits, yet PPC activations are consistently observed in neuroimaging studies of episodic retrieval. The 'episodic buffer' hypothesis proposes that something analogous to the episodic buffer, whose function is to temporarily maintain and/or manipulate retrieved multisensory, multidimensional information, resides in the inferior parietal lobe (Vilberg & Rugg, 2008). Several of our prior findings can be interpreted as supporting this hypothesis: PPC damage can cause impaired autobiographical free recall (Berryhill et al., 2007) and diminished visual short-term memory (Berryhill et al., 2008). Here, we directly test one prediction of the episodic buffer hypothesis, that PPC damage will impair memory for narratives when tested immediately or after a delay. Two patients with bilateral PPC damage were tested in immediate- and delayed- recall of short narratives. Findings provide partial support for the episodic buffer hypothesis, indicating that this hypothesis has merits but will require modifications to fully account for emerging findings.

A69

IMPROVING THE PERFORMANCE OF PARKINSON'S DISEASE PATIENTS ON A SELECTIVE-ATTENTION-DEMANDING, CATEGORY-LEARNING TASK *Shawn Ell[1], Lacey Favreau[2]; [1]University of Maine, [2]FHC, Inc.* – Numerous studies have demonstrated a category-learning impairment in Parkinson's disease (PD) patients. The most consistent findings have been on selective-attention-demanding, category-learning tasks where patients attempt to learn to categorize based upon a subset of the possible stimulus information. The goal of the present study was to investigate the efficacy of training PD patients on a category learning task with low selective-attention demands on the subsequent performance of a category learning task with high-selective attention demands. Participants were assigned to one of two training conditions that varied in selective-attention demand. In the low selective-attention (LSA) condition, the stimuli varied only along the relevant dimension. In the high selective-attention (HSA) condition, the stimuli also varied along an irrelevant dimension. Following training, all participants completed a categorization test phase using the HSA condition categories. Preliminary data was collected from PD patients in the LSA and HSA conditions, as well as age- and education-matched, healthy control participants in the HSA condition. Consistent with previous work, patients in the HSA condition were impaired relative to controls. The accuracy of PD patients in the LSA condition, but not the HSA condition, was indistinguishable from controls by the end of the test phase. These results suggest that categorization training with low selective-attention demand improves the subsequent performance of PD patients on a categorization task with high selective-attention-demand. Basic research studies such as these are a necessary step in the development of successful interventions that will improve cognitive functioning in PD patients.

A70

AN FMRI EXAMINATION OF THE EFFECTS OF AGING ON MEMORY MONITORING FOR SOURCE AND ITEM RECOGNITION *Jennifer Pacheco[1], Natalie Dailey[1], Maria Olivares[1], Caitlin Tenison[1], David M. Schnyer[1]; [1]The University of Texas at Austin* – Evidence has shown that memory monitoring in older adults is impaired in a domain-specific manner. The neural activity associated with memory monitoring ability was assessed in a group of older adults (61-74 years old) and younger adults (20-30 years old) using retrieval confidence ratings in an item and source recognition memory fMRI paradigm. Participants were shown a series of sentences read aloud by a male or female speaker and their memory for both the sentence and speaker was tested; participants also reported ratings of 'certain' or 'probable'. Both young and older adults showed highly accurate item recognition performance as well as accurately calibrated monitoring assessments - higher accuracy rates for those items rated 'certain' verses 'probable'. Performance for source memory was lower than item memory for both groups, significantly worse for older adults compared to younger adults. Younger adults maintained calibrated source monitoring ratings but elderly subjects demonstrated significantly less accurate source memory monitoring. Functional MRI images collected during the test phase of the experiment were analyzed using standard methods in FSL. Bilateral medial temporal lobe, right frontal, and left parietal activation is seen in the younger adults for accurate 'certain' responses when compared to inaccurate 'certain' responses; dissociable frontal activation is seen for accurate versus inaccurate 'probable' responses, with less significant MTL activation. These results suggests a network of frontal and MTL regions that contribute to the accuracy of source memory monitoring in young adults, we expect to be able to uncover differences in this network for older adults.

A71

THE DEVELOPMENT OF BRAIN SYSTEMS FOR EPISODIC MEMORY RETRIEVAL *Noa Ofen[1], Xiaoqian J. Chai[1], John D.E. Gabrieli[1]; [1]Brain and Cognitive Sciences, MIT, Cambridge, MA* – Multiple brain regions are involved in episodic memory retrieval in adults, but the brain regions that support episodic memory retrieval in children have not been

identified. This study investigated the development of brain regions involved in episodic memory retrieval. Participants (age range 8-24, n = 73) studied 140 pictures of indoor and outdoor scenes and then were given a recognition test while being scanned with 3T MRI scanner. Participants made old/new decisions for the previously studied pictures and 140 new pictures. Participants correctly recognized 0.52 ±0.14 of the studied pictures (Hit rate, mean ±SD) and correctly gave a 'new' response to 0.75 ±0.12 of the new pictures (CR rate). Recognition accuracy (Hit + CR) increased with age ($r = 0.50$, $p < 0.001$). Frontal, parietal and temporal cortical regions and medial temporal lobe (MTL) and basal ganglia regions were active for successful retrieval (Hits > CR). Within these regions activations associated with successful retrieval increased with age in left lateral parietal cortex (BA 7/40), left dorsolateral prefrontal cortex (PFC) (BA 8/9), left ventrolateral PFC (BA 46), bilateral inferior frontal gyri (BA 47) and basal ganglia. Activation for both Hits and CR decreased with age in regions of the MTL, but, these age dependent reductions in activation were not selective to successful memory retrieval. These results suggest that with age, frontal, parietal and basal ganglia regions are progressively recruited to reach adult-like pattern of brain activation during episodic memory retrieval. Age-related changes in MTL activation during episodic memory retrieval may however, be independent of successful memory retrieval.

A72

NEURAL CORRELATES OF EMOTIONAL AROUSAL AND SEMANTIC PROCESSING DURING MEMORY FORMATION: A LEVELS-OF-PROCESSING APPROACH *Maureen Ritchey[1,2], Sheldon Rudisill[1], Kevin S. LaBar[1,2], Roberto Cabeza[1,2]; [1]Center for Cognitive Neuroscience, Duke University, [2]Duke University* – Results from the animal and human literatures have highlighted the amygdala and its interaction with the MTL memory system as supporting improved consolidation for emotional memories. However, behavioral and neuroimaging results in humans have also implicated emotion-driven enhancements during encoding as predicting improvements in subsequent memory. In particular, it has been proposed that emotional stimuli are subject to deeper semantic processing during encoding, evidenced by the presence of greater memory-related activity in the left inferior prefrontal cortex (LIPC), a region frequently associated with semantic processing, during emotional relative to neutral memory encoding. This hypothesis, however, has not yet been explicitly tested. In the present study, participants were scanned using fMRI while encoding emotional and neutral images. Half were encoded with a semantic description task and half with a non-semantic perceptual feature task. Behavioral results indicate an interaction between emotion and task: the enhancement of emotional over neutral memory was strongest for items encoded in the non-semantic task. Neuroimaging results likewise suggest that the amygdala best distinguishes between remembered and forgotten emotional items in the non-semantic condition. Although the LIPC is overall more activated during semantic encoding, it similarly distinguishes memory best in the non-semantic condition. These results support the hypotheses that amygdala engagement benefits emotional memory most when encoding resources are diminished, and that under these circumstances, emotional items may also benefit from incidental semantic encoding. These mechanisms thereby serve to protect emotionally arousing items from the mnemonic consequences of shallow encoding.

A73

REWARD MODULATION OF MEDIAL TEMPORAL LOBE SUBREGIONS DURING ASSOCIATIVE ENCODING AND CUED RECALL *Sasha M. Wolosin[1,2], Dagmar Zeithamova[1,2], Nicolaus T. Schmandt[1,2], Alison R. Preston[1,2]; [1]The University of Texas at Austin, TX, [2]Center for Learning and Memory, The University of Texas at Austin, Austin, TX* – The medial temporal lobe (MTL) is critical for episodic memoryómemory for individual events. Emerging data suggest that MTL processing is modulated by midbrain regions under conditions of reward resulting in enhanced episodic encoding. Current theories further suggest that MTL subregional function may be differentially influenced by midbrain inputs that signal reward. Using high-resolution fMRI, the present study characterized MTL subregion function during associative encoding under reward as well as reward-related effects on later cued recall performance. During associative encoding, high- and low-value monetary cues preceded paired associates indicating potential reward for successful retrieval. At test, participants performed cued recall followed by match (correct association) or mismatch (incorrect association) probe decisions and received feedback on their performance. Behaviorally, cued recall performance was superior for pairs preceded by high reward cues at encoding relative to pairs preceded by low reward cues. Initial analyses revealed successful memory formation associated with activation in hippocampus, perirhinal cortex, and midbrain regions that was modulated by reward with greater subsequent memory effects observed for high relative to low reward pairs. Successful memory retrieval during cued recall was further modulated by reward status where correct relative to incorrect retrieval was greater for high relative to low reward pairs in hippocampal and perirhinal regions. Moreover, hippocampal and midbrain activation differentiating associative novelty at probe (mismatch vs. match) was greater for high relative to low reward pairs. These findings suggest that motivation during learning affects MTL-based memory formation as well as later retrieval processes through interactions with midbrain regions.

A74

SYSTEMS CONSOLIDATION OF LONG-TERM REAL-LIFE-LIKE MEMORY: A FUNCTIONAL NEUROIMAGING STUDY *Orit Furman[1], Yadin Dudai[1]; [1]Weizmann Institute of Science, Rehovot, Israel* – Systems consolidation is a hypothetical slow process of reorganization whereby memory storage and retrieval come to rely on different brain systems with the passage of time. Of particular relevance is the relationship between declarative memory retrieval and the involvement of medial temporal lobe (MTL) over time. The present study aims to characterize systems consolidation of declarative memory, using a novel movie-memory paradigm we recently devised for the study of long-term and remote memory under real-life-like conditions (Furman et al., Learning & Memory 14, 457, 2007; Hasson et al., Neuron, 57, 452, 2008). A 27-min documentary movie (created in-house specifically for memory research) was the memoranda, and a computerized questionnaire was used to assess recall and recognition of events sampled every ~20 sec of the movie. Metamemory was also assessed. Three groups of subjects were scanned in a 3T MRI scanner during both movie viewing and memory testing, allowing comparison of neural activity during retrieval at three different study-test intervals: 3 hours (N=13), 3 weeks (N=15) and 3 months (N=14). Participants in a control group (N=13) completed the questionnaire without viewing the movie. While involvement of a distributed neural network remained similar over time, MTL activation during recognition was significant only when memory was recent (3 hours, 3 weeks) but not remote (3 months). During recall tasks, which involved instructions to imagine movie episodes, MTL activation was significant in all groups, including control, suggesting this area's time-independent involvement in re-experiencing or mental imagery of complex events.

A75

UTILIZATION OF CONTEXTUALLY GENERATED EXPECTATIONS *Elissa Aminoff[1], Michael Miller[1]; [1]University of California Santa Barbara* – Repeated exposure to typical environments (e.g., restaurant) allows one to generate expectations about objects likely to be encountered in that context (e.g., a menu). This can be advantageous to subsequent cognition, e.g., faster at recognizing related objects (Biederman et al., 1982); but can also lead to subsequent cognitive errors, e.g., false recognition of related objects (Aminoff et al., in press). Is it possible to control the use of contextually generated expectations? The current experiment tests this by having participants name two sequentially presented objects. The objects were either contextually related (e.g., cow and tractor), or contextually unrelated (e.g., bed and acorn). On each trial,

a cue indicated how likely the second object was related to the first: highly likely (70%), or unlikely (30%). Using the cue, we expected participants to modulate how much they utilized contextually relevant expectations. Behavioral results indicate that when objects were contextually related, participants were significantly faster at naming the second object if it was cued to be highly likely related to the first object compared to when the second object was most likely unrelated to the first object. Furthermore, in the unlikely cued condition, participants were significantly slower at naming a related object compared to naming an unrelated object. Although this trend was significant in the group, variability revealed individual differences in the control and use of contextual expectations. What these results reveal about the mechanism underlying contextual processing, and how neural activity sensitive to contextual associations can predict these results, will be discussed.

A76

SYMPATHETIC AND PARASYMPATHETIC EFFECTS ON COGNITIVE PERFORMANCE *Shannon McCoy[1], Brandon Cosley[1], Shawn Ell[1]; [1]University of Maine* – Recent research in cognitive neuroscience has shown that social pressure may enhance performance on certain cognitive tasks (Markman et al., 2006). One reason social pressure may lead to differences in cognitive performance may be linked to its effects on physiological arousal or stress. When the body responds to psychosocial stressors the primary system that leads to increases in arousal is the sympathetic nervous system. Conversely, the parasympathetic nervous system acts to attenuate the arousing effects of the sympathetic system helping the body return to homeostasis. Drawing on this research, we hypothesized that when the sympathetic nervous system is aroused explicit reasoning processes are impaired. In contrast, the inhibitory effects of increases in parasympathetic activation are predicted to help restore explicit reasoning. In order to assess these differential effects of the two branches of the autonomic system on cognitive performance, participants performed an information-integration category learning task and a uni-dimensional task following a 20 minute social stressor (i.e. TSST; Krishbaum et al., 1993). In information-integration tasks, optimal performance requires the integration of information from two or more stimulus dimensions, and is not highly dependent upon explicit reasoning. In uni-dimensional tasks, optimal performance requires hypothesis testing strategies to determine the dimension of categorization. As predicted, the more participants experienced sympathetic arousal the better their performance on the information integration task. Conversely, greater influence of the parasympathetic system was found to be positively related performance on the uni-dimensional task.

A77

LEARNING MORE, KNOWING LESS: REPETITION MODULATES MEDIAL TEMPORAL LOBE AND BASAL GANGLIA CONTRIBUTIONS TO LEARNING AND GENERALIZATION *Nathaniel Clement[1], Karin Foerde[1], Daphna Shohamy[1]; [1]Columbia University* – Studies of the neural bases of learning and memory suggest that the medial temporal lobe (MTL) and basal ganglia support distinct memory systems. The MTL supports rapid learning and creates flexible memories that can be easily generalized, while the basal ganglia support gradual learning of inflexible stimulus-response associations that do not generalize. This predicts that extended learning experience may lead to knowledge that is less generalizable. The goal of this study was to test this prediction by examining how experience during learning impacts generalization. We used functional imaging (fMRI) to examine MTL and basal ganglia activity while subjects engaged in a two-phase learning and transfer task. Subjects engaged in feedback-based learning of associations that repeated either many times (high-repetition condition) or few times (low-repetition condition). Next, subjects were asked to generalize their learned knowledge to novel stimulus combinations. We predicted that fewer repetitions would permit greater generalization. Results indicated that learning of trained associations was similar for both conditions, but generalization was greater for the low-repetition condition. FMRI data revealed that MTL regions showed greater activation to low-repetition stimuli during learning than to the high-repetition stimuli; furthermore, the magnitude of that difference was related to better generalization for the low-repetition condition. The basal ganglia showed decreased activation over learning, across both conditions. These findings are consistent with the idea that the basal ganglia support iterative learning while the MTL supports the generalization of learned associations, and suggest that interactions between these systems over learning have implications for subsequent representations.

A78

NEUROPHYSIOLOGICAL EVIDENCE THAT EXEMPLAR-SPECIFIC REPRESENTATIONS SUPPORT VISUAL OBJECT CATEGORIZATION AND IMPLICIT MEMORY AFTER 200 MS *Stephen Maher[1], Haline Schendan[1]; [1]Tufts University* – The timing and format of visual knowledge representations supporting object categorization are largely unknown. Previous event-related potential (ERP) research indicates that visual object representations that are view- but not contour-specific are activated between 200 and 400 ms, indexed by a frontopolar N350, and support object model selection from a perceptual representation system in occipitotemporal cortex to enable a category decision. This experiment investigated whether these and later representations are specific to the particular exemplar of a basic level category experienced and vary with exemplar typicality (e.g., cell vs. rotary phone). People categorized objects during an indirect memory test in a 3 study (same or different exemplars of repeated categories, new category) x 2 typicality (high, low) design. Repetition effects showed that, regardless of typicality, knowledge underlying the N350, as well as a later parietal P600 implicated in post-model selection processes, was specific for the same exemplar. A centrofrontal FN400, implicated in conceptual implicit memory with some perceptual information, demonstrated perceptual specificity but also generalization to different exemplars. These findings support and extend a two-state interactive account of visual object knowledge and multiple memory systems theories. After 200 ms, a perceptual representation system for model selection during the N350 also stores perceptual implicit memory, coding each view of a category exemplar. Afterwards, conceptual knowledge representations shared by multiple exemplars and implicated in conceptual implicit memory are activated during the FN400. Finally, memory during the P600 is highly specific for the local contours in a specific view of a category exemplar.

A79

FUNCTIONAL CONNECTIVITY OF IMPLICIT PROBABILISTIC SEQUENCE LEARNING IN AGING *Jessica R. Simon[1], Eric R. Murphy[1], Chandan J. Vaidya[1,2], James H. Howard Jr.[1,3], Darlene V. Howard[1]; [1]Georgetown University, [2]Children's Research Institute, Children's National Medical Center, [3]Catholic University of America* – Implicit sequence learning, an acquired sensitivity to regularities without explicit awareness, requires a high level of functional integration among underlying neural networks. We used functional Magnetic Resonance Imaging (fMRI) to identify age differences in functional connectivity, i.e. temporal correlation between distinct brain regions, during an implicit probabilistic sequencing task. fMRI is increasingly being used to study functional connectivity, but this analysis has rarely been applied to study aging. Over 3 fMRI runs, 11 young and 12 healthy old adults viewed a series of three sequential stimuli: 2 cues and 1 target. Participants responded to only the target stimulus using a corresponding button. Unbeknownst to them, the first cue's location predicted one target location for most trials (High Probability) and another location for the rest (Low Probability). Both age groups demonstrated learning (e.g. faster responses to High vs. Low Probability trials). To investigate age differences in functional connectivity as modulated by cognitive events, we conducted a voxel-based correlation analysis. Given the striatum's importance in processing sequential and probabilistic information, we used the peak caudate voxel in each subject as a seed for psychophysiological interaction analysis and performed a brain-wide search for voxels where BOLD covaried signifi-

cantly with this interaction term. Learning was supported by different patterns of functional integration in young and old adults; for example, in Run 3, caudate connectivity was greater with the putamen and cerebellum for the young but the hippocampus in the old. These findings may reflect age-related compensation and/or changes in white-matter integrity.

A80

AN FMRI STUDY OF ITEM, ASSOCIATIVE, AND INTEGRATIVE EPISODIC MEMORY PROCESSING *Scott M. Hayes[1,2], James Kragel[1,2], Roberto Cabeza[1,2]; [1]Center for Cognitive Neuroscience, Duke University, Durham, NC, [2]Duke University, Durham, NC* – Regions within both prefrontal cortex (PFC) and the medial temporal lobes (MTL) are thought make distinct contributions to item and associative memory. According to some dual-process models of memory, forming associations between distinct items relies on the hippocampus, whereas item memory is thought to be mediated by rhinal cortex. More recently, it has been suggested that perirhinal cortex processes item details and that it may play a critical role in processing integrated or unitized stimuli. To examine this issue, we collected whole-brain fMRI data during encoding and retrieval of abstract figures. Participants studied monochromatic abstract figures (Item condition), multi-chromatic abstract figures (Integrative condition), or pairs of monochromatic abstract figures (Associative condition). At test, participants made old/new recognition judgments using a four-point confidence scale (definitely old, probably old, probably new, definitely new). Results of fMRI analyses revealed bilateral prefrontal cortex activation during both Associative and Integrative retrieval relative to the Item recognition. Within the medial temporal lobes, preferential activation was observed in the hippocampus during Associative retrieval relative to the Integrative and Item conditions. Overall, these data are consistent with the idea that different PFC and MTL regions contribute to item and associative memory.

A81

TOP-DOWN MODULATION OF MEDIAL TEMPORAL ACTIVITY DURING EPISODIC RETRIEVAL *Norbou Buchler[1], Ian Dobbins[2], Roberto Cabeza[1]; [1]Center for Cognitive Neuroscience, Duke University, [2]Washington University in St. Louis* – It is generally assumed that medial temporal lobe (MTL) activity during episodic retrieval reflects the recovery of memory traces, and hence, it is mainly driven bottom-up by the recovered memories. However, MTL activity could also reflect the intention to remember, and be partly driven top-down by memory control processes mediated by the prefrontal cortex (PFC). To investigate these issues we conducted an fMRI study in which we manipulated top-down processes by varying intention to remember, and bottom-up processes, by varying stimulus oldness. While in the scanner, previously studied words and new words were presented in an incidental non-memory or an intentional memory task. Our design first examined the patterns of MTL and PFC activity that are elicited automatically in a non-memory lexical decision task, and then examined the patterns of activity associated with intentional uses of memory, such as recognizing old and new words, and also the retrieval of more specific source information. Our data demonstrated bottom-up influences in the non-memory task, that MTL activity can be elicited automatically, independently of whether there is intention-to-retrieve. Top-down influences were observed across types-of-tasks for intentional remembering and were associated with greater PFC and MTL activity. Pure top-down influences were observed by varying instructional emphasis on recognizing new or recognizing old words, resulting in greater PFC and MTL activity to new or old stimuli, respectively. The finding that MTL activity can be modulated top-down by retrieval intentions indicates that MTL activations cannot be simply attributed to memory recovery.

A82

VALUE GENERALIZATION IN CONDITIONING: BRAIN MECHANISMS SUPPORTING HUMAN SENSORY PRE-CONDITIONING WITH MONETARY REINFORCEMENT *G. Elliott Wimmer[1], Michael Szeto[1], Daphna Shohamy[1]; [1]Columbia University* – When pairs of stimuli are related through coinciding experiences - say, a new couple that one has become acquainted with - how does learning new value information about one pair member impact the value of the other? This value generalization effect, referred to as sensory preconditioning, has been known experimentally since the early days of conditioning research. However, the neural and cognitive mechanisms supporting sensory preconditioning remain largely unknown. Guided by recent animal research, we hypothesized that sensory preconditioning may depend on multiple cognitive processes and neural systems: the dopamine-innervated basal ganglia may support initial value learning, while the medial temporal lobe may be necessary for successful generalization of value. To test this hypothesis, we used fMRI and a newly developed monetary reinforcement sensory preconditioning paradigm. In the task, stimuli are first incidentally paired (with no reinforcement). Then, one stimulus from each pair is used as a predictor of monetary reinforcement (gain, loss, or null outcome). Behavioral results show that the primary conditioning procedure was effective, as evidenced by significant changes in stimulus liking ratings and strong post-conditioning forced-choice preference for the reward-predicting stimulus over the punishment-predicting stimulus. Importantly, this acquired value also transferred to the paired stimuli that were never conditioned, and thus had no reward history of their own. Functional magnetic resonance imaging analyses provide insight into the neural substrates underlying successful value generalization in sensory preconditioning, with particularly important roles for the basal ganglia in value prediction and for the medial temporal lobe in generalization.

A83

PARIETAL CORTEX TRACKS THE AMOUNT OF INFORMATION RETRIEVED FROM MEMORY EVEN WHEN IT IS NOT THE BASIS OF A MEMORY DECISION *Scott Guerin[1], Amy Frithsen[1], Michael Miller[1]; [1]University of California, Santa Barbara* – A growing number of fMRI studies are raising the prospect that the parietal cortex may play a role in memory. In recognition memory studies, regions of the parietal cortex appear to track the amount of information retrieved from memory and the participant's subjective impression that an item is old. Since parietal cortex tracks the subjective impression that an item is old, it may be encoding the decision variable that determines the outcome of the decision process: if activity in this region exceeds a certain threshold, the participant responds "old"; otherwise, the participant responds "new". We used a frequency discrimination paradigm to dissociate the amount of information retrieved from memory and the decision variable. In this task, the participant studies a series of stimuli that repeat a variable number of times. Then, in the memory test, the participant is presented with two items, one of which was presented more frequently than the other during the study session. The participant's task is to choose the stimulus that was presented more frequently. In yes/no recognition, the decision is based on the absolute amount of information retrieved. In frequency discrimination, the decision is based on the relative amount of information retrieved. Nonetheless, we observed that activation in the angular gyrus and precuneus tracked the absolute amount of information retrieved, even when it was not the basis of the participant's decision. This suggests that parietal cortex does not encode the decision variable that underlies recognition decisions.

A84

EPISODIC MEMORY FOR FEEDBACK EVENTS DURING PROBABILISTIC LEARNING *Karin Foerde[1], Nathan Clement[1], Daphna Shohamy[1]; [1]Columbia University* – Multiple systems in the brain support learning and memory. Feedback-based, incremental learning of stimulus-response associations is supported by the basal ganglia. A distinct mem-

ory system supports rapidly formed memories of single-trial episodes and depends on the medial temporal lobes. The present study tested the hypothesis that a critical factor driving learning to depend on one system or the other is the timing of response-contingent feedback. To test this prediction, participants underwent functional imaging (fMRI) while engaged in a feedback-based probabilistic learning task that included a trial-by-trial measure of episodic memory. Participants learned to associate abstract symbols with a category outcome, using trial-by-error feedback that was delivered either immediately, or after a 3 or 6 second delay. The feedback was provided in the form of trial-unique scene photographs. Outside the scanner participants were given a surprise memory test: they classified all the encountered feedback images and an equal number of novel images according to whether they had seen them during scanning or not, and additionally indicated their confidence in the decision. Subjects performed the learning task equally well after learning with varying feedback delays. However, subsequent memory performance was impacted by the timing of the feedback: longer delays during learning resulted in enhanced subsequent memory of the feedback events, in particular for negative feedback. During learning, greater activity was seen in the parahippocampal gyrus for negative compared to positive feedback events. These results suggest that the timing of response-contingent feedback during learning affects the systems that support learning and memory.

A85

DIFFERENCES IN BRAIN ACTIVITY DURING ENCODING AND RETRIEVAL OF WORDS AS A FUNCTION OF STRATEGY, COGNITIVE STYLE, AND STRUCTURAL CONNECTIVITY

Danielle R. King[1], Christa-Lynn Donovan[1], Michael B. Miller[1]; [1]University of California, Santa Barbara – Episodic memory is by nature an unconstrained and strategic task. There has been little investigation of how mnemonic strategies used spontaneously by learners relate to brain activity patterns in episodic memory tasks. To test whether different strategies engage different networks, 20 subjects were scanned during intentional encoding and retrieval of highly imageable words. Subjects completed a visualizer/verbalizer test battery, from which visual and verbal factor scores were computed to reflect the subject's tendency to process information visually/verbally. Subjects also reported their encoding strategy, which was subsequently classified as "visual" or "verbal." Subjects were then subdivided into groups based on their reported strategy. A two-sample t-test was conducted to identify regions differentially active between groups. This identified several right-lateralized regions in the prefrontal and temporal cortices, and a left-lateralized region in the precuneus. Regions of interest (ROIs) were then defined functionally using clusters identified in the 2-sample t-tests. To test whether the laterality of these activations was associated with differences in connectivity across the corpus callosum (CC), mean fractional anisotropy (FA) values were computed in each subject for the anterior CC, which connects the prefrontal regions, and the posterior CC, which connects temporal/parietal areas. A correlation analysis assessed the relationships between mean FAs, activity in the ROIs, reported strategy and visual and verbal factor scores. Results show that differences in strategy and cognitive style are associated with different functional activity during encoding and retrieval and that these differences may be related to the structural connectivity of the individuals' brain.

A86

INDIVIDUAL VARIABILITY IN BRAIN ACTIVITY DURING EPISODIC ENCODING AND RETRIEVAL: WITHIN- AND BETWEEN-SUBJECTS VARIABILITY OVER THE COURSE OF ONE YEAR

Christa-Lynn Donovan[1], Meghan Roarty[1], Michael B. Miller[1]; [1]University of California, Santa Barbara – We have previously shown extensive individual variability in brain activity during episodic retrieval. The purpose of this study was to compare sources of within- and between-subject variability during encoding and retrieval. Of particular interest was to what degree variability in brain activity was related to differences in mnemonic strategy and further, how does this compare to variability related to differences in anatomy, physiology and other sources of individual differences? Twelve participants were scanned with functional MRI while they intentionally encoded lists of highly and lowly imageable words and completed subsequent recognition memory tests. After scanning, subjects were asked to report their strategy, and to complete a Visualizer-Verbalizer test battery and personality questionnaire. Subjects returned 4 more times within one year. Each time, they performed the same tasks (with new stimuli). Our results show how between-subjects variability relates to differences in brain anatomy, connectivity, coherence of the default network at rest, reported mnemonic strategy, memory performance, visualizing/verbalizing trait and personality. Further, it's shown that within-subjects variability is predicted by changes in mnemonic strategy over time. Our results demonstrate that individuals can recruit widely dispersed brain regions during an episodic memory task, that individuals patterns of activity are relatively stable over time and that interindividual differences in activity patterns are related to a number of factors including anatomical features of the individual's brain, the individual's unique mnemonic strategy as well as trait factors such as visualizing/verbalizing ability and personality.

A87

THE HUMAN HIPPOCAMPUS AND RECOGNITION MEMORY: EVIDENCE FROM YES/NO TESTS AND FORCED-CHOICE TESTS WITH EITHER CORRESPONDING OR NON-CORRESPONDING LURES

Annette Jeneson[1], C. Brock Kirwan[1], John T. Wixted[1], Larry R. Squire[1,2]; [1]University of California, San Diego, La Jolla, [2]VA Healthcare System, San Diego – The hippocampus has been proposed to support both recollection and familiarity. Alternatively, it has been suggested that the hippocampus selectively supports recollection and that adjacent cortex can support familiarity. The latter view has led to two suggestions: (a) both recollection and familiarity are involved in yes/no recognition but familiarity can support forced-choice recognition, at least when the targets and lures are quite similar; and (b) familiarity is better able to support good recognition performance when targets are presented with highly similar lures (termed corresponding lures) than when targets are presented together with lures that are similar to other targets (termed non-corresponding lures). By this view, patients with hippocampal lesions should exhibit a greater impairment in yes/no recognition than in forced-choice recognition tests that use corresponding lures. Second, patients with hippocampal lesions should benefit more from a forced-choice test that uses corresponding lures than from a forced-choice test that uses non-corresponding lures. We administered yes/no, forced-choice corresponding, and forced-choice non-corresponding tests to five memory-impaired patients with circumscribed hippocampal lesions and 14 controls. In recognition tests of photographs of objects as well as in recognition tests of silhouette images, hippocampal lesions impaired performance on all three tests (yes/no, forced-choice corresponding, and forced-choice non-corresponding). For silhouettes, the pattern of performance across the three tests was similar in patients and controls. For objects, patients tended to perform better on the forced-choice corresponding test than on the other tests, though this effect depended largely on the performance of a single patient.

A88

OSCILLATORY CORRELATES OF EPISODIC RETRIEVAL DURING ITEM AND SOURCE MEMORY CONFIDENCE JUDGMENTS

Andrew J Watrous[1], Richard J Addante[1], Andrew P Yonelinas[1,2], Charan Ranganath[1,2]; [1]Neuroscience Graduate Group, University of California-Davis, [2]University of California-Davis – A significant question regarding episodic memory is whether recollection and familiarity are unique, qualitatively distinct processes, or if they reflect a single process along a graded strength continuum. In accord with the dual process account, some findings from event-related potential studies indicate that recollection and familiarity may have dissociable neural correlates. However, much less is known about the oscillatory correlates of episodic memory. For example,

in both animals and humans, theta oscillations arising from the hippocampus have been implicated in memory processes, but the exact role of theta oscillations in episodic memory processing remains controversial. We sought to further characterize this relationship by recording scalp electroencephalography (EEG) data during encoding and retrieval of verbal material. During encoding, participants made animacy or pleasantness judgments. During each retrieval test, studied and unstudied words were presented and participants made confidence judgments as to whether the item was previously studied and as to which task was performed with each item. We have employed time-frequency analysis techniques to elucidate which frequency bands are associated with episodic memory processes. Initial analyses of data during the retrieval phase show that power in the theta band was modulated by successful recognition of studied items. Further analyses will characterize and compare oscillatory correlates of recollection and familiarity during retrieval.

A89

ERP CORRELATES OF RECOLLECTION AND FAMILIARITY: ITEM AND SOURCE MEMORY CONFIDENCE *Richard James Addante[1,2], Andrew P. Yonelinas[1,2,3], Charan Ranganath[1,2,3]; [1]University of California - Davis, [2]Center for Neuroscience, [3]Center for Mind and Brain* – Memory judgments can be based either on recollection of qualitative information about a previous event or on rapid assessments of stimulus familiarity. Evidence for this 'dual process' view is quite extensive, but a major competing 'single process' account is that recollection simply reflects stronger memory traces than familiarity. We used a novel item and source recognition confidence method to provide behavioral measures of recollection and familiarity that overcomes several limitations associated with prior procedures, and recorded Event-related potentials (ERPs) during retrieval. Subjects studied words under conditions of pleasantness or animacy judgments, then made item recognition and source recognition confidence judgments at test. Event-related potentials (ERPs) during retrieval revealed two different effects that differentiated between old and new items: an early mid-frontal negativity, and a later onsetting, parietally-distributed effect. Examination of the data as functions of both item and source memory judgments indicated that the mid-frontal effect was correlated with familiarity, whereas the parietal effect was correlated with recollection. Moreover, the results from the item confidence analysis and the source contrasts provided convergent results. The parametric confidence approach used reveals a number of further findings that would not have been apparent using standard methods for both item recognition and source monitoring. The results support dual process models of recognition memory and additionally show the utility of acquiring continuous measures of memory confidence in neuromonitoring studies.

A90

NEURAL CHANGES DURING THE DEVELOPMENT OF AUTOMATICITY IN PERCEPTUAL CATEGORIZATION *Jennifer G. Waldschmidt[1], Jessica Roeder[1], Maria Schellenberger[1], F. Gregory Ashby[1]; [1]University of California, Santa Barbara* – This study used fMRI to examine changes in neural activation that accompanied the development of automaticity in a difficult perceptual categorization task. Each participant completed 20 sessions of training in an information-integration categorization task (approximately 12,000 trials). Sessions 2, 4, 10, and 20 were completed inside the scanner. Stimuli were circular sine-wave gratings, each category had hundreds of exemplars, and category membership was determined by a rule that required integrating perceptual information about bar width and bar orientation in a way that could not be described verbally. At the behavioral level, accuracy gradually increased to near perfect levels and response times decreased to a low nearly constant value. Both results are classic markers of automaticity. The fMRI data generally supported a recent computational model called SPEED (Subcortical Pathways Enable Expertise Development; Ashby, Ennis, & Spiering, 2007, Psychological Review), which assumes that the development of automaticity is mediated by a transfer of control from a subcortical pathway through the basal ganglia to a faster purely cortical pathway from sensory association cortex to the relevant areas of premotor and motor cortex.

A91

UNIQUE NEURAL CORRELATES OF AUTOBIOGRAPHICAL MEMORY AND THEORY OF MIND *Jennifer S. Rabin[1], Donald T. Stuss[2,3], Asaf Gilboa[4], Raymond A. Mar[1], R. Shayna Rosenbaum[1,2]; [1]York University, Toronto, Canada, [2]Rotman Research Institute, Baycrest, Toronto, Canada, [3]University of Toronto, Neurology, Rehabilitation Sciences, Canada, [4]University of Haifa, Mount Carmel, Israel* – Neuroimaging studies report a common network of brain regions involved in thinking about one's own past experiences during autobiographical memory (AM) and other people's current experiences during theory of mind (ToM). However, lesion data show that amnesics have intact ToM, suggesting that distinct neural mechanisms support the two abilities. This study examined the brain regions and processes involved in imagining one's own and other people's experiences using a real-world 'family photos' test. Participants were scanned with fMRI as they recollected past events in response to personal photos ('AM' condition) and generated possible events in response to strangers' photos ('ToM' condition). Content and vividness were matched across the AM and ToM photos. Analyses revealed a common network of brain regions, including bilateral medial prefrontal cortex (mPFC), inferior frontal gyrus, medial temporal lobes (hippocampus, parahippocampus), posterior cingulate/retrosplenial cortex, temporal poles, and middle temporal gyrus. However, activity within the entire network was greater during AM except for left inferior frontal gyrus, which was greater during ToM. More specific analyses of event construction and elaboration revealed greater mPFC and hippocampal activation during elaboration for both conditions, although the precise location of activity within these regions differed across conditions. Moreover, right temporal-parietal junction (rTPJ) activation was unique to ToM during event elaboration. These data suggest that differences in AM and ToM emerge when vividness is taken into account, particularly during event elaboration. Furthermore, mPFC and rTPJ, but not the hippocampus, may be needed for ToM, given that this ability is intact in amnesics.

A92

PREFRONTAL ACTIVATION DURING SUCESSFUL ENCODING OF TASK-RELEVANT AND IRRELEVANT INFORMATION *Andrew Heusser[1], Francis Richter[1], Ian Ramsay[2], Dan Ragland[1,2], Cameron Carter[1,2], Charan Ranganath[1,2]; [1]Center for Neuroscience, University of California- Davis, [2]Imaging Research Center, University of California-Davis* – Regions in the lateral prefrontal cortex are critical for working memory control processes that support selection of goal-relevant information. Activity in the ventrolateral prefrontal cortex (VLPFC) has been reliably linked with successful long-term memory encoding, but the role of the dorsolateral prefrontal cortex (DLPFC) in encoding is unclear. Some research suggests that DLPFC may represent abstract rules that determine what information is task-relevant, whereas the VLPFC may more specifically support the selection of relevant stimulus or response information. Building on this idea, we conducted an event-related FMRI study to test whether these regions differentially support long-term memory formation. Subjects were scanned while performing a context-dependent encoding paradigm with two different conditions. On blocks of 'no rule' trials, participants were told to make animacy judgments on a series of words. On 'target/nontarget' blocks, participants were first shown a target color (orange or green) and instructed to make animacy judgments for words shown in the target color or to make a non-target response for words in the other color. Following scanning, participants were given a recognition test consisting of all words, along with unstudied foil items. Behavioral data demonstrated that recognition memory was better for words from no-rule blocks than for words from target/nontarget blocks, and that recognition was superior for target words than for non-target words. Preliminary FMRI analyses revealed that prefrontal activation was modulated by task condition and successful encoding. Further analyses will assess interactions between task and subsequent memory status and activity in DLPFC and VLPFC.

A93

PERSPECTIVE DIFFERENTIALLY MODULATES NEURAL ACTIVATION DURING REMEMBERING AND IMAGINING AUTOBIOGRAPHICAL EVENTS *Christine L. Cox[1], Lynn Nadel[1], Lee Ryan[1]; [1]Cognition and Neuroimaging Laboratories, University of Arizona* – The perspective from which autobiographical memories (AM) are retrieved can influence their subjective experience. Participants report reduced detail, emotionality, and sense of reliving for AMs recalled from third-person "observer" perspective (3pp) compared to those recalled from first-person "field" perspective (1pp; Berntsen & Rubin, 2006; McIsaac & Eich, 2002). Recent studies indicate that recalling AMs and imagining fictitious autobiographical events (FAE) recruit largely overlapping neural networks (Addis et al., 2007; Hassabis et al., 2007). Despite evidence that perspective is important in AM retrieval, and that recalling AMs and imagining FAEs engage similar processes, the effects of perspective on the neural correlates of these tasks are currently unknown. Participants in the present study underwent fMRI scanning while retrieving AMs and imagining FAEs, subsequently indicating from which perspective (1st/3rd) they saw themselves in each event. Parametric modulation analyses were performed, determining brain regions whose activation was modulated by differences in perspective. Results indicated that while 1pp modulated activity in medial prefrontal cortex during AM retrieval, activity in lateral parietal cortex and the cerebellum was modulated during FAE imagination. And while 3pp modulated activity in dorsolateral prefrontal cortex and the precuneus during AM retrieval, activity in anterior prefrontal cortex, premotor cortex, basal ganglia, and lateral parietal cortex was modulated during FAE imagination. These findings suggest that recalling and imagining oneself from the first and third person differentially engage brain regions implicated in self and other processing, motor planning, and spatial cognition, demonstrating the important role played by perspective in the (re-)construction of autobiographical events.

A94

THE RELATIONSHIP BETWEEN PERCEPTUAL/CONCEPTUAL PRIMING EFFECTS AND REPETITION SUPPRESSION IN POSTERIOR/FRONTAL CORTICAL REGIONS *Chun-Yu Lin[1], Lee Ryan[1]; [1]University of Arizona, Tucson, AZ* – Priming refers to the change in speed, accuracy or bias in processing a stimulus following prior exposure to the same stimulus. Neuroimaging studies have revealed that behavioral priming is typically accompanied by reduced activity (i.e. repetition suppression, or RS) in several cortical regions. When a perceptual priming task is used, RS is usually found in posterior cortical regions, and when a conceptual priming task is used, RS is normally found in frontal regions. It is hypothesized that RS may be the neural basis for behavioral priming. If this is the case, the magnitude of behavioral priming (i.e. the amount of facilitation in reaction time) should correlate with the magnitude of RS. However, reviews showed that so far several studies have reported frontal RS correlated with behavioral conceptual priming effects, but no strong evidence has been published yet supporting the correlation between posterior RS and perceptual priming effects. Therefore, the main goal of the present functional magnetic resonance imaging (fMRI) study was to examine the relationship between posterior/ frontal RS and perceptual/conceptual priming. Each participant performed three perceptual priming tasks (symmetry judgment on novel shapes or known objects, and picture naming on known objects) and one conceptual priming task (natural or man-made judgment on known objects). Results showed that more posterior than frontal RS effects were found in perceptual priming tasks, and the magnitude of behavioral perceptual priming also correlates with the extent of posterior RS, supporting the view that posterior regions are important for perceptual priming.

A95

DISTINCT PATTERNS OF FUNCTIONAL CONNECTIVITY BETWEEN PERIRHINAL CORTEX AND OTHER CORTICAL REGIONS IN RECOGNITION MEMORY AND PERCEPTUAL DISCRIMINATION *Edward ONeil[1], Anthony Cate[2], Jordan Poppenk[3,4], Stefan Köhler[1]; [1]The University of Western Ontario, [2]VA Research Service, Martinez, CA , [3]University of Toronto, [4]Rotman Reseach Institute* – The prevailing view of the medial temporal lobe (MTL) holds that its structures are dedicated to declarative memory. Recent evidence challenges this position, suggesting that perirhinal cortex (PRc) in the MTL may also play a role in online processing of objects when perceptual discriminations of stimuli with highly overlapping visual features are required. Here, we conducted an fMRI experiment to compare functional interactions of PRc with other cortical regions in recognition memory and in perceptual discrimination. The perceptual task required an 'oddball' judgment on sets of morphed faces. The memory task involved forced-choice recognition of a studied face among similar morphed lures. In previously reported analyses, we identified a right PRc region whose activity was related to accuracy in both tasks. In our new analyses, we aimed to determine whether these accuracy effects involved distinct interactions between PRc and other cortical regions. Specifically, we tested whether these patterns included (i) correlations between PRc and prefrontal regions previously implicated in retrieval monitoring that were specific to recognition memory, and (ii) correlations between PRc and ventral visual-pathway regions previously implicated in face perception that were specific to perceptual discrimination. A multivariate partial least-squares (PLS) analysis with a seed in the critical PRc region uncovered distinct patterns of functional connectivity that confirmed our hypotheses. Together these findings suggest that it is not engagement of PRc as such, but its pattern of interactions with other cortical regions that is uniquely associated with successful performance in recognition memory as compared to online processing of objects.

A96

LONG-TERM REPRESENTATIONS OF FAMILIAR LANDMARKS AND SCENES AS REVEALED BEHAVIOURALLY AND WITH EYE MOVEMENTS *Sabrina Agnihotri[1,2,3], Jennifer D. Ryan[2,3], Morris Moscovitch[2,3], Gordon Winocur[2,3], Marie-Eve Couture[2], R. Shayna Rosenbaum[1,2]; [1]York University, [2]Rotman Research Institute: Baycrest Hospital, [3]University of Toronto* – Research suggests that spatial memory representations of familiar environments are organized as schematic cognitive maps that preserve the gist of the environment without rich contextual details that may be necessary for re-experiencing it. In this sense, remote spatial memories can be considered similar to remote semantic or context-free memories, which can be retrieved independently of the hippocampus. It has also been suggested that, under certain conditions, eye movements are sensitive markers of hippocampal activity. To better understand long-term spatial memory representations and retrieval, the current study examined the ability to detect modifications to well-known landmarks located in downtown Toronto in a group of healthy young adults with extensive experience navigating in that environment. In general, participants demonstrated great difficulty identifying scenes containing altered landmarks, even if the modification was to the relative size of landmarks, to their internal features, or to the surrounding context. Their performance was best when a landmark was transposed to a different location. This pattern was reflected in the eye movement data, suggesting that there was a change in viewing time only in response to the few modifications for which participants were aware. These results support the contention that very familiar landmarks are strongly integrated within the spatial context in which they were first experienced, and that as long as the overall spatial configuration of landmarks remain intact, changes to fine or incidental details can go unnoticed.

A97

EXPLORING THE CONTRIBUTIONS OF CORTICOSTRIATAL LOOPS TO CATEGORIZATION LEARNING USING TEMPORAL DIFFERENCE MODELING AND GRANGER CAUSALITY MODELING *Carol Seger[1], Erik Peterson[1], Dan Lopez-Paniagua[1], Corinna Cincotta[1]; [1]Colorado State University* – We used multiple fMRI analysis methodologies to identify the roles of three corticostriatal loops in categorization: the motor loop connecting putamen with motor cortex, the visual loop connecting caudate with visual cortex, and the motivational loop connecting ventral striatum with ventromedial frontal cortex. Subjects viewed a face or house, responded whether it belonged to category A or category B, and received feedback. Stimuli were arbitrarily assigned to categories and category assignment could not be learned via a rule or pattern. We performed three analyses: (1) General linear model (GLM) contrasts identifying activity specific to correctly categorized trials (2) Regression analysis using temporal different model predictors of the error function (identifying regions sensitive to feedback processing and expectancy) and the value function (identifying regions coding correct category response) (3) Granger causality modeling (GCM) to identify directed influences between regions. GLM analyses found that striatal regions in both the motor loop (putamen) and visual loop (caudate) were associated with categorization learning. However, the putamen was sensitive to the value function and exerted directed influence on motor cortex, whereas the caudate received directed influence from visual cortex regions. These results indicate that the motor loop is involved in motor responding and the visual loop is involved in visual analysis during categorization. Activity in the ventral striatum was predicted by the error function, which is consistent with this region playing a role in reward and feedback processing within the motivational corticostriatal loop.

A98

SOURCE MEMORY AND FUNCTIONAL CONNECTIVITY *Paul Metzak[1,2], Elton Ngan[1], Liang Wang[1,2], Jen Whitman[1,2], Todd Woodward[1,2]; [1]University of British Columbia, [2]Provincial Health Services Authority, BC Mental Health and Addictions Research Institute* – Previous fMRI research on source memory suggests that this process is associated with dorsolateral prefrontal cortex activity. In the current study, we sought to investigate the functionally connected neural networks underlying source memory task performance, and their temporal progression throughout a trial. Twenty-four healthy participants were scanned while presented with words they had seen during training. Specifically, they were asked to recall whether, for a given word, they had (1) quietly read it, (2) provided an associated word, (3) said it themselves as the solution to a word puzzle, or (4) heard it as a digitized sound file solution to a word puzzle. Using a Finite Impulse Response (FIR) basis set modelling the peristimulus time points in conjunction with constrained principal component analysis (cPCA) for fMRI data, we extracted 3 functionally interacting but separate components. In the first component, the highest loadings were found bilaterally in the hippocampus and in the cerebellum. In the second component, the highest loadings were found in the visual cortex. In the third component, the highest loadings were found bilaterally in the dorsolateral prefrontal cortex, and in the dorsal anterior cingulate. The importance of each component over peristimulus time was computed and subjected to a test of statistical significance. The interaction between memory performance (miss/recall) and time point was found to be significant for all three components, indicating that all three neural networks are associated with successful source memory performance.

A99

ELECTROPHYSIOLOGICAL AND BEHAVIORAL MEASURES OF SWITCHING BETWEEN MEMORY TASKS *Kristine A Wilckens[1], Eric D Signoff[1], Ashley J Abraham[1], David A Wolk[2], Mark E Wheeler[1]; [1]University of Pittsburgh, [2]University of Pennsylvania* – Cognitive set, or retrieval orientation, can influence the effectiveness and accuracy of memory retrieval. To test the extent to which behavioral and electrophysiological measures of retrieval performance are influenced by orientation, we used a task-switching paradigm in which subjects were cued on every trial to perform either a semantic (living or nonliving) or an episodic (old or new) memory task. Here we report preliminary data (n = 5) from a study that will ultimately compare older and younger adults on behavioral and neural measures of retrieval orientation. Stimuli consisted of common visual objects, and studied (old) and non-studied (new) items were intermixed randomly at test. We were interested in the degree to which event related potential (ERP) old/new effects were modulated by the need to either switch from one task to another (switch) or to continue performing the same task on the previous one (stay) and two (stay+1) trials. We also tested for retrieval orientation effects by comparing ERPs of new items following either semantic or episodic cues. Behaviorally, subjects were slowest on switch trials and fastest on stay+1 trials. ERP data showed an old/new effect in left posterior superior (LPS) sites. Further, there appeared to be a step-wise increase in the old/new effect across switch, stay, and stay+1 conditions which corresponded with the behavioral data. Moreover, we found differences between processing of new stimuli following episodic vs. semantic task cues, which may reflect retrieval orientation. These data suggest that processing of a stimulus differs when switching between memory tasks.

A100

INTERACTIVE CORTICAL AND SUBCORTICAL STRUCTURES SUPPORT DIFFERENT TIME SCALES IN MOTOR SEQUENCE LEARNING *Nicholas F. Wymbs[1], Scott T. Grafton[1]; [1]University of California, Santa Barbara* – Nonlinear performance changes during sequence learning suggest that motor skills may be acquired on multiple time scales. We hypothesized that the underlying neural substrates supporting learning reflect these multiple time scales. It was predicted that prefrontal and rostral premotor areas and their basal ganglia (BG) projections support initial improvement, whereas caudal premotor and motor cortex and their BG connections support slow improvement. We used a cued sequence production task and functional magnetic resonance imaging. Participants translated a visually instructed explicit 12-element sequence into responses by the four fingers of the left hand. The entire sequence was presented at once, which served as the imperative to respond. Participants practiced three sequences frequently (189 trials/sequence), three occasionally (27 trials/sequence), and nine additional sequences rarely (8 trials/sequence) over the course of three sessions completed within five days, allowing us to use frequency of exposure to identify brain areas that are sensitive to the amount of training. Analyses of BOLD activity identified transient activity in prefrontal cortex and rostral basal ganglia for rare sequences, consistent with a novelty effect. Sequences that were practiced occasionally recruited pre-SMA, rostral PMd and associated BG that diminished with frequent practice. In parallel, there was a progressive increase of activity in caudal PMd, SMA, motor cortex and sensorimotor BG with frequent practice. Different brain regions are more prominent at particular times during motor learning, with a shift of recruitment from rostral to caudal premotor and associated subcortical areas.

A101

EEG CORRELATES OF PROCESSING THREATENING VISUAL STIMULI *Clifford Calley[1], Matthew Brier[1], Thomas Ferree[2], Rajen Patel[1], Yana Gelman[1], Gail Tillman[1], Michael Kraut[3], John Hart[1]; [1]Center for BrainHealth: University of Texas at Dallas, [2]University of Texas Southwestern Medical Center, [3]Johns Hopkins University School of Medicine* – An organism's ability to rapidly detect threatening stimuli is crucial to its survival. Previous fMRI studies of pictures of threatening and nonthreatening stimuli across a variety of categories demonstrated differential signal change of BA 18 and 19 for threatening compared to non-threatening stimuli. The fMRI data, however, were uninformative as to the timing of whether the para-striate visual regions was being activated directly from feed-forward connections of striate cortex or late through feedback from more rostral cortical regions. To address this issue, we recorded surface EEG as subjects performed the same task used for the fMRI experiment

noted above. Subjects were shown threatening and non-threatening images, as well as their phase-scrambled equivalents. Time-frequency analysis was performed using 0.25-sec moving windows. For threatening versus non-threatening stimuli, there were differences in the theta band EEG power in the left occipital-temporal region at about 1 sec and in the fronto-central region at about 1.3 sec. The findings support the contention that the previously observed BA 18 and 19 fMRI signal changes reflect feedback activation as opposed to direct feedforward information flow, which is consistent with axonal connections from the amygdala to visual regions which have been shown to influence processing in visual cortices. The finding of theta-band activity involved in threat detection in humans is consistent with previous findings in animals for threat recognition in the amygdalo-hippocampal circuit.

A102

PROCESSING OF SOUNDS DURING SLOW WAVE SLEEP IN HUMANS: AN EEG/FMRI STUDY OF AUDITORY STIMULATION IN NON-REM SLEEP *Manuel Schabus[1,2], Thanh Dang-Vu[2], Melanie Boly[2], Anabelle Darsaud[2], Genevieve Albouy[2], Virginie Sterpenich[2], Christophe Phillips[2], Pierre Maquet[2]; [1]University of Salzburg, Austria, Division Physiological Psychology, [2]University of Liege, Belgium, Cyclotron Research Centre* – The present study aimed at identifying the neurophysiological responses associated with auditory stimulation during deep non-rapid eye movement (NREM) sleep using simultaneous EEG/fMRI recordings. It was reported earlier that auditory stimuli produce bilateral activation in auditory cortex, thalamus, and caudate during both wakefulness and NREM-sleep (Portas et al., 2000). However, due to the spontaneous membrane potential fluctuations cortical responses may be highly variable during NREM. Here we now examine the modulation of cerebral responses to tones depending on the phase of the slow oscillation. Up to now 7 healthy young subjects were scanned successfully during slow wave sleep in the first half of the night in a Siemens-Allegra-3T scanner (EPI sequence:32 slices, TR:2460ms). Subjects were not sleep-deprived and sounds which were occurring around the peak negativity of NREM slow-waves were identified. These detected sounds were then entered as regressors of interest in fMRI analyses. Results are consistent with the hypothesis that brain responses during deep NREM-sleep vary as a function of the fluctuating state of thalamo-cortical circuits. In accordance with Massimini and colleagues (2003) larger evoked responses are observed at the negative slope of the slow oscillation. The presence of short temporal windows during which the brain is open to external stimuli is consistent with the fact that even during deep sleep meaningful events can be detected. Altogether, brain responses during NREM sleep appear to be non-stationary and highly dependent upon the phase of the slow oscillation which may also determine the faith of incoming stimuli while asleep.

A103

NEURAL MECHANISMS OF THE DISTRIBUTED PRACTICE EFFECT *Michael Mozer[1], Harold Pashler[2]; [1]University of Colorado, [2]University of California, San Diego* – When individuals learn facts (e.g., foreign language vocabulary) over multiple study sessions, the temporal spacing of study has a significant impact on memory retention. Behavioral experiments have shown a nonmonotonic relationship between interstudy interval (ISI) and retention, with intermediate ISIs yielding better performance than short or long ISIs, and the optimal ISI strongly depending on the retention interval. Many theories have been proposed to explain these effects, but none captures the wealth of data. We propose a hybrid theory that combines features of three existing models: Anderson and Milson (1989), Raaijmakkers (2003), and Staddon, Chelaru, and Higa (2002). Our theory is cast as a neural network, and is based on the notion that items are encoded with a time-varying contextual representation, of the sort that has been proposed to reside in the dentate gyrus of the hippocampus (Aimone, Wiles, & Gage, 2006). The similarity of the contexts at study and test determines the probability of retrieval success. Extending previous models, our theory posits a context that wanders on multiple time scales. The model can fit data over a range of interstudy intervals from minutes to months. Moreover, the model has strong predictive power: Given the forgetting function for a set of items studied once, the model successfully determines the spacing of study sessions that yields optimal retention.

A104

THE EFFECT OF SLEEP ON TEMPORAL ORDER IN EPISODIC MEMORIES *Andrea Hoffmann[1], Kerstin Hoedlmoser[1], Hermann Griessenberger[1], Wolfgang Klimesch[1], Manuel Schabus[1]; [1]University of Salzburg, Division Physiological Psychology* – Meanwhile there is plenty of evidence indicating that sleep has a beneficial effect on declarative and procedural memory consolidation. Here we study the influence of sleep versus sleep deprivation on temporal order in episodic memories. 34 young participants either slept or had to stay awake during the whole night after learning various stories. Each story consisted of 12 pictures (6 faces and 6 objects) presented in sequence and participants had to invent a story with themselves being a part of it. In addition to a previous screening/adaptation night the "sleep group" slept in the sleep laboratory after learning with full polysomnography attached. Retest was done the next morning, as well as after 2 recovery nights in order to circumvent fatigue effects of the sleep-deprived group. Results revealed that performance in temporal order memory was only deteriorated in the post-training sleep deprived group. Furthermore, we report a positive relationship of rapid eye-movement (REM) sleep after learning and performance in temporal order recall. Last but not least we could confirm earlier findings reporting positive association of (fast) non-REM sleep spindles and cognitive abilities (as revealed by the Wechsler Memory Scale- revised and Raven`s Advanced Progressive Matrices). This repeatedly found general association might indicate that sleep spindles are a good indicator for cognitive capability because they allow a rough estimation about the degree of thalamocortical connectivity.

Memory: Other

A105

RECOLLECTION BENEFITS AND THE REACTIVATION OF SENSORY-SPECIFIC BRAIN REGIONS DURING THE RETRIEVAL OF CONTEXT INFORMATION *Erin Skinner[1], Myra Fernandes[1], Cheryl Grady[2,3]; [1]University of Waterloo, Ontario, [2]Rotman Research Institute, Baycrest Center for Geriatric Care, Toronto, Ontario, [3]University of Toronto, Ontario* – The neural correlates underlying the retrieval of contextual details during recollection were investigated using event-related fMRI. Previous work suggests that participants can use contextual detail provided at study to benefit later memory performance (Skinner & Fernandes, in press). We examined whether such a benefit is associated with the reactivation of sensory-specific brain regions. The fusiform face area was localized in fourteen younger adult participants, who subsequently performed three study-test sessions. During study, participants viewed words presented with pictures of faces, or scrambled faces, and in a subsequent scanned recognition test made remember, know, or new judgments to the words presented alone. Overall, behavioural results showed no difference in recognition performance for words studied with faces or scrambled faces. Neuroimaging data, however, showed higher fusiform activation during remember responses to words studied with faces as compared to words studied with scrambled faces. In a further analysis, we divided the participants based on behavioural performance: 8 participants who gave more remember responses to words studied with faces than scrambled faces (Context-benefit group) and 6 participants who did not show this pattern (Context-neutral group). Whereas the Context-benefit group showed higher fusiform activation during remember responses to words studied with faces as compared to scrambled faces, the Context-neutral group did not. The results suggest that the retrieval of contextual detail during recollection is associated with the reactivation of sensory-specific brain regions, and that this is supported by processes that bind item and context information at study, improving subsequent recollection.

Poster Session B

Cognitive and brain development

B1

NEURAL CORRELATES OF AUDITORY PHONOLOGICAL PROCESSING IN TYPICAL READING DEVELOPMENT AND DYSLEXIA *Elizabeth S. Norton[1,2], Ioulia Kovelman[1], Nadine Gaab[3,4], Joanna A. Christodoulou[4,1], Dan A. Lieberman[5,1], John Lymberis[1], Susan Whitfield-Gabrieli[1], Maryanne Wolf[2], John D.E. Gabrieli[1]; [1]Massachusetts Institute of Technology, [2]Tufts University, [3]Children's Hospital Boston/Harvard Medical School, [4]Harvard University Graduate School of Education, [5]Harvard Medical School* – Phonological awareness (PA), our ability to manipulate the phonemic units of language, is predictive of successful reading acquisition. Children with dyslexia are often impaired on PA tasks. Neuroimaging studies find differences in brain function between typical and dyslexic readers using visual (written text) PA tasks. Although deficits in visual PA tasks are thought to originate from diminished auditory language PA, little is known about auditory PA brain differences between typical and dyslexic children. We compared neural correlates of auditory PA in typically-developing and dyslexic children. METHOD: Dyslexic readers (n=13, ages 7-12), age-matched typical readers (n=13), and kindergarteners, PA ability-matched to dyslexics (n=10, ages 5-6), completed word-rhyming PA and word-matching control tasks during fMRI. RESULT: Age-matched typical readers exhibited left dorsolateral prefrontal cortex (DLPFC) activation for word-rhyming relative to word-matching. Activation was significantly greater than in dyslexics, who did not exhibit DLPFC activation. Kindergarteners exhibited left DLPFC activation similar in magnitude to the typical readers. CONCLUSIONS: Left DLPFC appears to support PA for auditory language in typically developing children before (kindergartners) and during (age-matched readers) reading instruction. Dyslexic readers do not appear to engage DLPFC for PA. These findings suggest that auditory PA is important for successful reading acquisition, that left DLPFC plays a role in auditory language PA, and that dyslexics have differences in DLPFC function that cannot be accounted for by reading or PA proficiency. Rather, these differences in the left DLPFC region supporting auditory PA may play a critical role in the etiology of dyslexia in many children.

B2

THE ROLE OF INDIVIDUATION VERSUS CATEGORIZATION IN THE DEVELOPMENT OF PERCEPTUAL EXPERTISE *Lisa Scott[1]; [1]University of Massachusetts Amherst* – Prior research investigating the acquisition of perceptual expertise in adults suggests that increased expertise is exhibited in those who are trained to discriminate at more specific levels. It is possible that the manner in which perceptual expertise is acquired in adults is similar to the manner in which face expertise is acquired through experience during development. Here it was predicted that experience discriminating novel types of faces and objects at the individual level, but not the category level, during the first year of life, will lead to specialized processing for those trained stimuli. Four groups of infants completed pre-training (6 months) and post-training (9 months) behavioral (Visual-Paired Comparison) and electrophysiological (Event-Related Potentials) assessments, which indexed face and object discrimination. Following the pre-training assessment, two groups of infants were sent home with training books of monkey faces or of strollers, which were labeled at the individual level (i.e. all faces and strollers had individual names). Two more groups of infants were sent home with books of monkey faces or strollers labeled at the category level (i.e. all faces were named 'monkey' or 'stroller'). Infants returned at 9-months and results revealed both behavioral and electrophysiological (N290; P400) differences from 6 to 9 months, and between training conditions such that infants trained at the individual level exhibited a differential pattern of neural activity relative to those trained at the category level. These results are discussed in relation to visual perceptual narrowing and the development of face processing.

B3

DO INFANTS SHOW THE COMPATIBILITY EFFECT? AN EVENT-RELATED POTENTIAL STUDY OF GAZE-EMOTION INTERACTION *Silvia Rigato[1], Teresa Farroni[1,2], Mark H. Johnson[1]; [1]Centre for Brain and Cognitive Development, School of Psychology, Birkbeck College, London, UK, [2]Dipartimento di Psicologia dello Sviluppo e della Socializzazione, Universita' di Padova, Italy* – Event related potentials were recorded from four-month-old infants while they viewed pictures of faces with direct or averted gaze displaying happy, fearful, and angry expression. We predicted differential emotional expression processing, at least between certain facial expressions, at the infant face sensitive ERP components (N290, P400) and at the negative component (Nc). Further, we expected to observe modulation by gaze direction for happy and angry expressions. Electrophysiological activity was recorded by using 128 channels Hydrocel Geodesic Sensor Net, while infants were seated on their mum's lap in front of a 40X29 cm monitor. Their attention was drawn to the middle of the screen by a colour cartoon, which lasted between 1400-1800 ms, and then a face replaced it for 1000 ms. Face stimuli were counterbalanced, presented in random order and with equal probability for as long as the babies were willing to look at them. 42 babies participated in the study. Analysis showed that the Nc is affected by emotional expression, with larger amplitudes for happy and angry than fearful face stimuli. Significant gaze effects were found at the Nc in response to angry expressions, and at the frontal sites for happy faces only. Our results suggest that infants' brain responses differ between emotional expressions, showing larger activation to happy and angry expressions, possibly reflecting a greater allocation of attention. Infants discriminate gaze direction in these emotions revealing an interaction between emotion and gaze direction in approach-oriented emotions.

B4

FACE-SPECIALIZED CORTICAL AREAS EMERGE SLOWLY: A DEVELOPMENTAL FMRI STUDY *Kathrin Cohen Kadosh[1], Frederic Dick[1,2], Roi Cohen Kadosh[3], Richard N. A. Henson[4], Mark H. Johnson[1]; [1]Centre for Brain and Cognitive Development, School of Psychology, Birkbeck College, University of London, UK, [2]Center for Research in Language, University of California, San Diego, CA, [3]Institute of Cognitive Neuroscience, University College London, London, UK, [4]MRC Cognition & Brain Sciences Unit, Cambridge University, Cambridge, UK* – Faces are complex social stimuli that convey much information, such as for example the identity, or the emotional state of a person. Several studies have shown that children's abilities to process different facial features are delayed in comparison to other objects categories (Carey & Diamond, 1977; Mondloch et al., 2003). Recent fMRI evidence suggested that immature behavioural abilities might be related to the slow emergence of face-sensitive cortical areas (Scherf et al., 2007). In the current study we evaluated the neuro-cognitive mechanisms of different facial features as a function of development. Forty participants (14 adults, 12 children (7-8 years), 14 children (10-11 years)) had to detect a specific identity, emotional expression, or direction of eye gaze in a stream of consecutively presented faces. The adult participants showed comparable performance for all tasks, while the neural processing of the different facial features varied as a function of task and facial fea-

ture, in particular in the fusiform gyrus, the inferior occipital gyrus and the superior temporal sulcus. The children's performance varied significantly depending on the specific facial feature and age, and neural activation showed reduced functional integration between the facial features, as both children groups relied on additional frontal and parietal brain areas. Thus, our findings suggest that previous reports on improvements in behavioural abilities for face processing observed between 7-11 years of age, are mirrored by slowly changing neuronal activation patterns that depend on task requirements and the specific facial feature investigated.

B5

NEUROBIOLOGY OF SEX DIFFERENCES IN PARIETAL LOBE DEVELOPMENT *Joel Salinas[1,2], Peg Nopoulos[2]; [1]Doris Duke Clinical Research Fellowship Program, University of Iowa, [2]University of Iowa* – Structural MRI studies continue to provide evidence for sexual dimorphism in the human brain, especially overall cerebral volume. Previously, our lab found adult males to have parietal lobe surface area proportionately greater than females; however, females had a greater ratio of parietal lobe cortex to parietal lobe white matter. To our knowledge there are no studies examining this sexual dimorphism of parietal lobe structure in younger populations or in the context of development and aging. This study evaluates structural differences of the parietal lobe in younger males and females (ages 7-18). Also, by adding the cohort of previously studied adults (ages 18-50), sexual dimorphism of parietal lobe morphology was examined across ages 7-50. In the youth sample, we found that the ratio of parietal cortex to parietal white matter was greater in girls compared to boys. Unlike the adult sample, however, there was no sexual dimorphism in the parietal surface area. When examining the youth and adult samples together, though, parietal surface area was found to have a significant sex by age interaction. Both sexes had linear decreases in parietal surface area over time, but the slope was significantly steeper for females compared to males. Therefore, in youth, parietal surface area is not significantly different between the sexes, but, in adults, males end up with larger parietal surface area. These findings support the notion of clear structural sexual dimorphism in the parietal lobe, not only in the context of cross sectional assessment, but also in terms developmental trajectories.

B6

THE ONTOGENY OF HANDEDNESS: EVIDENCE FROM THE KISS SYNDROME *Sebastian Ocklenburg[1], Corinna Buerger[1], Christine Westermann[1], Daniel Schneider[1], Heiner Biedermann[2], Onur Guentuerkuen[1]; [1]Institute of Cognitive Neuroscience, Ruhr-University Bochum, Germany, [2]Private Practice, Cologne, Germany* – The ontogeny of functional lateralisation and especially of handedness has often been explained with genetic models. In birds, however, it has been shown that epigenetic factors also play a critical role in the development of lateralisation. In pigeons and chicks a skewed visual input during development has been found to modulate morphological and functional asymmetries. To test the hypothesis that epigenetic factors, especially visual experience, may also modulate human functional lateralisation, children with the KISS (Kinematic imbalances due to suboccipital strain) syndrome were tested. These children have a permanently fixed asymmetric posture of the head due to a functional disorder of the occipito-cervical region. This head tilt can be to the left or to the right side, leading to opposing asymmetries in visual experiences of the two hands. We compared functional asymmetries in children with a left- or right-sided KISS syndrome with those in healthy controls. Childrens' individual handedness, footedness and eye-preference were assessed using behavioural tasks. Right-handedness was more frequent in children with a head tilt to the left than in control children. Children with a head tilt to the right, in turn, had a lower frequency of right-handedness than controls. For footedness and eye-preference no differences between the three groups were observed. These findings show a clear influence of an epigenetic factor on handedness and therefore strongly suggest a combined genetic-epigenetic model for its development.

B7

DEFAULT NETWORK FUNCTIONAL CONNECTIVITY DEPENDS ON WHITE MATTER MATURATION *Evan Gordon[1], Philip Lee[2], Jose Maisog[2], Jennifer Foss-Feig[2], Michael Billington[2], John VanMeter[2], Chandan Vaidya[2,5]; [1]Interdisciplinary Program in Neuroscience, Georgetown University Medical Center, [2]Georgetown University, [3]Children's Research Institute, Children's National Medical Center* – Functional connectivity measured between the medial prefrontal cortex (mPFC) and the posterior cingulate cortex (PCC), known collectively as the 'default network', is correlated in adults with the structural integrity of the cingulum white matter bundle which runs between these two regions. While previous work in children has demonstrated that functional connectivity within the default network increases with age, it is not known whether this developmental increase correlates with an increase in white matter integrity; nor are the behavioral correlates of these connectivity increases well characterized. We examined the relationship between default network functional and anatomic connectivity in fourteen boys age 9 to 12 years who had been assessed with a neuropsychological battery. We measured both functional connectivity between the network components (as indexed by the coherence of the fMRI signal during rest) and the structural integrity of the cingulum bundle (as measured by the mean Fractional Anisotropy within the cingulum, obtained via Diffusion Tensor Imaging). We found a significant positive relationship between the integrity of the white matter in the cingulum bundle and the functional connectivity between the mPFC and the PCC ($r(12)=.55$, $p = .05$). Behaviorally, functional connectivity in this network correlated positively with cognitive processing speed ($r(12)=.62$, $p<.05$), but not with motor processing speed ($p=.28$) or with executive function ($p=.31$). Thus, the functional integrity of the midline default network relies upon maturation of the underlying white matter and influences efficiency of information processing. Funded by MH65395.

B8

HEMISPHERIC LATERALIZATION OF VERBAL AND SPATIAL WORKING MEMORY EXISTS IN DEVELOPING YOUTH *Megan M. Herting[1], Damien Fair[1], Richard Bruno[1], Bonnie J. Nagel[1]; [1]Oregon Health and Science University* – Adult functional magnetic resonance imaging (fMRI) literature suggests that a left-right hemispheric dissociation may exist between verbal and spatial working memory (WM), respectively. However, investigation of this type has been obscured by incomparable verbal and spatial working memory tasks and/or visual inspection at arbitrary thresholds as means to assess lateralization. Furthermore, it is unclear if hemispheric lateralization exists in youth, or when during development this pattern emerges. This study, therefore, used comparable verbal and spatial WM n-back tasks during fMRI and a bootstrap analysis approach to calculate lateralization indices (LI) across several thresholds to examine the potential of a left-right WM hemispheric dissociation in youth ages 10 to 15 (verbal WM: $n=38$; $M=13.04$, $SD=1.63$; spatial WM: $n=31$, $M=13.31$, $SD=1.58$). By applying a bootstrap algorithm to our group statistical maps, we were able to generate mean LIs and mean weighted LIs (LIW) for each task that do not rely on qualitative visual inspection or arbitrary thresholds (Wilke & Schmithorst, 2006). We found a significant hemispheric lateralization ($p=.003$) for both verbal (left, $LI=.16$, $p<.05$; $LIW= .27$) and spatial WM (right, $LI= -.11$, $p<.001$; $LIW= -.18$). Although no relationship was observed between LI and age, significant age-related activations were seen within regions of lateralized WM activity. Our findings highlight the importance of utilizing non-biased statistical methods and comparable tasks for determining patterns of functional lateralization. Our findings also suggest that, while a left-right hemispheric dissociation of verbal and spatial WM is present by early adolescence, age-related functional activations during WM are present.

B9

DEVELOPMENTAL TRAJECTORIES OF MAGNITUDE PROCESSING AND INTERFERENCE CONTROL: AN FMRI STUDY *Guilherme Wood[1], Anja Ischebeck[2], Florian Koppelstaetter[2], Thaddaeus Gotwald[2], Liane Kaufmann[2]; [1]University of Salzburg, Austria, [2]Innsbruck Medical University, Austria* – Neurodevelopmental changes regarding interference and magnitude processing were assessed in three age groups (children n=10, young adults n=11, elderly n=9) by using an fMRI version of the numerical Stroop task. Behaviorally, comparable distance and size congruity effects were found in all three age groups. Distance effects were most pronounced in the more difficult numerical task, while size congruity effects were comparable across tasks. Imaging results disclosed an almost age-linear trend in the pattern of activation observed in left and right prefrontal and inferior temporal regions of the brain. This implicates that with increasing age interference control requires increasing effort (possible explanations for children's relatively lower interference effects are provided). In contrast, the distance effect produced a negative linear trend in right prefrontal, SMA and intraparietal cortex. This suggests that relative to old adults, children and young adults had to recruit a larger network upon processing magnitude. The latter findings are even more remarkable considering that the behavioral effects were similar across groups.

B11

ELECTROPHYSIOLOGICAL CORRELATES OF INFANT MEMORY: NOVELTY, FAMILIARITY, OR RECENCY? *Kelly Snyder[1], John Garza[1], Liza Zolot[1], Anna Kresse[1]; [1]University of Denver* – Event-related potential (ERP) studies of memory in young infants have shown that prior experience with a visual stimulus modulates the amplitude of a late slow wave (LSW) component. In a previously unrelated line of research, intra-cellular recordings in non-human primates have demonstrated that different populations of neurons in the temporal lobe encode information regarding stimulus novelty, familiarity, and recency of occurrence (Xiang & Brown, 1998). We used high-density electroencephalography to investigate the functional significance of the LSW in 6-month-olds by examining effects of repetition of highly familiar and novel stimuli on the amplitude of the LSW. Twenty-four familiar pictures (pictures of items from the infant's home such as people, pets, and toys) and twenty-four novel pictures (pictures of similar items from another infant's home) were each repeated exactly once while ERPs were recorded. We found that (a) immediate repetition caused equivalent suppression of LSW amplitude for familiar and novel stimuli [Repetition x Lead interaction at central leads, $F(2,44) = 3.79$, $p = .03$; LSW amplitude was smaller in response to repeated stimuli at right-central leads, paired-t $(22) = 2.50$, $p = .02$], and (b) there were no effects of repetition on the LSW when there was a single intervening item between the first and second presentations of a stimulus. These effects are most consistent with the response properties of recency neurons in inferio-temporal cortex, suggesting that the LSW may reflect neural activity associated with the incidental encoding (or updating) of the immediate visual environment into a short-term perceptual store.

B12

CROSSMODAL SYNCHRONY AND ASYNCHRONY PERCEPTION IN 6-MONTH-OLD INFANTS *Franziska Kopp[1], Claudia Dietrich[1], Ulman Lindenberger[1]; [1]Max Planck Institute for Human Development, Berlin* – Close temporal proximity of sensory modalities is an important prerequisite for intersensory integration to form a coherent percept. In contrast to adults, the temporal threshold to detect intersensory asynchrony is higher in infants. The aim of the present study was to investigate brain dynamics related to perception of audio-visual synchrony and asynchrony in 6-month-old infants using event-related potentials (ERP). In a behavioral experiment, infants were habituated to a synchronous social stimulus. Once infants met the habituation criterion, an asynchronous test trial of the same stimulus was presented in which the visual stream was delayed to the auditory stream by 400 ms. Only infants who discriminated this change in temporal alignment on behavioral level were included in further EEG assessment. The EEG experiment varied between two conditions: In the synchronous condition the visual and auditory stream were in synchrony, whereas in the asynchronous condition the visual stream was delayed to the auditory stream by 400 ms. ERP data showed longer latencies of the Nc component in the asynchronous condition. An additional negative component peaking between 300 and 400 ms after stimulus onset was identified only in asynchronous stimuli. Furthermore, the auditory P2 component showed significantly longer latencies in asynchronous as compared to synchronous trials. Because auditory stimulation occurred at the same point in time in both conditions, this result indicates that a temporal delay of activity might be an adequate mechanism of the infant brain to integrate both modalities.

B13

INFANTS' EYE MOVEMENTS DURING FAMILIARIZATION WITH AN OBJECT CATEGORY: A TRANSITION FROM SALIENCY-DRIVEN TO OBJECT-BASED LOOKING PATTERNS *Nadja Althaus[1], Denis Mareschal[1]; [1]Centre for Brain and Cognitive Development, School of Psychology, Birkbeck, University of London* – Past research has shown that infants' perceptual category formation in familiarization paradigms depends on the feature distributions present in the familiarization set (Mareschal, French, & Quinn, 2000). However, infants' processing of the stimuli during familiarization has rarely been studied directly and therefore there is no account of the learning process as such: evidence for perceptual learning would involve a change in infants' looking patterns across familiarization. The current study therefore uses eye tracking to investigate the impact of bottom-up saliency, as measured by saliency maps based on neural processing principles, on infants' fixation targets over the course of familiarization with a category (color images of deer). Twenty-five 12-month-olds and 34 4-month-olds were presented with a sequence of eight images of deer, followed by a test trial consisting of a novel deer paired with a horse. Category learning was successful in both age groups, as indicated by infants' preferential looking at the horse. In order to investigate to which degree infants' eye movements were driven by bottom-up saliency, i.e. initiated by early visual brain areas, we compared recorded fixation locations to a saliency map of the corresponding stimulus image (Itti & Koch, 2001; Kienzle, Wichmann, Schoelkopf, & Franz, 2007). Results show that for both age groups the impact of bottom-up saliency on infants' fixation targets is large prior to learning, but much lower after familiarization. This indicates that infants' looking is initially driven by bottom-up saliency, but increasingly influenced by categorization-based higher-level visual processing as learning progresses.

B14

THE RIGHT INFERIOR OCCIPITOTEMPORAL CORTEX: A CONVERGENCE ZONE FOR READING-RELATED COGNITIVE ABILITIES *Stefan Heim[1,2,3], Marion Grande[2], Elisabeth Bay[1,2], Helen Schreiber[1,2], Simon B. Eickhoff[1,2,3], Juraj Kukolja[4], Nadim J. Shah[1], Katrin Amunts[1,2,3]; [1]INB3-Medicine, Research Centre Jülich, [2]Medical Faculty, RWTH Aachen University, [3]Medical Faculty, JARA, RWTH Aachen University, [4]University Hospital Bonn* – Successful reading depends on a number of cognitive functions, including phonological awareness and visual attention. In this fMRI study, we demonstrate that the neural basis underlying the influence of these cognitive variables on reading is located in the right inferior occipitotemporal cortex (IOTC). 38 children (mean age: 9 years; 19 dyslexics, 19 controls) read aloud German words. Reading-related brain activation in the right IOTC, overlapping with cytoarchitectonic area hOC4v, was modulated by scores for phonological awareness and visual attention. This modulation was stronger for controls than for dyslexic readers. In two additional fMRI studies we further demonstrated that in right IOTC, reading ability modulates the activation during phonological decisions and visual attention. Together, these findings indicate that different cognitive influences on reading converge in the right IOTC, contralateral to the visual word form area, and thus con-

tribute to understanding the neurocognitive basis of reading and dyslexia.

B15

MAPPING DA-RELATED GENETIC VARIATION INTO ATTENTION-RELATED BRAIN ACTIVATION IN 5 YEAR-OLD CHILDREN *M. Rosario Rueda[1], Purificacion Checa[1], Pascale Voelker[2]; [1]Universidad de Granada, Spain, [2]University of Oregon* – The sequencing of the human genome has allowed examination of the genetic basis of cognitive functions in the past several years. Recent studies have shown that the executive control of cognition and action is among the highest heritable psychological functions (Friedman et al., 2008 JEP:G). Performance of conflict tasks such as Stroop and flanker has been related to activation of the executive attention network which involves the anterior cingulate cortex (ACC) and lateral prefrontal areas and appears to be modulated by dopamine (Posner, Rueda & Kanske, 2007 Handbook Psychophy). Variations in particular genes affect dopaminergic pathways in the brain through different molecular mechanisms (Diamond, 2007 CeCortex). We have looked at polymorphisms in several genes thought to influence dopaminergic pathways (DAT1, COMT and DRD4) in a group (n=37) of children. Then, we examined EEG activation during performance of a flanker task in relation to genotype. Children having the 9-repeat polymorphism in the DAT1 gene showed smaller flanker interference than children homozygous for the 10-repeat polymorphism. Smaller flanker effects (although not statistically significant) were also observed for children with the 7-repeat in the DRD4 gene, as well as those with at least one Val allele of the COMT gene. Better performers also showed larger negative amplitudes for the incongruent trials at the frontal midline leads. Further analysis of brain activation using source-localization models suggest that the pattern of activation shown by good performers is due to greater differentiation of activation in the medial frontal gyrus for incongruent compared to congruent trials.

B16

DOES REASONING ABILITY IN CHILDREN IMPROVE WITH TRAINING? *Allyson Mackey[1], Susanna Hill[1], Natalie DeShetler[1], Carter Wendelken[1], Silvia Bunge[1]; [1]University of California, Berkeley* – We present encouraging preliminary data suggesting that fluid reasoning, an ability critical for academic achievement, can be trained in children. In a pilot study, children ages 5 to 10 (n=6) played a variety of store-bought computerized games and board games for one hour a day, for 16 to 24 days, over the course of 6 weeks. Children who played the game with the strongest problem solving demands (n=3) exhibited a mean increase of 7 points in performance IQ as measured by the Wechsler Abbreviated Scale of Intelligence. This change seemed to be driven by improvements in the Block Design component of the scale, which improved an average of 4.25 points, while scores on Matrix Reasoning remained steady. In addition to these standardized measures, children also performed a relational integration task modified from Smith et al., 2007 pre- and post-training. Interestingly, accuracy on one-relational items did not improve with training, but accuracy on two-relational problems improved on average 23%. These children participated in the same number of training sessions on average (22) so outcome differences were not due to training duration.Differences are also not explained by improvements in visual processing, because performance on the Rapid Visual Information Processing task from the CANTAB did not improve. In summary, children who played a complex problem solving game improved in measures of visual spatial reasoning and relational integration. A larger study is currently underway to compare gains in reasoning ability from reasoning training (n=15) with speed of processing training, an active control (n=15).

B17

EFFECT OF DOPAMINE TRANSPORTER GENOTYPE ON CAUDATE VOLUME IN CHILDHOOD ADHD AND CONTROLS *Devon Shook[1], Colin Brady[1], Philip Lee[1], John VanMeter[3], Edwin Cook[4], Mark Stein[4], Laura Kenealy[2], Chandan Vaidya[1,2]; [1]Georgetown University, Washington DC, [2]Childrens National Medical Center, Washington, DC, [3]Center for Functional and Molecular Imaging, Georgetown University Medical Center, Washington, DC, [4]University of Illinois, Chicago, IL* – Structural neuroimaging studies of Attention Deficit Hyperactivity Disorder (ADHD) have identified grey matter volumetric reductions in prefrontal striatal regions. While multiple neurotransmitter systems influence prefrontal function, striatal regions such as the caudate are primarily dopaminergic. Striatal dopamine levels are regulated by the dopamine transporter. The present study examined differences between alleles of the dopamine transporter genotype (DAT1) on caudate volume, a nucleus shown to differ functionally between ADHD and control children. We hypothesized that caudate volume would differ by DAT1 functional polymorphism and diagnosis. We performed structural magnetic resonance imaging (MPRAGE) in 7-13 year old children with either two copies (10/10) or 1 copy (9/10) of the 10 repeat allele of DAT1. Using a region of interest (ROI) approach, we compared caudate volumes in a DAT1 (10/10, 9/10) X Diagnosis (ADHD, Controls) X Hemisphere (Left, Right) ANOVA. Results showed main effects of diagnosis indicating smaller caudate volumes in ADHD compared to controls, and DAT1 indicating smaller caudate volumes in 10/10 compared to 9/10 children. Further, a DAT1 X Hemisphere interation indicated that caudate differences by DAT1 were driven by differences in the left rather than right hemisphere. Genotypic differences did not vary by diagnosis. Thus, structural striatal maturation is influenced by genetic differences in dopamine transporter function. Funded by NIMH MH065395

B18

ASSOCIATIONS AMONG MORPHOMETRIC MEASURES, ELECTROPHYSIOLOGICAL CORTICAL RESPONSES AND LANGUAGE ABILITIES IN CHILDREN: PREDICTING FROM 6 MONTHS TO 24 MONTHS OF AGE *Silvia Ortiz-Mantilla[1], Judy Flax[1], Cecylia K. Chojnowska[1], Myong-sun Choe[2], P. Ellen Grant[2], April A. Benasich[1]; [1]Center for Molecular & Behavioral Neuroscience, Rutgers University, Newark, NJ, [2]Center for Morphometric Analysis, Neuroscience Center, Massachusetts General Hospital at Harvard Medical School* – Recently, there has been much interest in identifying relations among morphometric indices (e.g. brain volumes), electrophysiological responses (EEG/ERPs) and measures of language and cognition across early development. In this study, structural MRIs and high-density EEG/ERPs to complex tone-pairs were collected in normally developing children at 6 months of age. Standardized language and cognitive assessments were administered at 24 months. We found that children with larger right amygdala (RA) volume at 6 months had lower expressive ($r = -.55$, $p = .015$) and receptive ($r = -.51$, $p = .027$) language scores at 24 months. Children that at 6 months had larger N2 amplitude at left frontal channels scored higher on expressive ($r = -.74$, $p = .001$) and receptive ($r = -.54$, $p = .025$) language. Infant RA size and N2 amplitude together predicted performance at 24 months on both expressive ($F = 6.47$, $p = .010$) and receptive ($F= 15.6$, $p = < .001$) language. At 24 months, 41% of variance in expressive language was accounted for by RA size (24%) and amplitude of N2 (17%). Similarly, for receptive language, 65% of variance was explained by RA size (23%) and N2 amplitude (42%) at 6 months. These results suggest that the amygdala plays a significant role during early language acquisition, although the mechanisms involved are as yet unclear. Further, links among amygdala volume, auditory cortical responses in infancy and later language abilities are identified, emphasizing the importance of using converging methodologies to elucidate the course of infant development.

B19

DEVELOPMENTAL CHANGES IN BRAIN MECHANISMS UNDERLYING RECIPROCITY *Wouter van den Bos[1,2], Michiel Westenberg[1,2], Eric van Dijk[1], Serge A. R. B. Rombouts[1,2,3], Eveline A. Crone[1,2]; [1]Leiden University, Institute for Psychological Research, Leiden, the*

Netherlands, [2]Leiden Institute for Brain and Cognition, Leiden, the Netherlands, [3]Leiden University Medical Center, Leiden, the Netherlands – Reciprocity, or repayment of what others have provided us, is an important aspect of social exchange and undergoes changes until late adolescence. Prior studies have demonstrated a network of brain regions important for social exchange and reciprocity, including the anterior medial prefrontal cortex (amPFC) and the dorsolateral prefrontal cortex (DLPFC), but the developmental trajectories of these regions are currently unknown. In this event-related functional MRI study we examined behavioral choices and neural responses in a variant of the Trust Game (Berg et al., 1995), in 54 participants between ages 12-22 (12-14-years, n=21, 15-17-years, n=15, 18-22-years, n=18). Participants were playing numerous one-shot games with unknown age-matched peers and were trusted money on a proportion of trials. We examined whether on those trials, participants reciprocated trust by sharing a large proportion of the money with the trustor, or defected by sharing a small proportion of the money but maximizing their own gains. FMRI data were analyzed for reciprocal and defective choices and resulted in two main findings. First, bilateral anterior insula and anterior cingulate cortex were positively correlated with reciprocity behavior, and this pattern was similar for all age groups. Second, our analysis revealed an age-related decrease in the amPFC for reciprocate choices and an age-related increase in DLPFC for reciprocate and defect choices. These results were interpreted to suggest increased selectivity for self referential thought across adolescent development (Amodio & Frith, 2006). The current findings will be discussed vis-à-vis current theories of social cognitive brain development and psychopathology.

B20

HOW NATURE SHAPES NURTURE: A COMPUTATIONAL ACCOUNT OF GENETIC INFLUENCES ON THE NEURAL SUBSTRATES OF FACE PROCESSING *Lee Newman[1], Thad Polk[1]; [1]University of Michigan* – A number of findings suggest that genetics play a more important role in shaping the processing of faces compared with other visual stimuli. For example, brain damage immediately after birth can produce lasting, selective deficits in face recognition (Farah et al., Cogn Neuropsy, 17:117, 2000), but there are no similar reports of early brain damage producing selective deficits in the recognition of other categories like cars or birds. Patterns of cortical activation evoked by face processing are also more similar in monozygotic twins than in dizygotic twins, but that is not true for patterns evoked by other visual stimuli such as words and chairs (Polk et al., Jnl Neurosci, 27:13921, 2007). By what mechanism could genetics influence the cortical processing of faces more than the processing of other visual stimuli? We hypothesize that an innate subcortically-driven preference to look at faces in early development (Johnson, Nature Rev Neurosci, 6:766, 2005) interacts with established principles of cortical self-organization to lead to the observed effects. We present a neural network model that makes explicit how this hypothesis could work. In particular, we demonstrate that manipulating the similarity of initial connectivity patterns in different models (to simulate the effect of zygosity) has a much bigger effect on the similarity of activity patterns evoked by faces than by other visual stimuli. The model therefore provides a computationally explicit account of the observed effects of zygosity on neural activation patterns in human twins and, more generally, explains how genetics could influence face processing preferentially.

B21

AN ODDBALL INVESTIGATION OF MONOLINGUAL AND BILINGUAL INFANTS' PHONETIC DISCRIMINATION USING FUNCTIONAL NEAR-INFRARED SPECTROSCOPY (FNIRS) *Matthew Dubins[1], Melody S. Berens[1], Ioulia Kovelman[2], Mark Shalinsky[1], Laura-Ann Petitto[1]; [1]University of Toronto, [2]Massachusetts Institute of Technology* – For decades, behavioral data have not adjudicated the question of whether infants use general-auditory or language-specific mechanisms to learn the set of phonetic units that comprise their native language. Here we ask this question by using functional Near-Infrared Spectroscopy (fNIRS, Hitachi ETG-4000) to investigate the neural correlates of language processing in monolingual and bilingual infants. Using an Oddball/Event paradigm, monolingual and bilingual Young infants (age 2-6 months, n = 19), Older infants (age 10-14 months, n=14), and Adults (n=38) were presented with nonlinguistic Tones, and linguistic syllables that differed by one phonetic feature in English, and in Hindi, while undergoing fNIRS. fNIRS measures hemodynamic change (deoxygenated, oxygenated, total hemoglobin), is child-friendly, quiet, portable, and tolerates movement. Its temporal resolution (10-Hz) and spatial resolution (~3-4 cm depth) are excellent for cortical studies of language. Results: Specific neural tissue classically associated with language processing was recruited differently across ages, reflecting maturational changes corresponding to universal linguistic timing milestones. Young monolingual and bilingual infants recruited Left Broca, and bilateral STG, while listening to native and non-native contrasts. Remarkably, all Older infants showed decreased neural recruitment of Left Broca for native English relative to non-native Hindi contrasts. Conclusions: The findings provide first-time imaging evidence that infants use language-specific tissue when learning the set of phonetic units in their native language. Significance: fNIRS allowed examination of the neural underpinnings of phonetic learning in infants, providing important information about the interplay between biology and experience in the developing brain. Funding-Petitto (P.I.): NIHR21HD05055802. NIHR01HD04582203.

B22

WHITE MATTER DIFFERENCES IN FRONTAL REGIONS PREDICTS COGNITIVE VULNERABILITY TO SLEEP DEPRIVATION *Matthew Rocklage[1], Victoria Williams[1], Jennifer Pacheco[1], David Schnyer[1]; [1]University of Texas at Austin* – The corpus callosum (CC) has been implicated in a number of important aspects of interhemispheric processes. Indeed, research has indicated that the CC in general and the genu in particular is important for tasks utilizing the prefrontal cortex (PFC) (Narberhaus et al., 2007). Using diffusion tensor imaging (DTI), we examined whether there were microstructural differences in the CC that predicted a person's vulnerability to the effects of sleep deprivation (SD). To this end, participants were asked to complete a simple visual-motor control task both before and after a span of 36 hr without sleep. A median split analysis was conducted using the percent change in accuracy from pre-SD to post-SD on this visual-motor control task to separate participants into susceptibility groups. A 25 direction DTI scan was acquired from each participant and fractional anisotropy (FA) was calculated and examined across 3 regions of the CC. The results revealed a relationship between a participant's susceptibility to SD and FA values in the genu of the CC, where vulnerable had significantly lower FA values relative to non-vulnerable. There were no differences in either the body or splenium of the CC between the two groups, thus demonstrating the specificity of the anterior CC. These results indicate that differences in the development of cross cortical communication pathways contribute to a person's ability to function effectively when sleep deprived.

B23

EVIDENCE FOR A LARGE IMPROVEMENT IN INTERFERENCE CONTROL OVER MIDDLE CHILDHOOD *Pedro M. Paz-Alonso[1,3], Jon Lovas[2], Chris Blais[1], Silvia A. Bunge[1,2]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]University of California, Berkeley, [3]University of Granada, Spain* – We sometimes experience difficulty distinguishing memories pertaining to the present from memories pertaining to the past, such as where we parked the car today. The ability to overcome interference from previously encountered information is a key component of executive functioning. Age-related increases in the ability to limit interference in working memory have been documented across childhood and adolescence. Here, we tested children aged 7-12 and young adults on a continuous recognition paradigm that places heavy demands on interference control (current N = 20). This task was originally developed by Schnider et al. (1996) to characterize monitoring deficits in confabulating patients. Participants must indicate whenever an

image is repeated within a run, which becomes more difficult as familiarity with the images increases from run to run. In the present study, four runs containing the same set of 110 pictures were presented. Preliminary results shown that increases in memory false alarms (FA) from run to run varied with age. 7-8-year-olds exhibited strong initial FA increases from Run1 (M = 6.20%) to Run2 (M = 30.33%), which diminished slightly in Runs 3-4 (M = 27.15%). 10-12-year-olds and adults both showed a gradual increase of FA from Run1 (M = 5.71%) to Run4 (M = 20.02%). These findings suggest that a large improvement in interference control occurs during middle childhood. For children but not adults, FA rate on the recognition task was positively correlated with response inhibition errors on a Go/No-Go task, suggesting that impulsive responding may influence memory monitoring failures observed during childhood.

B24

NEURAL CORRELATES OF FAIRNESS IN SOCIAL DECISION-MAKING ACROSS ADOLESCENCE AND ADULTHOOD *Berna Guroglu[1,2,3], Wouter van den Bos[1,2,3], Serge Rombouts[1,2,3], Eveline Crone[1,2,3]; [1]Leiden University, Institute for Psychological Research, [2]Leiden Institute for Brain and Cognition, [3]Leiden University Medical Center* – Displays of fair behavior play a crucial role in collaboration and reciprocal exchange in social interactions. The concerns for self versus other change across adolescence but the neural mechanisms that contribute to these developmental changes are currently unknown. The Ultimatum Game (UG), in which a responder can accept or reject an offer made by a proposer, is a well-established tool to study fairness concerns. In this study we have used an adapted version of the UG, the mini-UG, which is better suited for examining fairness and intentionality considerations in social exchanges (Falk, Fair, & Fischbacher, 2003). Prior neuroimaging studies based on the UG in adults have demonstrated that the insula is activated when unfair offers are rejected, whereas the lateral prefrontal cortex (lat-PFC) is activated when unfair offers are accepted and the tendency to reject unfair offers is overridden (Sanfey et al., 2003). We tested whether these brain areas are sensitive to low offers per se, suggesting self-oriented concerns, or to unfairness, suggesting self-other concerns, and the developmental time courses of these brain areas in participants between ages 12 and 25 (current n = 40). Preliminary results show that insula and lat-PFC activity associated with rejection of unfair offers is intention-dependent. Rejection of unfair offers when the proposer did not have a better (fairer) alternative was specifically associated with insula activity. Findings on age differences will be discussed based on the development of perspective-taking across adolescence.

B25

THE SHARED GENETIC UNDERPINNINGS OF IQ AND BRAIN STRUCTURE DECREASE WITH AGE DURING CHILDHOOD AND ADOLESCENCE *Greg Wallace[1], Eric Schmitt[2], Rhoshel Lenroot[1], Philip Shaw[1], Kenneth Kendler[2], Michael Neale[2], Jay Giedd[1]; [1]Child Psychiatry Branch, National Institute of Mental Health, [2]Virginia Institute for Psychiatric and Behavioral Genetics, Virginia Commonwealth University* – Our understanding of the relationship(s) between genes/environment, brain, and behavior remains relatively limited, particularly within the context of child and adolescent development. Given that both intelligence and brain structure are highly heritable, determining whether intelligence and neuroanatomic endophenotypes have shared genetic underpinnings has been a central question to cognitive neuroscience. However, most studies have indicated that the phenotypic correlations between intelligence and brain endophenotypes are surprisingly small. Using data from pediatric twins, siblings, and singletons (n=600) in an extended twin design, we evaluated the shared genetic and environmental correlations between brain structure (i.e., cortical thickness from MRI) and intelligence (measured by age-appropriate Wechsler Intelligence Scales) and how these relationships changed during the child and adolescent years. Within targeted brain areas (predominantly frontal regions) in which intelligence was related to cortical thickness in an age-dependent fashion (Shaw et al., 2006), we predicted and found higher shared genetic mediation of cortical thickness and intelligence than found in the remaining cortical regions. Moreover, despite small phenotypic and genetic correlations between intelligence and cortical thickness, we observed strong and statistically significant genetically mediated relationships when age was incorporated into the analysis. Children with high intelligence appear to have substantially higher genetic variance in cortical thickness, but only during the first decade of life. Our findings indicate that like many aspects of neurodevelopment, the associations between genes/environment, brain structure, and intelligence must be considered dynamic processes in order to fully understand their relationships in children and adolescents.

B26

DEVELOPMENTAL EFFECTS OF NEURAL ACTIVITY ON LANGUAGE PROCESSING: EVIDENCE FROM FMRI *Owens Elizabeth[1], Aznar-Besé Noemí[1], Meschyan Gayane[1], Hernandez Arturo[1]; [1]University of Houston* – The purpose of the present study was to compare neural mechanisms in bilingual children and adults, and to examine the effects of language proficiency level on neural activity during a single word, reading task. All participants were early Spanish-English bilinguals, having learned English by age 7, and having learned Spanish prior to learning English. During the functional magnetic resonance imaging (fMRI) experiment, a list of 60 very simple words, 30 English and 30 Spanish, were presented on a screen one at a time. Participants were instructed to read the words silently and to press a hand-held button when they had finished reading each word. Significant differences in neural activity were found between children and adults. Adults showed increased activity in precentral and middle-frontal gyri compared to children when reading in English. In addition, children showed greater activity in the amygdala, precentral, and postcentral gyri than adults when reading in Spanish. Furthermore, hemispheric differences emerged with activity being more left-lateralized in adults and right-lateralized in children. Taken together these results suggest that word reading progresses from a basic, emotional process to a more integrated, cognitive process as language proficiency changes across development.

B27

REACHING EXPERIENCE AND PERSONALITY INFLUENCE FACE-PREFERENCE - AN EYE-TRACKING STUDY OF INFANTS AND ADULTS *Klaus Libertus[1], Amy Needham[1]; [1]Duke University* – Newborn infants show preferential tracking of moving face-like stimuli (Johnson, Dziurawiec, Ellis, & Morton, 1991). This preference disappears over the course of the first month. Using static images, young infants show a preference for patterns and only around 4-5 months start to prefer faces (Keller & Boigs, 1991). What factors influence this face-preference and how does this behavior relate to infants' own abilities? Here we present two eye-tracking experiments that 1) replicate previous findings on young infants' face preference and also test older infants and adults using the same paradigm, 2) show how a simple motor manipulation - simulated reaching experience - is able to influence this preference, and 3) show correlations between face-preference and infant and adult personality scores. Without motor training, pre-reaching 3-month-old infants show no preference for images of faces over images of toys across two experiments (both $p>0.5$). However, age-matched infants who received two weeks of object-directed reaching training behave differently and do show a preference for faces ($p=0.028$), similarly to older infants between 4-14 months. Further, face-preference and parent-reported activity level (e.g. unfocused activity like kicking and squirming) show a negative correlation in infancy ($p<0.02$) while adults show a positive correlation between face-preference and the self-consciousness score on the IPIP personality inventory ($p<0.03$). Our findings suggest a relation between focused motor abilities and attention towards social stimuli in early infancy. Infants who experience being able to independently act on objects may – similar to adults – look towards faces for signs of social encouragement.

B28

GENETIC POLYMORPHISMS AFFECTING DOPAMINERGIC ACTIVITY PREDICT SPONTANEOUS BLINK RATE IN YOUNG CHILDREN *David Lindenbach[1], Courtney Stevens[1], Jeff Currin[2], Ted Bell[2], Helen Neville[2]; [1]Willamette University, [2]Brain Development Lab, University of Oregon* – Eye blink rate (EBR) has been shown in a variety of experiments to be a marker of central dopamine activity, with higher blink rate associated with higher levels of dopamine (e.g., Deuschl & Goddemeier, 1998; Jutkiewicz & Bergman, 2004). Related research suggests that EBR is associated with performance on some cognitive tasks, including executive functioning in adults (Muller et al, 2007; Dreisbach et al., 2005) and theory of mind in children (Lackner et al., 2008). The present study investigated the relationship between EBR, performance on cognitive tasks, and genetic polymorphisms in young children aged 3-5 years. Eighty children completed an ERP and behavioral battery as part of a larger study. EBR was measured from a 5-minute segment of the EOG/EEG data collected while children passively viewed a short cartoon. The behavioral battery included measures of executive function, theory of mind, and nonverbal intelligence. In addition, children were genotyped for a small set of genes affecting dopaminergic activity, including DAT1, DRD2, and DRD4. Results indicated that children's EBR was associated with their genotype and performance on some cognitive tasks. The largest association was between children's EBR and polymorphisms of the DRD4 gene, with presence of the 7 repeat associated with higher EBR. These findings suggest that EBR is related to both genetic variation and performance on cognitive tasks in young children.

B29

DIFFERENT AGES, DIFFERENT STAGES: A NEURODEVELOPMENTAL AGE-BASED DATABASE OF NORMAL BRAIN DEVELOPMENT FOR MAGNETIC RESONANCE IMAGING *Carmen Sanchez[1], Alexandra Basilakos[1], John Richards; [1]University of South Carolina* – The NIH Magnetic Resonance Imaging (MRI) study of normal brain development recently documented normal brain maturation in children ages 4 years, 6 months to 18 years (Evans, 2006). Using MRIs obtained from the Brain Development Cooperative Group's MRI database, this investigation explored the utility of developing brain templates based on age increments of 6 months. The main goal of the work was to create a database of age-normed MRI volumes and stereotaxic atlases for use with MRI and other forms of neuroimaging. Participants included 860 children and adolescents ranging from 4.5 years to 19.0 years and were divided into age groups by 6 month increments (i.e., children 4.5 to 5.0 years combined as one group). FSL was used to analyze all MRI Volumes. A 'pipeline' was created that produced T1-weighted, T2-weighted, brain and material-segmented (gray matter, white matter, CSF) files for each participant. Following the methods set forth by Evans, et al. (1993), each MRI volume was standardized to the appropriate age norm, and the individual MRIs were registered ('warped') to the age norm average, and then a final average was made. This average was used to develop average T1-Weighted, T2-Weighted, normed MRI volumes in six-month increments from 4.5 to 19 yrs. This database is available for use by qualified laboratories doing this kind of work and can be useful in identifying differences in normed data and in typical MRI work. Several aspects of the database were also examined with respect to known characteristics of brain development.

B30

IS FRAGILE X SYNDROME AN APPROPRIATE NEUROANATOMICAL MODEL FOR AUTISM? *Elizabeth Walter[1], Fumiko Hoeft[1], Joseph Piven[2], Allan Reiss[1]; [1]Stanford University, Center for Interdisciplinary Brain Sciences Research (CIBSR), [2]University of North Carolina, Chapel Hill, Neurodevelopmental Disorders Research Center* – Fragile X syndrome (FXS) is the most common known genetic cause of autism. However not all individuals with FXS are diagnosed with autism (AUT) and it is not presently clear whether FXS provides a helpful neuroanatomical model for AUT. If FXS is a good model for AUT, then both disorders should show similar anatomical differences from the brains of control participants, even from an early age. In order to explore this possibility, we performed voxel-based morphometry to compare the neuroanatomy of boys between the ages of 1.5 and 4 years old who were diagnosed with FXS or AUT (with no diagnosis of FXS), with a control sample comprised of typically developing (TD) and developmentally delayed (DD) boys (FXS: n=52; AUT: n=63; TD: n=31; DD: n=19). We found that FXS and control participants were maximally different in a region comprising bilateral basal ganglia, cingulate cortex and insula. In contrast, differences between AUD and controls were seen primarily in the cerebellum and ventral temporal lobe as well as bilateral inferior frontal gyrus. In addition, support-vector machine (SVM) analyses designed to maximally differentiate groups were best able to discriminate FXS brains from AUT, and FXS from control participants. The SVM was not very accurate at discriminating AUT from controls. This analysis provides further evidence that neuroanatomical development in FXS follows a trajectory that differs from boys with autism, as well as from control participants. In short, FXS may not provide a helpful anatomical model of autism, at least at this young age.

B31

REWARD SENSITIVITY AND RISK TAKING IN ADOLESCENT DEVELOPMENT *Linda Van Leijenhorst[1,2,3], Bregtje Gunther Moor[1,2,3], Michiel Westenberg[1], Serge Rombouts[1,2,3], Eveline Crone[1,2,3]; [1]Leiden University, Institute for Psychological Research, [2]Leiden Institute for Brain and Cognition, [3]Leiden University Medical Center* – Previous studies on adolescent decision-making have suggested that the protracted development of prefrontal relative to limbic brain regions could bias adolescents to focus on potential rewards and engage in risky behavior. This hypothesis is based on imaging studies using simple reward paradigms. How these regions contribute to decision-making on a trial-to-trial basis has not yet been tested in this age group. We collected event-related fMRI data in 46 participants aged 8 to 25 using a task in which participants repeatedly chose between safe gambles, associated with a 67% chance of winning 1 Euro, and risky gambles, associated with a 33% chance of winning 2, 4, 6 or 8 Euros. This design enabled us to examine brain regions sensitive to reward magnitude and their contribution to risk taking throughout adolescence. Behavioral data show that all participants chose more risky gambles as rewards were higher. Participants were increasingly risk averse, and differentiated more between reward amounts with age, which indicates strategy differences. Analysis of brain activation preceding choices revealed that in adults risky gambles were associated with decreased lateral prefrontal activation, whereas in adolescents risky gambles were accompanied by increased activation in the ventral striatum. We suggest that children and adolescents adopt an explorative strategy in contrast to an exploitative strategy used by adults because of immature contribution of prefrontal cortex regions. We are currently testing whether neural activation predicts risk taking in different age groups, and can increase our understanding of the role of reward sensitivity in adolescent decision-making under risk.

B32

WHITE MATTER MATURATION SUPPORTING THE DEVELOPMENT OF FLUID REASONING *Kirstie Whitaker[1], Elizabeth O'Hare[1], Zdena Op de Macks[2], Brian Johnson[1], Emilio Ferrer[3], Silvia Bunge[1,3]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]Leiden University, The Netherlands, [3]University of California, Davis* – Little is known about the changes in connections between brain regions that underlie cognitive development. The goal of this study (current N=24) is to investigate the structural integrity of white matter tracts using diffusion tensor imaging. We hypothesize that strengthened connections between frontal and parietal cortices are critical for the development of higher cognition. Here we present cross-sectional data from a longitudinal study examining how white matter development contributes to fluid reasoning ability, a key construct in human intelligence. Participants aged 6 to 19 years were scanned at 3T with a 64-direction diffusion-

weighted acquisition. These subjects also completed performance IQ (block design, matrix reasoning) subtests of WASI and the verbal IQ (vocabulary) subtest. Whole-brain correlations show strong age-related increases in FA throughout the brain. Functionally-derived regions of interest (ROI) in rostrolateral prefrontal cortex from our prior fMRI research on reasoning development (Wright et al., 2008) revealed a strong positive correlation between FA and age, but not with age-corrected IQ measures. We also created an ROI in left inferior parietal cortex based on our recent finding of an age-independent positive relationship between cortical thickness and fluid reasoning ability in left inferior parietal cortex (O'Hare, CNS abstract submission, 2009). In the white matter regions surrounding these coordinates, we saw a significant correlation between mean FA and age-corrected scores on block design ($r = 0.411$, $p = 0.023$). In this limited sample, structural changes in parietal cortex are most predictive of individual differences in fluid reasoning from age 6 to 19.

B33

DOPAMINERGIC MODULATION OF SPATIAL WORKING MEMORY PERFORMANCE IN ADOLESCENCE: A MOLECULAR GENETIC APPROACH *Monica Luciana[1,2], Dustin Wahlstrom[1,2], Tonya White[1,2]; [1]University of Minnesota, [2]University of Minnesota, Center for Neurobehavioral Development* – Dopamine modulates cognitive processes that are prefrontally and striatally-mediated, including spatial working memory. This modulatory role has been studied in animals using lesion and pharmacological approaches and confirmed in adult humans using pharmacological probes. It is unknown whether dopamine modulates behaviors prior to adulthood in a manner that is similar to its role in adult behavior. We have assessed dopamine's modulation of spatial working memory in human adolescence (broadly defined) using a molecular genetic approach focusing on single nucleotide polymorphisms that regulate various aspects of dopamine activity: catabolism (COMT Val/Met 158/108), postsynaptic receptor activity (DRD2 Taq1A allele),and presynaptic regulation/transporter mechanisms (DAT). Participants, (n=182, ages 9 to 23), provided a DNA sample and completed neurocognitive tasks, including a visuomotor spatial delayed response task requiring participants to recall spatial locations after delays of 0, .5 and 8 seconds. Task performance improves until age 13 and stabilizes thereafter. Performance is modulated by the COMT and DRD2 genotypes, which interact with age to influence performance. Individuals who are Val-Val homozygotes for COMT and possess the low receptor activity DRD2 allele perform worst when working memory demand is high. The influence of COMT on working memory likely occurs through prefrontal mechanisms; the D2 receptor system's influence on spatial working memory more strongly involves striatal versus frontal regions. Thus, dopamine activity in both regions contributes to spatial working memory performance as adult levels of performance are being attained. Findings will be discussed in relation to mechanisms that underlie adolescents' vulnerabilities to impairments in executive function.

B34

THE EFFECT OF SYNTACTIC COMPLEXITY AND SENTENCE LENGTH ON ORAL LANGUAGE PROCESSING IN CHILDREN: A FUNCTIONAL NEUROIMAGING STUDY *Jason Yeatman[1], Michal Ben-Shachar[2,3], Gary Glover[1], Heidi Feldman[1]; [1]Stanford University, School of Medicine, [2]Stanford University, [3]Gonda Brain Reseach Center, Bar Ilan University* – Though language is conceptualized as a left lateralized brain function, adult neuroimaging studies document bilateral activation for sentence comprehension when task demands are high. We sought to describe changes in neural networks of children comprehending sentences of varying length and syntactic complexity. Participants were 11 through 14 year olds (n=8) with normal language abilities. Functional magnetic resonance imaging data were collected on a 3T scanner using a spiral in/out sequence. Each subject completed four runs of an event-related, sentence verification task with 24 different sentences presented in random order. A general linear model was estimated for each subject; contrasts were generated for syntactically hard > easy and long > short sentences. These contrasts were used in a random effects analysis to generate group maps. The hard > easy contrast showed significant peaks ($p<0.001$) in the right insula and right occipital lobe (lingual gyrus) for the group. The long > short contrast showed significant peaks in the left and right superior and middle temporal gyri, with more significant voxels on the right side for the group. 2 out of 8 subjects showed significant peaks ($p<0.01$) in the inferior frontal gyrus on hard > easy and 3 out of 8 on the long > short contrast. Right hemisphere regions appear to play a greater role in understanding spoken language for children, as syntactic complexity and sentence length increase. Future studies will determine if children's language abilities are related to individual differences in active brain regions.

B35

PARENT TRAINING INTERVENTIONS ENHANCE SELECTIVE AUDITORY ATTENTION IN 3- TO 5- YEAR OLD CHILDREN *Jeff Currin[1], Jessica L. Fanning[1], Scott R. Klein[1], Helen J. Neville[1]; [1]University of Oregon, Institute of Neuroscience* – The development of selective attention skills begins at an early age and continues through early adulthood. Evidence suggests that proper development of selective attention skills is crucial for self-regulation abilities and academic achievement. Research has shown event related brain potentials (ERPs) can be used to index mechanisms of selective attention in 3- to 5- year old children (Sanders et al 2005). Additionally, Stevens et al.(in press) reveals that children from low socio-economic status (SES) backgrounds have reduced amplitude selective attention effects compared to higher SES children. This study investigates the effectiveness of an attention-training program designed for typically developing, economically disadvantaged children and families to improve cognitive performance and attention. Prior to the seven-week training period, parents were randomly assigned to a control group or to receive training. Training consisted of eighteen hours over seven weeks of discussion on parenting methods and strategies. The training also included seven hours of attention building activities for children. Children were tested before and after the training period on an array of behavioral assessments and ERP paradigms. Specifically, children participated in a Hillyard type auditory selective attention task while ERPs were recorded to attended and unattended stimuli. Children in the training group revealed significant increases in ERP amplitudes as well as a more global distribution of the attention effect when compared to controls. Gains in a variety of behavioral tests were also observed. This evidence suggests that modifications in parenting behavior and child attention training lead to marked enhancements in children's cognitive function.

B36

MEG MEASURES OF NEURAL SYNCHRONY AND PERCEPTUAL REPRESENTATION IN AUDITORY LANGUAGE CORTEX IN CHILDREN WITH AUTISM AND TYPICALLY DEVELOPING CHILDREN *Nicole Gage[1], A. Lisette Isenberg[1], Paul Fillmore[1], Kathryn Osann[1], M. Anne Spence[1]; [1]University of California, Irvine* – We used Magnetoencephalography (MEG) to assess neural synchrony and activation levels in auditory language cortex in children with autistic disorder (AD) and typically developing (TD) controls. Previously, we reported reduced hemispheric synchrony in left and right M100 peaks in children with AD vs. controls. Here we recorded M100 latency and amplitude in response to speech (consonant-vowel syllables) to assess hemispheric synchrony and neural activation levels over time during brief (4m) scans. Our sample included 10 boys (5 AD, 8-12 years). For each child, the recorded scan was divided into 4 equal blocks representing the first, second, third, and final 100 epochs. We assessed the time course of neural processing by measuring M100 latency and amplitude for each block. Hemispheric symmetry: TD - M100 LH-RH latencies were tightly coupled in time and decreased from the 1st (19.5ms) to final block (12.5ms). AD - M100 latencies were more offset and this increased from the 1st (26 ms) to the final (35.8) block. Neural activation: TD - M100 amplitude increased 20% from initial to final block. AD - M100 amplitude decreased -0.04% from first to

final block. Results provide evidence that TD children have LH and RH responses that are initially tightly coupled in time and become more synchronized, with increased neural activation levels, over time. In sharp contrast, children with AD have LH and RH responses that are initially offset in time and become more dyssynchronous, with decreased activation levels, over time.

B37

ADOLESCENT DEVELOPMENT AND PRISONER'S DILEMMA TASK STRATEGIES: COGNITIVE, PERSONALITY, AND PSYCHOPHYSIOLOGICAL CORRELATES *Elizabeth Olson[1], Paul Collins[1], Monica Luciana[1]; [1]University of Minnesota* – The Prisoner's Dilemma is a task that reflects decision-making in social circumstances in which choice behavior affects not only oneself but also a partner. We have previously reported findings regarding cognitive, personality, and psychophysiological correlates of Prisoner's Dilemma task behavior in college-aged students (Olson et al., CNS poster, 2006). The present analysis will expand upon this work by presenting developmental changes in younger adolescents' strategic approaches to the Prisoner's Dilemma task as compared to college students. Both overall cooperation rates and trial-by-trial responses to ongoing interactions are examined. Relationships between Prisoner's Dilemma behavior and impulsive decision-making on a delay discounting task are reported. Task performance is evaluated with respect to performance on measures of intelligence, executive functioning (Iowa Gambling Task, Go-NoGo task), and personality factors on the Multidimensional Personality Questionnaire (MPQ). Skin conductance and heart rate data are examined for physiological correlates of task performance. Individual differences in skin conductance responses to feedback predict task strategies. Results are discussed in terms of the relative rates of maturation during adolescence of ventral versus dorsal prefrontal cortices, regions that support social decision-making processes.

B38

CONNECTING THE DOTS: HOW LOCAL STRUCTURE AFFECTS GLOBAL INTEGRATION IN INFANTS *Melanie Palomares[1], Mark Pettet[1], Vladimir Vildavski[1], Chuan Hou[1], Anthony Norcia[1]; [1]The Smith-Kettlewell Institute* – Glass patterns are moirés created from a sparse random dot field paired with its rotated, expanded or translated copy. Because discrimination of these patterns is not based on local features, they have been used extensively to study global integration processes. Here, we investigated whether 4-5.5 month old infants are sensitive to the global structure of Glass patterns by measuring Visual Evoked Potentials (VEPs). Although we found strong responses to the appearance of the constituent dots, we found sensitivity to the global structure of the Glass patterns in the infants only over a very limited range of spatial separation. In contradistinction, we observed robust responses in the infants when we connected the dot pairs of the Glass pattern with lines. Moreover, both infants and adults showed differential responses to exchanges of between line patterns portraying different global structures. A control study varying luminance contrast in adults suggests that infant sensitivity to global structure is not primarily limited by reduced element visibility. Together our results suggest that the insensitivity to structure in conventional Glass patterns is due to inefficiencies in extracting the local orientation cues generated by the dot pairs. Once the local orientations are made unambiguous or when the interpolation span is small, infants can integrate these signals over the image.

B39

CORTICAL SOURCES OF INFANT VISUAL PREFERENCES *Greg Reynolds[1], John Richards[2], Mary Courage[3]; [1]University of Tennessee, [2]University of South Carolina, [3]Memorial University* – The major goal of this study was to identify the cortical sources of infant visual preferences. Paired-comparison trials were embedded within the modified-oddball ERP procedure in order to assess the distribution of infant visual preferences throughout ERP testing. The cortical sources of ERP components associated with visual preferences were localized with equivalent current dipole (ECD) analysis. Forty-seven infants were tested at 4.5, 6, or 7.5 months of age. Infants were videotaped during testing and high-density EEG was recorded. Paired-comparison trials were embedded within the modified-oddball ERP procedure. This involved blocks of brief stimulus ERP presentations of frequent familiar, infrequent familiar, and infrequent novel stimuli, alternated with a single paired-comparison between stimulus types. Looks were coded to determine visual preferences. A spatial Independent Component Analysis (ICA) was run on the EEG data. The location of cortical sources from the ICA weights was estimated with ECD analysis. The cortical source models for the ECD analysis used 'finite-element model' (FEM) mapping to map the source locations onto anatomical MRIs obtained from infant participants. The cortical sources for the 4.5-month-olds were scattered across the medial-lateral aspects of the basal prefrontal cortex. There was an increasing trend with increased age for infants to show a larger proportion of active midline areas. The best fitting areas in common between the brief stimulus and paired-comparison procedures were in the inferior prefrontal regions. This common activation indicates that these areas of the brain are involved in infant visual preferences and the allocation of attention toward a given stimulus.

B40

ASSOCIATIONS OF EVENT-RELATED POTENTIAL MEASURES OF COGNITIVE CONTROL WITH NEUROIMAGING-DERIVED INDICES OF STRUCTURAL BRAIN DEVELOPMENT IN ADOLESCENCE *Paul Collins[1], Kristin Sullwold[1], Ryan Muetzel[1], Kelvin Lim[1], Monica Luciana[1]; [1]University of Minnesota* – Studies of adolescent brain development have documented age-related changes in event-related potentials (ERPs) associated with response monitoring and cognitive control, such as the stimulus-locked N2 and the response-locked error-related negativity (ERN). Neuroimaging research has demonstrated that maturational changes in cortical structure continue throughout adolescent development, including age-related decreases in gray matter and increases in white matter. This study used ERP time and frequency analyses to investigate response monitoring and inhibitory control during a go no-go task performed by adolescents and young adults (n=50; age range 11-25 years, median age 17 years). Participants also completed a structural MRI protocol, including a T1 scan that was processed to derive cortical thickness measures for a broad set of parcellated anatomical regions. As expected, ERN amplitude was greater in older participants while N2 amplitude was greater for younger participants, effects that were particularly pronounced in theta-band frequencies. Additionally, ERN and N2 amplitudes in both the time and theta-band frequency domains were associated with cortical thickness in the middle cingulate cortex, as well as in immediately adjacent cortical regions (e.g., postcentral gyrus). The results will be interpreted in relation to interactions involving structural and neurophysiological brain development during adolescence within regions that modulate cognitive control.

B41

THE DEVELOPMENT OF COGNITIVE CONTROL IN CHILDREN AND ADOLESCENTS WITH AUTISM SPECTRUM DISORDERS *Marjorie Solomon[1,2,3], Stanford Ly[1], Cameron Carter[1,3]; [1]University of California, Davis, [2]MIND Institute, [3]Imaging Research Center* – Individuals with autism spectrum disorders (ASDs) exhibit impairments in cognitive control. As yet, there has been little study of the developmental trajectory of the neural correlates of cognitive control in these individuals. Participants included 4 groups of 15 individuals with ASDs and typical development (TYP), divided into younger (12-15) and older (16-18) ages. Slow event-related fMRI was used to examine differences in performance between the groups in the Preparing to Overcome Prepotency task, a stimulus response incompatibility paradigm. Beta series correlations were used to investigate developmental changes in functional connectivity during the task in frontal regions including anterior PFC (aPFC) and DLPFC using a method adapted from Dosenbach et al., (2008). Younger individuals exhibited higher levels of brain activation in frontal and parietal brain regions than older ones. The TYP group exhibited increases in

functional connectivity with increased cognitive control demands over time for regions of the aPFC and the DLPFC. In TYPs, aPFC connections were limited in younger children, however integration with occipital cortex became evident for older ones. For the DLPFC, younger TYPs exhibited connectivity with aPFC, thalamus and temporal parietal junction. Older TYPs did not exhibit DLPFC connectivity. For the young ASD group, connectivity with aPFC and DLPFC was limited, however, by the older age period, the ASD group demonstrated patterns of regional connectivity comparable to younger TYPs. In ASDs, connectivity patterns show a delayed developmental trajectory compared to TYPs. Further studies are needed to determine whether functional brain integration may catch up in ASD's.

Higher level cognition: Other

B43

ESCAPING THE PRISONERS DILEMA: AN FMRI STUDY OF SOCIAL COOPERATION IN A COORDINATION GAME *Timothy Hodgson[1], Francesco Guala[2], Tim Miller[3], Hannah Enke[1], Ian Summers[4]; [1]Exeter Centre for Cognitive Neuroscience, School of Psychology, University of Exeter, UK, [2]School of Humanities & Social Sciences, University of Exeter, UK, [3]School of Business & Economics, University of Exeter, UK, [4]Peninsula MR Research Centre, School of Physics, University of Exeter, UK* – Previous studies have used the prisoners dilema task to study brain mechanisms involved in social cooperation. But is life really a prisoners dilema? We suggest that strong mutual incentives usually exist which bias behaviour towards social cooperation. Opportunities to break cooperative conventions only occur infrequently in the real world. We report the results of an fMRI study of a 'coordination game' in which pairs of participants make a choice to press one of two response buttons. On most rounds participants receive monetary reward only when they choose the same response key. These coordinating or 'normal' rounds are interspersed with 'special' rounds on which the participant in the scanner is given an incentive to defect (analogous to breaking a social convention). Compared to normal rounds the decision period on special rounds was associated with increased activity in widespread areas of the prefrontal cerebral cortex. Regions which showed greater activity for defect compared to cooperate decisions included the caudate nucleus and the orbitofrontal cortex. On rounds for which participants opted to continue cooperation, activity was observed in inferior (BA47) and rostral medial (BA10) prefrontal cortex along with more ventral areas of the striatum. The number of rounds of successful coordination prior to the first special round was a significant predictor of anterior cingulate activity during decision periods. We conclude that periods of successful cooperation modify the degree of decision conflict when defection opportunities arise. Participants who sustain cooperation engage mentalising processes which bias decision making against responses based on proximal rewards.

B44

NEURAL SYSTEMS CODING WHO IS THE ACTOR IN GOAL-DIRECTED ACTION *Richard Ramsey[1], Antonia Hamilton[1]; [1]School of Psychology, University of Nottingham, University Park, Nottingham, UK* – The identity of other people is critical for the meaning of social interactions. For example, handing #10 to a shop-keeper or to a man with a knife are two very different things. That is, the meaning of a simple, goal-directed action can vary depending on the identity of the actors involved. Research examining action understanding has identified a mirror neuron system (MNS) in the inferior frontal gyrus (IFG) and inferior parietal lobe (IPL) which encodes action features such as goals and kinematics. However, it is not yet known how the brain represents actor identity within the context of goal-directed action. In the present paper, we used a repetition suppression (RS) paradigm during functional magnetic resonance imaging (fMRI) to examine the neural representation of actor identity within the context of goal-directed actions. Participants watched video clips of two different actors with two different goals. Repeated presentation of the same actor suppressed the blood oxygen level-dependent (BOLD) response in right middle frontal gyrus (MFG), a region superior to the classic MNS region of IFG. This data suggests that right MFG contains a population of neurons that encodes the agent of action - that is; they encode who is performing goal-directed action. Our data support the hypothesis that the MNS is agnostic with respect to who is performing the action, and other brain regions are needed to make complete sense of social situations. These results advance our understanding of the neural basis of social cognition.

B45

TUNING IN: PREFERRED MUSICAL RHYTHMS BOOST PREMOTOR ACTIVITY *Katja Kornysheva[1], D. Yves von Cramon[1,2], Thomas Jacobsen[3], Ricarda I. Schubotz[1,2]; [1]Max Planck Institute for Neurological Research, Cologne, Germany, [2]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, [3]BioCog-Cognitive and Biological Psychology, Institute of Psychology I, University Leipzig, Germany* – Recent studies showed that motor-related areas become involved both during rhythm tasks and preference-related responses to music. Does attention to preferred rhythms increase activity in the motor system? Our goal was to determine whether the BOLD-response in the motor system is enhanced by preferred compared to not preferred rhythmic musical rhythms and whether this activity can be traced back to the most important timing-related preference, namely tempo (i.e., beat frequency). Based on the subjects' aesthetic judgments, individual preferences were determined for the different constituents of the systematically controlled musical rhythms. Results demonstrate activity in several motor-related areas to be elevated by preferred musical rhythms and reveal a central role of the ventral premotor cortex (PMv) in timing-related preference, specifically during attention to preferred tempo.

B46

PRESTIMULUS EEG FRONTAL THETA AND OCCIPITAL ALPHA ACTIVITIES REFLECT PRESTIMULUS TOP-DOWN PROCESSING *Byoung-Kyong Min[1,2], Jae-Jin Kim[1,2,3], Hae-Jeong Park[1,2,3]; [1]Brain Korea 21 Project for Medical Science, Yonsei University College of Medicine, Seoul, Korea, [2]Nuclear Medicine and Research Institute of Radiological Science, Yonsei University College of Medicine, Seoul, Korea, [3]Yonsei University College of Medicine, Seoul, Korea* – The prestimulus reflection of poststimulus events was recently reported in human EEG alpha activity. Nevertheless, it still remains unclear whether other oscillatory activity can reflect top-down processing, even before stimulation. Since theta activity has been implicated in working memory processing, we investigated whether EEG theta activity reflects top-down inhibitory control in advance of stimulus onset. EEG was recorded from 15 healthy controls performing a color and a shape discrimination task. Both tasks required inhibition of the task-irrelevant feature. To investigate the time course and power of oscillatory activity, EEG signals were convolved with Morlet wavelets. We observed that the amount of both frontal theta and occipital alpha power in the prestimulus period was modulated by subsequent task relevance. Taken together with behavioral results, the difficult task (shape task) was preceded by significantly higher occipital alpha and frontal theta power compared to the easy task (color task). Since such task-differences were already reflected in prestimulus alpha and theta power, not only prestimulus alpha but also prestimulus theta activity may convey a top-down preparation of the subsequent task performance.

B47

SOCIAL AND SEMANTIC PROCESSING IN THE ANTERIOR TEMPORAL LOBES: EVIDENCE FROM AN FMRI CONJUNCTION TASK *Lars A. Ross[1,2], Marian Berryhill[1,2], David Drowos[1,2], Ingrid Olson[1,2]; [1]Temple University, Philadelphia, PA, [2]University of Pennsylvania, Philadelphia, PA* – The anterior temporal lobes (ATL) have been hypothesized to have semantic memory functions and social-emotional functions, such as theory of mind (ToM). Insufficient discourse between different

divisions of the literature has motivated recent attempts to reconcile these distinct functions. In the fMRI experiment reported here we contrasted conditions that have been found to stimulate ATL activity in past experiments in order to investigate overlap between activations evoked by stimuli of vastly different nature. Since functional imaging of the ATL's often suffers from signal dropout due to their proximity to the nasal sinuses, we used an optimized pulse sequence and small voxel size. Our findings are discussed in reference to recent evidence of the involvement of the ATL's in social semantic processing and neuropsychological data from patients with frontotemporal dementia.

B48

RHYTHM EVOKES ACTION: PROCESSING OF METRIC DEVIANCES IN EXPRESSIVE MUSIC BY EXPERTS AND LAYMEN REVEALED BY ELECTRICAL NEUROIMAGING *Clara E. James[1,2], Christoph M. Michel[1,3], Juliane Britz[1,3], Patrik Vuilleumier[1,3], Claude-Alain Hauert[1,2]; [1]Geneva Neuroscience Center, Switzerland, [2]Faculty of Psychology and Educational Sciences, University of Geneva, Switzerland, [3]Fundamental and Clinical Neurosciences, University of Geneva, Switzerland* – Within expressive classical piano compositions, temporal expectancies were manipulated by alternating conventional masculine cadences at metrically strong positions with less common feminine or metrically unaccented cadences. Interspersed pieces terminating on conventional and deviant cadences were presented to 13 expert pianists and 13 musical laymen while high density EEG was recorded. D-prime scores revealed that experts detected deviant cadences better than laymen. An early positive frontal ERP component was elicited by both conventional and deviant closure (~ 150-300 ms) in both groups; analyses on a large array of ERP difference waves (deviant minus conventional) showed stronger amplitudes at frontal and parietal electrodes in experts. An ANOVA on Global Field Power (GFP) for this time window exhibited a Group X Condition interaction; contrasts confirmed stronger GFP in experts for metric deviance. Using an ERP source imaging approach, we localized putative contributive sources for this component by means of statistical parametric mapping. In a subset of 50 regions of interest, activated by both groups, including bilateral supplementary motor areas, posterior cingulate cortex, right (pre)cuneus and right medial temporal areas, experts manifested overall stronger activation. Later on (470-600 ms), posterior cingulate cortex was exclusively activated in experts. Like in a previous study, using harmonically incongruent cadences with the same participants and compositions, stronger right medial temporal activations occurred early in time in experts. However, differences were overall much larger for harmonic than for metric deviances. In conclusion the broadly distributed concurrent motor activations in response to metric deviances suggest that rhythm particularly evokes action.

B49

ARE YOU LEFT BRAINED OR RIGHT BRAINED? DIFFERENCES BETWEEN DEMOCRATS AND REPUBLICANS ON A POLITICAL FLANKER *Scott McLean[1], Sandra Wiebe[1], Michael Dodd[1], John Hibbinig[1], Kevin Smith[1], Kimberly Espy[1]; [1]University of Nebraska-Lincoln* – Recent findings suggest a role for genetic factors in political attitudes (Alford et al., 2005). Differences in political attitudes are also tied to neural and behavioral performance in a go/no-go task tapping sensitivity to cues altering a habitual response (Amodio et al., 2007). We used the Eriksen flanker paradigm to measure interference control in another way, using political stimuli (faces of current political figures) and non-political stimuli (happy and angry faces). Participants were 63 undergraduates at a Midwestern university. In a pretest, participants reported their own political affiliation and rated a battery of potential task stimuli in terms of likability; the two highest-rated happy and own-party faces and the lowest-rated angry and other-party faces were used. In the flanker task, participants pressed one of two buttons indicating like/dislike of the center target picture, flanked by either congruent or incongruent stimuli. Reaction time (RT) was averaged by target and flanker. For Democrats, a significant flanker congruency effect for RT occurred only for angry targets with angry flankers (relative to angry flanked by happy; p=.03), whereas for Republicans significant effects were found for Republican/Republican vs. Republican/Democrat (p=.002), happy/Republican vs. happy/Democrat (p=.05), and happy/happy vs. happy/angry faces (p=.04). This is consistent with previous findings suggesting politically conservative individuals' performance is more susceptible to interference from conflicting information. These results will be discussed in relation to neural regions involved in the processing of conflict information.

B50

EVENT-RELATED POTENTIALS OF SUBJECTS WHO FEEL STUDIED LARGELY DIFFER FROM THOSE OF SUBJECTS WHO DO NOT HAVE THIS FEELING *Marie Prévost[2,3], J. Bruno Debruille[1,2,3]; [1]McGill University, [2]McGill University, Neurology and Neurosurgery, [3]Douglas Mental Health University Institute* – The feelings of being studied and submitted to magnetic or electrical fields could have an impact on the way subjects process stimuli during fMRI or TMS experiments. The present study is a first attempt at exploring this impact. Subjects were placed behind a one way mirror and were told that electrical fields could be emitted to temporarily change the way their brain functions. A short scale was created with three items to assess feelings of being studied and two items to assess whether the subjects felt that their functioning was changed. The event-related potentials (ERPs) of 38 subjects were recorded during a semantic categorization task. In the N400 time window, ERPs were more positive over left frontal electrodes in subjects who felt studied than in subjects who did not feel studied. These feelings did not impact the N400 amplitude over centro-parietal electrodes, where it is classically maximal. Interestingly, subjects who felt studied had greater late positivities than those who did not and this large difference was widespread over the scalp. The late positivity has been proposed to reflect processing about the self and others. It is thus possible that subjects who felt studied were more focused on the experimenters and on themselves, as they were aware of the attention devoted to them. In contrast, the feelings of having one's functioning changed had no impact on the ERPs. These results are of major importance for neuropsychological studies, as it is often assumed that all subjects react similarly to the laboratory environment.

B51

MODULATIONS OF NEURAL RESPONSES TO FACIAL ATTRACTIVENESS BY PERSON-KNOWLEDGE *Jasmin Cloutier[1], William Kelley[2], Todd Heatherton[2]; [1]MIT, [2]Dartmouth College* – This study examined how person-knowledge modulates the neural substrates underlying the perception of facial attractiveness. Using fMRI, female subjects were imaged while viewing faces varying on physical attractiveness. Prior to seeing the faces, participants were sometimes presented with descriptive information (i.e., person-knowledge). Subjects were instructed that, when available, they should use the person-knowledge to form impressions of the subsequently presented faces. Importantly, this information depicted the person in either a positive, neutral, or negative light. Of interest was the neural activity to faces varying on attractiveness as a function of the type of person-knowledge presented. Analyses focused on brain areas previously shown to be sensitive to the reward value of facial attractiveness (Cloutier, Heatherton, Whalen, & Kelley, 2008). Results revealed that the ventral striatum was only preferentially responsive to attractive faces when no person-knowledge or when neutral person-knowledge preceded the faces. In contrast, ventral medial prefrontal brain regions were preferentially recruited when viewing faces preceded by positive information, irrespective of facial attractiveness.

B52

DEFAULT NETWORK FUNCTIONAL CONNECTIVITY IS MODULATED BY SMOKING *Brett Froeliger[1], Rachel Kozink[1], Avery Lutz[1], Jed Rose[1], F. Joseph McClernon[1]; [1]Duke University Medical Center* – Smoking abstinence has been shown to result in persistent changes in spontaneous brain activity using electroencephalographic measures (Gilbert et al., 1999, 2004). Recently, fMRI and PET methods have elucidated correlated

spontaneous brain activity in the absence of task demands in a network of midline structures including the precuneus, medial prefrontal cortex and anterior cingulate cortex. Functional connectivity (fc) of the 'default network' likely reflects non-goal directed, introspectively oriented cognition. The current study sought to evaluate the effects of smoking abstinence on the spatial distribution of this network. BOLD-fMRI images were collected in smokers (n = 15) during a 5-minute eyes-closed resting period during two sessions: once following 24 hr abstinence, and once following smoking as usual. In each session, fc was observed between brain regions previously identified as comprising the default network. Session differences revealed increased default network fc during satiety relative to abstinence in left caudate, while greater default network fc during abstinence relative to satiety was observed in right superior temporal gyrus, left superior parietal and paracentral lobules. The caudate is known to be highly innervated by dopaminergic neurons, and smoking has been shown to increase dopamine release in the caudate. The present findings suggest the caudate to be more functionally connected to the default network during satiety than during abstinence. This shift to increased caudate-default network connectivity during satiety may reflect the reinforcing aspects of smoking addiction. Implications for understanding the relationship between caudate and default mode within the framework of smoking addiction will be discussed. Research funded by a grant from the National Institute on Drug Abuse (K23DA017261; FJM). CORRESPONDING AUTHOR: F. Joseph McClernon, Ph.D., Tobacco Research Laboratory, Department of Psychiatry and Behavioral Sciences, Duke University Medical Center, Box 2701, Durham, NC 27708.

B53

GONADAL STEROID HORMONES MODULATE SUBGENUAL ACTIVITY IN WOMEN DURING REST *Shau-Ming Wei[1], Erica B. Baller[1], Daniella Furman[2], Philip D. Kohn[1], Peter J. Schmidt[1], Karen F. Berman[1]; [1]National Institute of Mental Health, National Institute of Health, [2]Standford University* – There is considerable evidence that gonadal steroids modulate neural circuits underlying cognitive and affective behaviors in humans. To further investigate the effects of gonadal steroids on neural function, we used PET to assess resting regional cerebral blood flow (rCBF) as a function of hormone condition. Twenty-five healthy, regularly-menstruating women underwent two eyes-open resting PET scans (10 mCi H215O IV per scan) during each of three different hormone conditions: ovarian suppression (i.e. hypogonadism) induced by the gonadotropin-releasing hormone agonist leuprolide acetate (Lupron); Lupron plus estradiol replacement; and Lupron plus progesterone replacement. The two scans per hormone condition were averaged and entered into a second-level random effects analysis (SPM5) to compare across hormone conditions. Additionally, rCBF values extracted from a sphere centered on the between-hormone-condition difference in subgenual cortex (BA25) were entered into a whole-brain cross-correlation analysis to assess BA25 connectivity. In the presence of estradiol and progesterone, there was significantly increased ($p<0.002$, uncorrected) activity in BA25 compared to Lupron treatment alone (i.e. in the absence of ovarian hormones). With estradiol replacement, connectivity analysis revealed positive functional interactions ($p<0.002$, uncorrected) between BA25 and several regions highly associated with affective processing, including anterior cingulate, left amygdala, hippocampus, and putamen. Our data demonstrate that the hormonal milieu is important for regulating circuit-level activity including BA25. Since BA25 is known to be important for pathophysiology and treatment of depression, our findings provide a framework for understanding affect control in general, and, more specifically, hormonally-dependent conditions, such as perimenopausal, post-menopausal and menstrual-cycle-dependent mood disorder.

B54

THE EFFECTS OF STIMULUS SALIENCE, ATTENTION-SWITCHING, AND WORKING MEMORY LOAD ON P3 AMPLITUDE IN A DECEPTION TASK: AN ERP STUDY *Laura Bradshaw-Baucom[1], Scott Meek[1], Michelle Phillips[1], Jennifer Vendemia[1]; [1]University of South Carolina* – Stimulus salience, attention-switching, and working memory load mediate event-related potentials (ERPs) associated with deception. College-aged students (N=45) performed one of three variations of a two-stimulus directed-lie task while ERPs were assessed with a 128-channel sensor net. Two ERPs were examined, a waveform related to workload and attention (P3b) and a waveform associated with attention-switching (P3a). Participants were assigned to respond deceptively to 20%, 50%, or 80% of trials. Previous ERP research suggests that P3b waveform amplitude decreases with increased working memory load while it increases in response to highly salient stimuli (Kok, 2001). Switching from a difficult response to an easier response produces an increase in amplitude of the P3a waveform (Comerchero & Polich, 1999). We expected to see a maximum decrease in P3b waveform amplitude when participants responded deceptively to 80% of trials due to increased working memory load. P3b amplitude was expected to be greatest when participants responded deceptively to 20% of trials due to increased salience of the stimuli pertaining to deception. We expected to see a maximum increase in P3a waveform when switching from making a more difficult deceptive response to making an easier truthful response when responding deceptively to 50% of trials. The findings are discussed as they relate to the theoretical link between stimulus salience, attention-switching, and working memory load in the formulation of deceptive responses.

B55

NEURAL MECHANISMS OF REWARD PROCESSING IN NICOTINE ADDICTION AND OBESITY *Laura Martin[1], Rebecca Chambers[1], Lisa Cox[1], Joseph Donnelly[2], Cary Savage[1]; [1]University of Kansas Medical Center, [2]University of Kansas* – Everyday individuals make decisions impacting health in which they weigh the benefits of short- versus long-term rewards. The purpose of the current study was to examine the similarities and differences between neural mechanisms of reward associated in nicotine addiction and obesity. The current study used fMRI to examine brain responses during prediction, anticipation, and delivery of monetary rewards and punishments in healthy weight (HW) non-smokers, HW smokers, and obese non-smokers. The task consisted of the presentation of cues predicting the delivery of a reward or punishment with 75% probability, followed by feedback for the current trial. To date, we have collected data in 7 HW non-smokers, 6 HW smokers, and 7 obese non-smokers. Preliminary results in smokers and obese participants show increased activation to rewards compared to punishments in the anterior cingulate cortex (ACC), a region associated with reward processing and impulse control. Smokers showed greater activation to rewards than punishments during prediction and anticipation and obese participants showed greater activation during delivery. By comparison, HW non-smokers showed greater activation to the anticipation of punishments than rewards in areas of prefrontal cortex and medial orbitofrontal cortex (OFC). These results demonstrate that smoking and obesity are associated with increased brain activation during reward processing; however, this difference is seen during anticipation for smokers and during delivery for obese individuals. HW non-smokers appear to be more sensitive to signals of punishment. These results are consistent with behavioral studies showing increased sensitivity to reward and decreased sensitivity to punishment in impulsive individuals.

B56

THE NEURAL SUBSTRATES OF IMPLICIT AND EXPLICIT MENTALIZING ARE DIFFERENTIALLY MODULATED BY GROUP MEMBERSHIP *Dylan D. Wagner[1], William M. Kelley[1], Todd F. Heatherton[1]; [1]Dartmouth College* – Previous psychological research has demonstrated an ingroup bias and outgroup deficit in the attribution of

complex emotions and mental states. Convergent evidence from brain imaging has found either reduced or differential recruitment of regions involved in mentalizing when making judgments about outgroup members. Based on previous work demonstrating spontaneous recruitment of mentalizing areas when viewing rich social material, we reasoned that recruitment of mentalizing regions when processing in- and outgroup members would differ according to level of processing (implicit vs. explicit). In the present study 14 participants made personality attributions or rated the degree to which a face was gender typical when the target was a racial ingroup or outgroup member. A subset of brain regions associated with mentalizing demonstrated an interaction between group status and level of processing. Dorsal medial prefrontal cortex (dMPFC), left temporo-parietal-junction (TPJ), left fusiform and right temporal pole did not distinguish between in- and outgroup targets during the explicit mentalizing condition but demonstrated increased activity to ingroup targets during the implicit condition. Additionally, the left temporal pole showed greater activity for outgroup members during the explicit condition, but also favored ingroup members during the implicit condition. These findings indicate that under explicit task demands participants are equally as likely to recruit mentalizing regions for in- or outgroup targets and may in fact show a bias in favor of outgroup members. However, during implicit processing of targets, mentalizing regions favor ingroup members.

B57

VENTROMEDIAL PREFRONTAL DAMAGE INCREASES UTILITARIAN MORAL JUDGMENTS FOR IMPERSONAL AND PERSONAL MORAL DILEMMAS *Bradley Thomas[1], Katie Croft[1], Daniel Tranel; [1]Division of Cognitive Neuroscience, University of Iowa* – Previous research has suggested that the ventromedial prefrontal cortex (VMPC) is involved in rejecting utilitarian moral judgments (or making non-utilitarian, deontological judgments) about personal, but not impersonal utilitarian moral dilemmas. Subsequent research examining patients with VMPC damage confirmed the previous findings, but also indicated that the VMPC is involved in high-conflict but not low-conflict personal moral dilemmas. In a high-conflict dilemma, the relative value of the consequences of the two horns of the dilemma (e.g., letting 5 strangers die versus killing your daughter) is difficult to compute in order to determine which horn is right.' In this sense, the vast majority of impersonal dilemmas so far examined in moral cognition research have been low-conflict. Thus, we sought to explore high-conflict impersonal dilemmas to determine if the VMPC is crucially involved in making non-utilitarian moral judgments of only high-conflict personal dilemmas, or of high-conflict dilemmas in general. We presented 8 high-conflict impersonal dilemmas to patients with circumscribed bilateral, adult onset VMPC lesions (VMPC group; n=10), and demographically matched normal (NC group; n=20) and brain damaged comparison participants (BDC group; n=5). As predicted, the VMPC group was more likely than NC and BDC groups to make utilitarian moral judgments of high-conflict impersonal dilemmas. These findings suggest that the VMPC is crucially involved in rejecting utilitarian judgments and making deontological judgments of high-conflict dilemmas in general.

B58

MOOD MODULATION OF INFERENCE PRIMING DURING STORY COMPREHENSION *Heather Mirous[1], Mark Jung-Beeman[1]; [1]Northwestern University* – When people comprehending stories hear a premise state (John was wearing jeans) and later a changed state (John is wearing a tuxedo), they bridge this gap by inferring a causal connection (John changed). Drawing such causal inferences is often necessary to maintain coherence during language comprehension. Mood, whether assessed or induced, affects performance in a variety of cognitive tasks that likely share some component cognitive processes with drawing inferences. In the current study, before participants listened to stories, we induced mood via film clips to examine the influence of positive affect and anxiety on drawing causal inferences. We contrasted priming of inference-related target words presented at an early time point (when the inference is predictive and optional) and a late time point (when a bridging inference is necessary to maintain story coherence) after each mood induction. Participants showed greater inference priming after positive mood induction than anxious mood induction, especially at the later time point. These results provide evidence that mood modulates inference processing during natural story comprehension. It is not yet clear whether mood is directly influencing the process of drawing inferences, or if the influence of mood is mediated through another cognitive mechanism, such as attention or working memory, which is under investigation. Though preliminary, these results could have implications for student learning.

B59

INVESTIGATING CONCEPTUAL PROCESSING WITH PICTURE-TO-PICTURE REPETITION PRIMING *Eric S. Clapham[1], Aaron T. Karst[1], C. Mark Wessinger[1,2,3]; [1]University of Nevada, Reno, [2]Charteroak State College, [3]Northcentral University* – The current study uses a repetition priming paradigm to investigate the extraction and encoding of conceptual information. The basic experimental trial began by exposing participants to briefly presented primes, followed by a target stimulus that remains visible until the participant makes a decision. Prime and target stimuli were drawn from a standardized pool of real world pictures. On each trial the number of primes preceding the decision task varied from 1 - 4. Primes were presented with forward and backward masks in order to limit processing to the specified exposure interval. Furthermore, the presentation time of each prime varied between 25 and 100 ms. Twenty-five ms was shown to be below visual awareness in a separate picture identification task. To assess conceptual processing, the priming task required participants to categorize target stimuli as natural or manufactured. In general, the congruent conditions resulted in a facilitation of performance in the form of reaction time gains. However, the gains tended to increase when the prime interval was larger.

B60

SEX DIFFERENCES IN STRESS EFFECTS ON BRAIN ACTIVATION AND BEHAVIOR DURING RISK TAKING *Nichole Lighthall[1], Michiko Sakaki[1], Sarinnapha Vasunilashorn[1], Sangeetha Somayajula[1], Eric Chen[1], Mara Mather[1]; [1]University of Southern California* – Sex differences in financial risk taking are frequently observed (e.g., Jianakoplos & Bernasek, 1998) and experimental research indicates that stress may enhance these sex differences (Mather et al., in press; Preston et al., 2007). Stress appears to activate prefrontal structures more in men and limbic structures more in women (Wang et al., 2007). Thus, stress-induced sex differences in risky behavior may stem from sex differences in how stress affects analytical versus emotional processing. To test this, we investigated the neural mechanisms of stress-sex interactions in financial risk taking by comparing stress effects on behavior and brain activation in 48 men and women during a computerized risk task. Prior to the risk taking game, half of the participants were exposed to cold stress and the other half completed a control condition. Functional imaging data was collected throughout the risk taking task; during the anticipated cortisol peak. Men and women had similar behavior and activated similar brain regions during the task under control conditions. However, stressed males earned more money during the risk task and increased activation in regions related to cognitive analysis such as the anterior cingulate, dorsolateral PFC, insula and medial PFC compared to control males, whereas stressed women earned less money and showed less activity in all of these regions but more activity in the amygdala and ventromedial PFC than control females. These findings suggest that stress will enhance decision making effectiveness in women when decisions benefit from emotional processing and in men when decisions benefit from cognitive analysis.

B61

DEFAULT NETWORK RELATIONSHIPS TO INTELLIGENCE AND CREATIVITY IN NORMAL SUBJECTS *Leonard Leyba[1], Andrew Mayer[1,4], Alexandre Franco[1], Robert Chavez[1], Shirley Smith[1,3], Alison Marshall[1], Ranee Flores[1], Rex Jung[1,2,3,4]; [1]Mind Research Network, University of New Mexico, [2]University of New Mexico, Neurosurgery, [3]University of New Mexico, Psychology, [4]University of New Mexico, Neurology* – Spontaneous brain activity in the absence of a cognitive task may be related to intelligence (Song et al., 2008). Low frequency oscillations (0.01-0.1 hz) of this spontaneous activity have been found to be consistent across subjects (Damoiseaux et al., 2006) and may be important in cognitive processing (e.g. Greicius et al., 2008). The present study examines whether the power of spontaneous fluctuations in the DMN at rest is correlated with intelligence or creativity. Full Scale Intelligence Quotient (FSIQ) was assessed with the Wechsler Adult Intelligence Scale; creativity was assessed with measures of divergent thinking described previously (Miller & Tal, 2007), from which a creative intelligence quotient (CIQ) was derived. Subjects underwent a 5-minute resting fMRI scan. Data was motion correction, placed in MNI stereotaxic space, and group ICA (GIFT matlab toolbox; Calhoun et al., 2004) was used to identify 33 spatially independent components. Four components were selected having high spatial correlation with anterior inferior, anterior superior, posterior inferior, and posterior superior regions of the DMN network (Correa et al., 2006). The power spectra of individual subject timecourses corresponding to these 4 spatial components was used to calculate the proportion of total power in the 0.01-0.1 Hz range. This power was regressed against FSIQ and CIQ scores. FSIQ had a correlation approaching significance (r=0.30, p=0.055) with the power (0.01-0.1 Hz) of the spatial component representing the posterior superior aspect of the DMN. The power spectra of no other components were related to FSIQ or CIQ scores.

B62

EFFECT OF PHYSICAL WARMTH ON ECONOMIC DECISION-MAKING PROCESS *Yoona Kang[1], John Bargh[1], Jeremy Gray[1], Lawrence Williams[2]; [1]Yale University, [2]Colorado University* – Recent lines of evidence suggest a link between physical and emotional perceptions. People rated others to have a warmer (colder) personality after incidentally touching a warm (cold) coffee cup (Williams & Bargh 2008, Science), suggesting a relation between physical temperature and interpersonal warmth (trust). Various studies indicate a possibility of a shared underlying mechanism for physical and interpersonal warmth. The insula, in particular, is shown to activate in response to physical warmth as well as perceived interpersonal trust. Using this paradigm, we tested whether physical warmth will increase interpersonal warmth, which may influence one's economic decision-making process. Study 1 was a behavioral study designed to be compatible with the constraints of MR imaging. We examined the effect of physical warmth (coldness) on participants' economic decision in an investment game. Participants conducted an ostensive product evaluation, which involved touching either a warm or cold therapeutic pack. In 29 individuals, those who touched a warm therapeutic pack entrusted significantly higher amount of money to their investment game partners than those who touched a cold pack. In addition, we tested two participants using fMRI. In both subjects, experimentally manipulated warmth led to greater activation in the anterior insula, consistent with prior work. Thus, we have found that perceptions of physical temperature influenced one's interpersonal economic decision making, potentially through the involvement of a common underlying neural mechanism.

B63

AGE DIFFERENCE IN THE MEDIATION OF COGNITIVE PROCESSING SPEED BY PREFRONTAL CORTEX *Michael Motes[1,2], Bharat Biswal[3], Bart Rypma[1,2]; [1]Center for BrainHealth, School of Behavioral Sciences, University of Texas at Dallas, [2]University of Texas Southwestern Medical Center, Psychiatry, [3]University of Medicine and Dentistry of New Jersey, Radiology* – Research has revealed age-related slowing on measures of cognitive processing speed and that processing speed declines account for age-related variability on a variety of more complex cognitive tasks. These findings have led to hypotheses that the efficient use of limited sets of cognitive operations governs a variety of age-related cognitive declines. fMRI was used in the present study to examine the neural basis for age-related differences in processing speed, particularly targeting prefrontal cortex (PFC). During scanning, groups of older and younger participants completed an fMRI-adapted version of a cognitive processing speed task. On each trial, participants determined whether a symbol-number pair also appeared in a simultaneously presented array of nine symbol-number pairs. Estimates of task-related BOLD signal-change were obtained for each participant. These estimates were then correlated with the participants' performance on the task. For younger participants, BOLD signal-change within PFC decreased with better performance, but for older participants, BOLD signal-change within PFC increased with better performance. The results suggest that differential efficiency in the use of PFC neural resources mediates age-related changes in processing speed, in particular, and cognitive performance, more generally.

B64

FUNCTIONAL DYNAMICS OF ANTERIOR INTRAPARIETAL SULCUS WITHIN THE ACTION OBSERVATION NETWORK DURING UNDERSTANDING OTHER PEOPLE'S INTENTIONS: EVIDENCE FROM COMBINED FMRI AND EEG REPETITION SUPPRESSION *Stephanie Ortigue[1], James Thompson[2], Raja Parasuraman[2], Scott Grafton[1]; [1]4D Brain Electrodynamics Lab, UCSB Brain Imaging Center, Institute for Collaborative Biotechnologies, [2]George Mason University* – Inferring intentions of other people based on the observation of their behavior recruits brain regions within the inferior fronto-parietal network (including the mirror neuron system) extending to the superior temporal sulcus (STS). However, the functional dynamics between these brain areas remains unclear. To assess this question, we tested repetition suppression (RS) effects in 24 healthy men who performed an intention inference task while their brain activity was recorded with high-spatial fMRI and high-temporal EEG recordings. During this task, participants were instructed to attend to video-clips displaying hand-on-object actions, and to try to decode 'why' actions were being performed (e.g., to use a gun or to transport it). Functional MRI results confirmed the specific role of the inferior frontal lobe, anterior intraparietal sulcus (aIPS) and STS in intention understanding. High-density EEG neuroimaging combining brain microstate analysis with LAURA distributed linear source estimations expanded these results by revealing the temporal dynamics within this brain network. Suppressed responses for intention decoding were observed in STS in the early stage of processing (~100ms after hand-on-object interaction). Then, a specific recruitment of aIPS was observed around 200ms. Finally, a combined STS and aIPS recruitment was observed around 330ms. Within this cascade of events, the recruitment of aIPS was more specifically observed for action goals than objects per se. Together, these results show the temporal dynamics of intention understanding within the human action observation network that are different than those used to decode lower level visual features related to the object per se.

B65

AGING EFFECTS ON RULE-BASED AND INFORMATION-INTEGRATION CATEGORY LEARNING *Bo Zhu[1], Jennifer Pacheco[1], Maia Langford[1], David M. Schnyer[1], W. Todd Maddox[1]; [1]University of Texas at Austin* – Rule-based (RB) and information-integration (II) category learning was investigated in healthy older participant (60 - 81 years old). Participants were asked to categorize single line stimuli that varied in length and orientation into one of four categories. In the RB condition, correct classification required that each line be classified as short or long and steep or shallow, and these decisions integrated using a conjunctive

rule. In the II condition, the optimal strategy had no verbal analog, but instead involved a pre-decisional integration of length and orientation. The RB and II categories were structurally equivalent in the sense that within- and between-category variance was constant. All other procedures were fixed across conditions (e.g., optimal accuracy, nature of the feedback, response requirements, etc). Each subject completed 6-100 trial blocks in each condition. Accuracy- and model-based analyses were performed. The results suggested that (a) elderly participants were less accurate than controls in the RB condition, (b) elderly participants were less accurate than controls in the II condition early in learning, but showed no II performance impairment during the last half of the session, and (c) the locus of the accuracy deficits (when they emerged) were due to a deficit in categorization rule learning, and not to increased variability in the application of the rule. These results replicate previous studies that show RB deficits in normal aging and extend them to conjunctive rule learning. The early learning II deficit converges with previous results, but the lack of impairment late does not.

B66

A NON-PHARMACOLOGICAL ALTERNATIVE FOR THE TREATMENT OF INSOMNIA - INSTRUMENTAL CONDITIONING OF BRAIN OSCILLATIONS *Kerstin Hoedlmoser[1], Thanh Dang-Vu[2], Martin Desseilles[2], Pierre Maquet[2], Manuel Schabus[1,2]; [1]University of Salzburg, Austria, Division Physiological Psychology, [2]University of Liege, Belgium, Cyclotron Research Centre* – Electroencephalographic recordings over the sensorimotor cortex show a very distinctive oscillatory pattern in a frequency range between 12-15Hz termed sensorimotor rhythm (SMR). SMR appears to be dominant during quiet but alert wakefulness, and synchronizes by the inhibition of motor behaviour. This frequency range is also known to be abundant during light non-rapid eye movement sleep, and is overlapping with the sleep spindle band. Given earlier findings we aimed at changing sleep quality and cognitive performance in humans by using instrumental conditioning (IC) of that SMR frequency band. Twenty-seven subjects were randomly assigned to either a SMR-conditioning protocol or to a randomized-frequency-conditioning protocol. Whereas the experimental group was trained to enhance the amplitude of their SMR-frequency range during 10 IC sessions over the course of 2 weeks, the control group participated in a placebo conditioning protocol. Before and after these IC blocks subjects had to attend the sleep laboratory to take a 90min nap and additionally had to perform a declarative memory task. Results confirmed the increase of 12-15Hz activity over the course of the ten training sessions in the experimental group. Interestingly, the increased SMR activity (i) was also expressed during subsequent sleep by eliciting positive changes in various sleep parameters like sleep spindle number or sleep onset latency and (ii) was associated with the enhancement of declarative memory performance. In addition, preliminary data from our own laboratory indicate that people suffering from insomnia could also benefit from SMR-conditioning as indicated by improved measures of subjective and objective sleep quality.

Linguistic processes: Semantics

B67

NEURAL PROCESSING OF ICONIC AND METAPHORIC CO-VERBAL GESTURES: WHAT MEMORY TELLS US ABOUT UNDERLYING PROCESSES *Benjamin Straube[1,2], Antonia Green[1], Anjan Chatterjee[2], Tilo Kircher[1]; [1]RWTH Aachen University, Aachen, Germany, [2]Center for Cognitive Neuroscience, The University of Pennsylvania, Philadelphia, PA* – Iconic and metaphoric gestures illustrate verbal utterances with shape, space or action information. However, these gesture types differ in reference to the abstractness of the sentence content. The question arises how the different information of speech and gesture is processed and stored on the neural level. This study tested the hypothesis that iconic and metaphoric gestures contribute to memory for spoken sentences and that they have different neural instantiations. During fMRI-data acquisition participants were presented with videos showing an actor performing iconic (IG), metaphoric (MG) or no gestures (NG) to corresponding concrete or abstract sentences, respectively. After scanning, participants performed a recognition task for videos of the spoken sentences without gestures of each condition. Behavioral results indicate that co-verbal gestures lead to better memory performances for spoken sentences than when the sentences were spoken without gestures. We found for the IG condition, bilateral temporo-occipital and parietal activation accompanied by predominantly right lateral hippocampal activation was associated with better subsequent discrimination. By contrast, for the MG condition fronto-temporal and predominantly left lateral hippocampal activation was related to better recognition. These results suggest differences in encoding processes for both gesture types. The right hippocampus is probably more involved in concrete visuo-spatial integration processes of speech and gesture. By contrast, the left hippocampus and a fronto-temporal network are more involved in semantic integration of abstract information of speech and metaphoric gestures.

B68

NEURAL SUBSTRATE FOR INTEGRATING SEMANTIC AND PHONOLOGICAL PROCESSING IN CHINESE CHILDREN *Shu-Hui Lee[1], Tai-Li Chou[1], Li-Ying Fan[1], Mei-En Hsieh[1]; [1]National Taiwan University* – Functional magnetic resonance imaging (fMRI) was used to examine the neural correlates of auditory semantic judgments to Chinese characters in a group of 10-15 year old Chinese children. The participants had to judge if two Chinese characters were related in meaning. The first character was visually presented and the second character was auditorily presented. Different from English, Chinese has plenty of homophones in which each pronunciation corresponds to many characters. This task required the participants to select a semantically appropriate answer among homophones, given that the first and the second characters were related in meaning. The participants showed activation in left middle temporal gyrus (BA 21, 22) and left inferior frontal gyrus (IFG, BA 45, 47) for semantic processing. Consistent with previous visual semantic findings, characters with stronger semantic association elicited greater activation in left inferior parietal lobule (BA 40). Different from previous visual semantic findings, characters with weaker semantic association elicited activation in left IFG (BA 45), suggesting greater engagement of selection among homophones for Chinese characters. We also examined whether age explained variance in the patterns of activation. Increasing age was correlated with greater activation in IFG (BA 45) for related pairs and in IFG (BA47) for unrelated pairs. The developmental results indicate greater integration of semantic and phonological processes to select the correct answer among homophones for related pairs, and demanding retrieval processes to judge unrelated pairs for older children. Our findings imply different roles for subparts of IFG, BA 45 and BA 47 during semantic judgments.

B69

MOOD AFFECTS SEMANTIC PROCESSING: EVIDENCE FROM N400 *Dorothee J. Chwilla[1], Constance, Th. W. M. Vissers[2], Daniele Virgillito[3], Dan Fitzgerald[4], Anne, E. M. Speckens[2], Indira Tendolkar[2]; [1]Donders Institute for Brain, Cognition and Behaviour, [2]Donders Institute for Brain, Cognition and Behaviour, Psychiatry, [3]Scuola Superiore di Catania, Catania, Italy, [4]Behavioral Science Institute* – N400 amplitude systematically varies with the degree at which a word is expected based on context. This N400 effect of cloze probability with larger amplitudes for less expected words is taken to reflect the ease with which a word is integrated into context. In this study we explored the interaction of language, in particular of semantics, with emotion. This was accomplished by investigating the effects of emotional state on N400. EEG was recorded while female participants (N=31) read high-cloze sentences ('In that library the pupils borrow books...') and low-cloze sentences ('The pillows are stuffed with books...'). Mood was manipulated between participants

by presenting short film clips that displayed fragments from a happy movie or a sad movie. These film clips have been shown to effectively induce the intended mood. The main results were as follows: Participants scored significantly higher on a 9 point-mood scale after watching the happy film clips than after the sad film clips ($p < .01$). For N400 (300 to 500 ms epoch), an interaction of cloze probability and mood was found for the midline and the lateral sites (ps < .05). For the midline sites an N400 effect was present in the happy mood but absent in the sad mood condition. For the lateral sites the interaction indicated that the N400 effect in the happy mood condition was more broadly distributed across the scalp than in the sad mood condition. The N400 data show that mood in healthy subjects affects semantic processing, in particular meaning integration.

B70

COMPREHENSION OF ACTION AND NON-ACTION VERBS IS PRESERVED IN PARKINSON'S DISEASE *David Kemmerer[1,2,3], Luke Miller[2], Megan MacPherson[1], Jessica Huber[1]; [1]Purdue University, Speech, Language, and Hearing Sciences, [2]Purdue University, Psychological Sciences, [3]University of Iowa, Neurology* – The Embodied Cognition Framework (ECF) maintains that action concepts depend in part on the primary motor and/or premotor cortices. This predicts that disturbances to those regions should impair comprehension of action verbs (e.g., throw) but not non-action verbs (e.g., think). A recent study reported reduced repetition priming for verbs but not nouns in non-demented patients with Parkinson's disease (PD), a movement disorder that indirectly affects the motor cortices due to abnormal input from the basal ganglia and the mesocortical dopaminergic pathway (Boulenger et al., 2008). However, in that study all the verbs encoded actions and all the nouns encoded objects, leading to a conflation of grammatical and semantic categories. In the current study we compared the performance of 10 non-demented PD patients with 10 healthy control subjects on a task assessing comprehension of action and non-action verbs. All participants received the Semantic Similarity Judgment Task, which requires determining which of two verbs is more similar to a third (Kemmerer et al., 2008). There were 144 items—24 for each of 6 classes of verbs, 4 classes involving actions (running, speaking, hitting, and cutting) and 2 classes not involving actions (changes of state, and psychological processes). The PD patients were tested both 'on' and 'off' their anti-parkinsonian medication. Relative to healthy controls, PD patients did not have significantly lower accuracies for any of the verb classes, regardless of medication status. Thus, PD patients appear to have intact comprehension of action and non-action verbs, raising important questions about the scope of the ECF.

B71

REVEALING THE ROLE OF THE ATL IN SEMANTIC COGNITION: EVIDENCE FROM DISTORTION-CORRECTED FUNCTIONAL MAGNETIC RESONANCE IMAGING *Richard Binney[1], Elizabeth Jefferies[2], Matthew A. Lambon Ralph[1]; [1]Neuroscience and Aphasia Research Unit, University of Manchester, UK, [2]University of York, UK* – The association between bilateral anterior temporal lobe (ATL) atrophy and a generalised semantic impairment in semantic dementia (SD) has led to the supposition that this region could be a core component of the cortical semantic network. However, despite the remarkable consistency of this association in SD, this hypothesis is still controversial. One reason for this is that fMRI studies of healthy individuals have thus far failed to provide consistent evidence for the involvement of the ATL in semantic tasks. This is at least partially explained by the fact that conventional gradient-echo echo-planar fMRI is vulnerable to geometric distortions and signal dropout in areas that are near to bone or air-filled cavities. One of the most severely affected areas is the ATL. However, it has recently been shown that it is possible to correct these distortions by using a combination of spin-echo echo planar imaging and a novel correction algorithm. We report the analysis of corrected images that revealed significantly greater ATL activation when healthy participants performed a semantic judgement task as contrasted with an equally-demanding control task. This is consistent with previous studies that used this same task and demonstrated that SD patients perform significantly more poorly than a healthy control group, and that semantic decision times of healthy participants are significantly slowed by inducing a 'virtual lesion' in the left or right temporal pole using low-frequency repetitive TMS. These findings add substantial weight to a growing body of evidence for the role of the ATL in semantic representation.

B72

ELUCIDATING THE NATURE OF DEREGULATED SEMANTIC COGNITION IN SEMANTIC APHASIA: EVIDENCE FOR THE ROLES OF PREFRONTAL AND TEMPOROPARIETAL CORTICES *Krist A. Noonan[1], Elizabeth Jefferies[2], Matthew A. Lambon Ralph[1]; [1]Neuroscience and Aphasia Research Unit (NARU), University of Manchester, UK, [2]University of York, Psychology, UK* – Semantic cognition - semantically-driven verbal and nonverbal behaviour - is composed of at least two interactive principal components: conceptual representations and executive control processes that regulate and shape activation within the semantic system. Previous studies indicate that semantic dementia follows from a progressive yet specific degradation of conceptual knowledge. In contrast, multimodal semantic impairment in aphasic patients (semantic aphasia) reflects damage to the control component of semantic cognition (Jefferies & Lambon Ralph, 2006). The purpose of the present study was to examine the nature of the semantic control deficits in semantic aphasia (SA) in detail for the first time. Seven patients with SA were tested on four comprehension and naming tasks which directly manipulated the requirement for executive control in different ways. In line with many theories of cognitive control, the SA patients demonstrated three core features of impaired control: they exhibited (i) poor online manipulation and exploration of semantic knowledge; (ii) poor inhibition of strongly associated distractors; and (iii) reduced ability to focus upon or augment less dominant aspects of semantic information, even though the knowledge itself remained and could be successfully cued by external constraints provided by the examiner. Our findings are consistent with the notion that the anterior temporal lobes are crucial for conceptual knowledge whilst the left prefrontal and temporoparietal cortices, damaged in patients with SA, play a critical role in regulating semantic activation in a task-appropriate fashion.

B73

THE DYNAMICS OF SENSE-MAKING: ERP EVIDENCE OF WORDS WITHIN WORDS *Petra van Alphen[1], Jos van Berkum[1,2]; [1]Max Planck Institute for Psycholinguistics, [2]Donders Institute, Centre for Cognitive Neuroimaging* – In two ERP experiments, we examined whether listeners, when making sense of spoken language, take into account the meaning of spurious words that are embedded in longer words, either at their onsets (e.g., pie in pirate) or at their offsets (e.g., pain in champagne). Listeners heard sentences in which the critical multisyllabic words contained either an initial or final embedding. The semantic fit of the carrier words and embedded words in the context was manipulated in such a way that semantic involvement of the embedded words should result in a modulation of the N400 components. The results of the first experiment showed that when the context supports the meaning of the embedding but not that of the carrier word, listeners briefly relate the meaning of both initial and final embeddings to the context. Crucially, the second experiment showed that when the carrier word but not the embedded word is supported by the context, final (but not initial) embeddings are still taken into account. This indicates that even when the comprehension system is already pursuing a sensible interpretation, it can still start a second sense-making stream for the following (stressed) syllable of the word, in parallel to the first one. The absence of an effect for the initial embeddings, however, could be taken to suggest that the system is not able to start two such processes at exactly the same time. These results give us new insights into the dynamics of the sense-making process and its link to lexical activation.

B74

CONFLICTS BETWEEN SYNTAX AND SEMANTICS: AN ERP-STUDY *Miriam Kos[1], Theo Vosse[1,2], Peter Hagoort[1,3]; [1]Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behaviour, Centre for Cognitive Neuroimaging, [2]University of Leiden, [3]Max Planck Institute for Psycholinguistics, Nijmegen* – Research has shown that conflicts between constraints for grammatical role assignment and thematic role biases elicit P600 effects (Kuperberg, 2007). This P600 has no apparent syntax-specific characteristic, and thus seems to be at variance with the dominant view that P600 effects are modulated by syntactic violations, ambiguities or complexities. To explain these findings it has been postulated that conflicts between syntax and semantics trigger a prolonged combinatorial or a monitoring process. We, however, favor a different interpretation: due to the strong semantic bias, the conflict between syntax and semantics was 'perceived' at the syntactic level. There can only be one winner and, in the ERP effect, 'the loser takes it all'. We investigated the nature of these conflicts further in a Dutch ERP study. First, participants read relative clause sentences, structurally ambiguous in Dutch, with strong semantic constraints (the dentist who(m) the client treats, the client who(m) the dentist treats). The conflict between syntax and semantics elicited an N400 effect. This is possibly due to subject-first strategies overriding the semantic-thematic bias. Second, we presented sentences containing a conflict between syntax and semantics at a point in the sentence at which the syntactic constraints were very strong (baseline condition: Father eats a sandwich / Father eats in a restaurant; thematic role violations: Father eats in a sandwich / Father eats a restaurant). The combinatorial and monitoring explanations predict a P600. However, in this case an N400 effect was observed, supporting our 'loser takes it all' account.

B75

ANAPHORIC REFERENCE TO QUANTIFIED STATEMENTS: AN EVENT-RELATED POTENTIAL STUDY *Ruth Filik[1], Linda Moxey[1], Anthony Sanford[1], Hartmut Leuthold[1]; [1]Centre for Cognitive Neuroimaging, University of Glasgow, UK* – We report two event-related potential (ERP) experiments examining how readers process sentences containing anaphoric reference to quantified statements. Previous studies (Moxey & Sanford, 1987; Paterson, Sanford, Moxey, & Dawydiak, 1998; Sanford, Moxey, & Paterson, 1996) have shown that positive (e.g. 'many') and negative (e.g. 'not many') quantifiers cause readers to focus on different sets of discourse entities. For example in 'Many of the fans attended the game', focus is on the fans who attended (the reference set), and subsequent pronominal reference to this set, as in, 'They cheered very loudly', is facilitated. In contrast, if 'many' is replaced by 'not many', focus shifts to the fans who did not attend (the complement set), and pronominal reference to this set, as in 'They stayed home instead', is preferred. In the current studies, the electroencephalogram (EEG) was recorded while participants read positive or negative quantified statements followed by anaphoric reference to the reference set or complement set. Results suggest that positive quantifiers make the reference set available on encountering the quantified statement, with reference to the complement set being perceived as anomalous. Specifically, following a positive quantifier, there was an N400 effect for complement set reference relative to reference set reference (Experiment 1). In contrast, for negative quantifiers, anaphoric reference to the reference set did not produce an N400 effect. Results instead suggest that the complement set is added to the discourse model on reading the anaphoric sentence (Experiment 2). Findings are discussed in relation to theoretical accounts of reference resolution.

B76

AGING MODULATES TOP-DOWN BUT NOT AUTOMATIC PROCESSES DURING LEXICAL AMBIGUITY RESOLUTION: AN ERP STUDY *Chia-lin Lee[1], Kara D. Federmeier[1]; [1]The Beckman Institute for Advanced Science and Technology, University of Illinois* – The current experiment investigated how older adults process noun/verb (NV) homographs (e.g., park) given prior syntactic and semantic contextual information. We compared ERP responses to NV-homographs and matched unambiguous words that completed sentences with either both semantic and syntactic contextual information (congruent sentences) or syntactic information only (syntactic prose sentences). Our earlier work with young adults demonstrated that, relative to unambiguous words, NV-homographs elicit (1) larger N400 responses in congruent sentences, suggesting a semantic mismatch between the context and the automatic activation of the contextually-inappropriate sense, and (2) a sustained frontal negativity in syntactic prose, suggesting the recruitment of top-down mechanisms mediated by frontal brain areas to aid semantic selection when semantic constraints are less available. In older adults as a group, there were similar (although smaller) N400 effects for congruent sentences, whereas the frontal negativity previously observed in the syntactic prose condition in the young was absent. Analyses of individual differences revealed a positive correlation between the size of the frontal negativity effect and verbal fluency scores, showing that more fluent older adults maintained a young-like effect pattern. These findings support the hypothesis that lexical ambiguity resolution engages multiple neural mechanisms. With age, more automatic semantic processing mechanisms seem to be relatively well-maintained, whereas top-down executive mechanisms may be less available or efficient.

B78

SYNTACTIC POSITION OUTRANKS SYNTACTIC FUNCTION: REFERENTIAL PROMINENCE REVISITED *Petra Schumacher[1], Dietmar Roehm[2,3]; [1]Johannes Gutenberg University Mainz, Germany, [2]University of Salzburg, Austria, [3]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany* – Accessing an antecedent expression during referential processing is guided by a variety of 'prominence features', such as discourse prominence (e.g. topic, non-topic), syntactic prominence (e.g. subject, object), form features (e.g. definite, indefinite, pronominal),... ERP research has reported enhanced N400-effects as indication of referential processing cost, e.g. when definite noun-phrases (contra pronouns) refer to highly prominent antecedents. Previously, we showed that a definite noun-phrase prefers i) an indefinite antecedent over a definite antecedent and ii) an object antecedent over a subject antecedent (evidenced by an enhanced N400 for the dispreferred entities). These findings indicate that a definite noun-phrase ideally refers to a less prominent entity in discourse. In the present investigation, we wanted to find out whether the latter prominence effect was driven by syntactic function alone (subject vs. object) or by the syntactic position (because we had only used subject-before-object order). Since German has a flexible word order, we were able to tease apart these two prominence features. We examined referential processing in a two-sentence reading study, where the first sentence manipulated the antecedent's syntactic function (subject, object) and its position (subject-before-object, object-before-subject), while the second sentence contained the referring noun-phrase. ERPs measured to the onset of the referring noun-phrase replicated our previous results (more pronounced N400 for subject over object antecedents in subject-before-object order) and also revealed an enhanced N400 for object over subject antecedents in object-before-subject order. This indicates that syntactic position - which encodes prominence features - is a stronger predictor for prominence than syntactic function is.

Linguistic Processes: Semantics

B79

BRAIN POTENTIALS AND THE PROCESSING OF (IN)DEFINITENESS IN LATE LEARNERS OF ENGLISH *John E. Drury[1,4], Erin J. White[2,4], Lydia White[3,4], Karsten Steinhauer[1,4]; [1]McGill University, School of Communication Sciences and Disorders, [2]McGill University, Psychology, [3]McGill University, Linguistics, [4]McGill University, Centre for Research on Language, Mind, and Brain* – Much research has examined the extent to which late second language (L2-)learners may attain native-like proficiency, including a recent surge of studies using

event related brain potentials (ERPs). However, ERP research in this domain has so far ignored L2-acquisition/processing of semantic/pragmatic distinctions such as (in)definiteness. The present ERP study tested adult native English speakers alongside two groups of late-learners of English (native French/Chinese speakers) in a sentence reading/judgment study examining two different types of violation paradigms: (i) syntactic category violations [e.g., The man hoped to *meal the enjoy with friends vs. The man hoped to enjoy the meal with friends], and (ii) violations of the definiteness restriction [DR-violations] in existential constructions [e.g., There was *the/a man in the room; note * marks deviance/unacceptability]. DR-violations have been shown elsewhere to yield late P600-type effects and concurrent late left anterior negativities [L-LANs] in English natives. We have previously shown that syntactic/type-(i) violations elicit LAN/P600 responses in English native-speakers and in (both French/Chinese) high-proficiency late-L2 learners, whereas corresponding low-proficiency (French/Chinese) L2-learners do not elicit a LAN. Here, in the same group of subjects, we demonstrate a complete absence of any ERP effects for DR-violations in both French and Chinese low-proficiency groups. In contrast, high-proficiency French/Chinese groups appear to approximate native-like ERP-patterns [both show late P600-like effects], but the two groups differed from each other both behaviourally and in the timing of ERP-effects. The full array of findings suggest that L1-background may differentially effect distinct linguistic sub-domains in late second language learning.

Linguistic processes: Semantics

B80

SEMANTIC PROCESSING IN WERNICKE'S APHASIA AND SEMANTIC DEMENTIA *Juliana Baldo[1], Jennifer Ogar[1,4], Nina Dronkers[1,2,3], Maria Luisa Gorno Tempini[4]; [1]VA Northern California Health Care System, [2]University of California, Davis, [3]University of California, San Diego, [4]University of California, San Francisco* – Anterior temporal cortex has been associated with semantic processing, as evidenced by both lesion and imaging studies. More posterior portions of temporal cortex, especially in the left hemisphere, have been implicated in lexico-semantic processing aspects of language. In the current study, we examined the role of these areas by comparing behavioral and anatomical changes in patients with semantic dementia (SD) and Wernicke's aphasia (WA). Ten patients with WA and ten SD patients were tested on measures of speech, language, and semantic association abilities. Performance of SD patients was evaluated at two different intervalsóinitial testing and 1-2 year follow-up. Both SD and WA patients exhibited significant language deficits that declined further over time in SD. Despite significant anomia in both groups, SD patients tended to have richer, more intelligible speech, relative to Wernicke's patients, but both groups exhibited significant lexico-semantic impairments in comprehension. One striking area of contrast was the impaired semantic processing evidenced by SD patients on a triadic comparison task, which was relatively intact in WA. Voxel-based morphometry in the SD patients revealed left anterior temporal atrophy, with some gray matter loss extending to medial portions of the left temporal lobe. In contrast, the WA patients had temporal lesions that overlapped to the greatest extent in the left posterior middle temporal gyrus. The differences between WA and SD in behavioral performance as well as anatomical involvement further support the critical role of left anterior temporal cortex in semantics and more posterior left temporal regions in core language processes.

B81

COVARIANCE STRUCTURES IN NARRATIVES STUDIED WITH FMRI - PROOF OF CONCEPT *Mikkel Wallentin[1,2], Peter Vuust[1,3], Kim Mouridsen[1], Andreas Roepstorff[1,4], Torben Ellegaard Lund[1]; [1]Center of Functionally Integrative Neuroscience, Aarhus University Hospital, [2]Center for Semiotics, University of Aarhus, [3]The Royal Academy of Music, Aarhus, [4]University of Aarhus, Social Anthropology* – Narratives are difficult to study scientifically. Changes in use of frequent words, however, must be followed by changes in meaning and thus be salient for a cognitive system involved in comprehension, e.g. if a story that has previously used only third person ('she') starts using first person ('I') then this signals a change in meaning (e.g. a shift to dialogue). Such changes can be observed as covariance between the most frequent words. This study investigated hemodynamic changes in language regions evoked by these changes. Covariance components were made by taking onsets for the 10 most frequent verbs, 9 pronouns and 10 prepositions from a recording of 'The Ugly Duckling' by Hans Christian Andersen. Onsets for each word was convolved with the HRF in SPM and these 29 regressors were then analysed with principal component analysis (PCA). To test the effects of these components with minimal variance we scanned the same subject 8 times while he listened to the recording. Scannings: on a 3T system (580 volumes/session, 34 slices, 3x3x3 mm, TR: 2200 ms). Data were analysed in SPM. 1st level: 10 primary covariance components were used as regressors in one GLM/session. 2nd level: The first six components entered into a factorial model treating sessions as random effects. Main result ($P<0.05$, FWE-corrected): A striking left lateralized pattern with two foci: Inferior frontal and posterior temporal cortex. This serves as proof of concept that monitoring linguistic covariance is an important part of language and that this may be studied using fMRI.

B82

HOW FAST CAN WE TELL DUCK FROM MUD: AN ERP INVESTIGATION OF CATEGORY DECISION *Xin Zheng[1], Sidney Segalowitz[1]; [1]Brock University* – In a previous ERP study (Segalowitz & Zheng, 2008), we found evidence in the N1 component suggesting early lexical access at 160 ms, P1 enhancement in semantic priming, and that individual differences in task performance correlated with the P1 sensitivity to semantic task manipulation. In the current study using a different paradigm, these effects were further tested. Participants (n=12) performed a living/nonliving category decision, in which words were visually presented, and participants pressed corresponding buttons. Half of the stimuli in both categories were 'new', as they were not previously seen in the study. In contrast, the other half of the stimuli were 'old' and had been used earlier in another task (a semantic priming task with words presented in pairs). Furthermore, these repeated stimuli could have been previously used either as a 'prime' or as a 'target'. Between 400 - 550 ms, there was a main effect for category in the N400: words of nonliving categories (e.g., mud) had a larger N400 than words of living categories (e.g., duck). The N400 was also affected by 'repetition'. It was smaller for words used as 'targets' than for words that were either 'new' or used as 'primes', while the N400 between the latter two were not different. In addition, the earliest category differentiation appeared as early as 160 ms in N1 component (trend, $p = .08$): nonliving items had larger N1 than living items. For P1, no main effects or interaction were found.

B83

ERP EVIDENCE FOR MODAL SUBORDINATION IN SPOKEN SENTENCES *Veena D. Dwivedi[1], Natalie A. Phillips[2], Shari Baum[3], John E. Drury[3], Karsten Steinhauer[3]; [1]Brock University, [2]Concordia University, [3]McGill University* – We used event-related brain potentials (ERPs) in an auditory study to examine the nature of anaphoric resolution in 2-sentence discourses. The first Context sentence was either Hypothetical (S1) or Factual (Control condition S1'). The subsequent continuation sentence either included (S2a) or excluded (S2b) a modal auxiliary (e.g., must,should) and contained a pronoun. Thus, either it was a Modal or a Non-modal sentence. S1: John is considering writing a novel. S1': John is reading a novel. S2a: It might end quite abruptly. S2b: It ends quite abruptly. The Modal sentence (S2a) is a natural continuation of the Hypothetical context (S1), but is also compatible with Control context S1'. In contrast, the Non-modal sentence (S2b) does not follow naturally from S1, since a novel does not exist yet, rendering the discourse anomalous.

No such anomaly results when combining the factual context S1' with the non-modal continuation sentence S2b. In terms of ERP patterns, we predicted that there would be no empirical difference between Modal continuation sentences that followed Hypothetical vs. Control contexts. In contrast, continuation sentences that were Non-modal should differ, depending on the previous context, where the Control context is felicitous but the Hypothetical context results in anomaly. Results showed that waveforms for Non-modal sentences in anomalous Hypothetical contexts elicited a positive-going deflection that reliably differed from Control contexts, whereas no such context-dependent difference emerged for Modal sentences. The P600-like effect replicated and extended our previous findings from a reading study -- lending ecological validity to our previous claims.

B84

HOW INPUT MODALITY AND ACTION PROPERTIES AFFECT SEMANTIC PROCESSING: EVIDENCE FOR GRADED SEMANTIC AND SOMATOTOPIC REPRESENTATIONS *Carrie Esopenko[1], Cummine Jacqueline[1], Sarty Gord[1], Borowsky Ron[1]; [1]University of Saskatchewan* – We examined the semantic processing of objects presented in picture and word format, in order to evaluate three models of semantic representation: an amodal semantic system (Caramazza et al., 1990), multiple semantic systems (Shallice, 1988), and a hybrid graded semantics model (Plaut, 2002). Previous neuroimaging research has supported the notion of a hybrid graded semantics model by showing both unique and shared regions of activation during the semantic processing of picture and word stimuli (Borowsky et al., 2005; Vandenberghe, Price, Wise, Josephs, & Frackowiak, 1996). Other neuroimaging research has shown a somatotopic-semantic organization in the premotor cortex during the processing of action-related language (Esopenko, et al., 2008; Hauk, et al., 2004; Tettamanti et al., 2005). We used an event-related fMRI paradigm to examine both the effect of input modality and action-properties within-participants using both a naming task and a semantic categorization task (SCT; i.e., is the object used by arm or leg?). Both tasks showed shared and unique areas of activation as a function of input modality and action-properties. Moreover, the premotor cortex was found to be organized somatotopically independent of input modality. This all-within participant's experiment further supports the graded semantics model and the somatotopic-semantic organization of the premotor cortex.

B85

REDUNDANCY EVALUATION VS. SEMANTIC COMPETITION: AN ERP INVESTIGATION OF PRONOUN-DROP IN TURKISH *Sukru B. Demiral[1], Matthias Schlesewsky[2], Ina Bornkessel-Schlesewsky[1]; [1]Independent Junior Research Group Neurotypology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, [2]English and Linguistics, Johannes Gutenberg University, Mainz, Germany* – Many languages allow for sentence participants to be omitted from an utterance. In Turkish, for example, subjects are omitted in approximately 70% of transitive sentences. Subject-drop is particularly pervasive with 1st- and 2nd-person-subjects, since these are also marked on the verb. How does the human language comprehension system deal with this 'covert' information? Is the avoidance of redundancy most important, hence favoring pronoun-drop? Alternatively, does the overt realization of subject pronouns reduce processing complexity as induced by the construction of the null-subject? These hypotheses were contrasted in an ERP study, which compared 1st-person-Pronoun-Object-Verb (POV) to Object-Verb (OV) sentences in Turkish. Objects were marked with accusative case and were either animate or inanimate. Animacy was manipulated in order to examine the semantic competition for subjecthood; animate arguments are highly prominent and may compete for the subject position, especially when the subject is constructed on the verb. This may induce semantic processing cost reflecting as N400. ERP measures at the verb revealed an N400 for all conditions in comparison to the inanimate OV condition. Furthermore, the inanimate POV condition engendered a P600 in comparison to all other conditions. These findings suggest that the N400 effect appears to reflect both competition and the existence of the redundant pronoun. By contrast, the evaluation of the redundancy of the pronoun depended on the degree of competition: A P600 effect was engendered only when semantic competition was low. Redundancy evaluation was blocked when the overt-pronoun served to prevent competition, leading to an attenuated P600.

B86

NEURAL REPRESENTATION OF CONCRETE AND ABSTRACT CONCEPTS *Jing Wang[1], Julie A. Conder[1], Svetlana V. Shinkareva[1]; [1]University of South Carolina* – Many studies have attempted to identify the brain regions that can be associated with representation of abstract concepts. However, diversity among brain regions previously identified as involved in this process has resulted in controversy. This is perhaps due in part to the wide variety of tasks used to assess abstract concept representation. In the current study, we used event-related functional magnetic resonance imaging (fMRI) and a similarity judgment task to identify brain regions associated with representation of abstract and concrete concepts. While being scanned, participants were required to view word triplets consisting of three highly-related concepts. Stimulus words were selected from abstract and concrete categories. The abstract condition included words related to emotion or cognition, whereas the words in the concrete condition were related to tools or dwellings. In the similarity judgment task, participants were required to decide which word of two was most similar to a third word, thus eliciting semantic meaning for the concept represented by the word triplet. Results indicated that representation of abstract concepts is associated with increased activation in several right hemisphere regions including superior frontal gyrus, middle temporal gyrus, and cerebellum. These results do not support recent findings suggesting that left frontal and temporal regions play a larger role in abstract concept representation.

B87

CROSS-LANGUAGE PRIMING EFFECTS: EVIDENCE FROM RTS AND ERPS *Sofie Schoonbaert[1], Phillip J. Holcomb[2], Robert J. Hartsuiker[1]; [1]Ghent University, Belgium, [2]Tufts University, MA* – Our main goal was to further explore lexico-semantic organisation in a second language, using a translation priming paradigm. In the present study English-French bilinguals performed a lexical decision task while reaction times (RTs) and event related potentials (ERPs) were measured to L2 targets, preceded by non-cognate L1 translation primes versus L1 unrelated primes (Experiment 1a), and vice versa (Experiment 1b). Significant masked translation priming was observed, indicated by faster RTs and a decreased N400 for translation pairs as opposed to unrelated pairs, both from L1 to L2 (1a) and from L2 to L1 (1b), the latter effect being weaker (RTs) and less longer lasting (RTs, ERPs). The obtained N400-priming effects are taken as an indication of semantic involvement during priming in both directions, and therefore suggest strong lexico-semantic connections for L2 (as well as for L1). This can be interpreted as evidence against the Revised Hierarchical model (Kroll & Stewart, 1994), assuming only weak links from L2 to concepts. We provided evidence for the temporal delay assumption of the BIA+ model (Dijkstra & Van Heuven, 2002) by showing that effects to L2-targets occured later compared to L1-target effects. --- References: Kroll, J. F., & Stewart, E. (1994). Journal of Memory and Language, 33, 149-174. Dijkstra, T., & Van Heuven, W. (2002). Bilingualism: Language and Cognition, 5, 175-197.

B88

N400-LIKE EFFECTS EVOKED BY SINGLE PAIRS OF WORDS *Louis Renoult[1,3], J. Bruno Debruille[1,2]; [1]Douglas Mental Health University Institute, Montréal, Québec, Canada, [2]McGill University, Montréal, Psychiatry, Québec, Canada, [3]McGill University, Montréal, Neurology and Neurosurgery, Québec, Canada* – The N400 event-related potential (ERP) is an electrophysiological index of semantic processing. A number of studies have shown that N400 effects could be markedly reduced or suppressed by the inclusion of one or several stimulus repetitions. Neverthe-

less, we have recently shown that significant N400-like effects of semantic matching and category could be obtained with massively repeated target words in a prime-target semantic categorization task (Debruille & Renoult, in press). The present study aimed at extending these findings to the study of single pairs of words. A similar primed semantic categorization task was used. The prime could be one of two category words and the target one of two exemplar words. To control for physical matching, letter case was manipulated so that both the meaning (semantic matching) and case (physical matching) of target words could be compared to that of prime words. The effect of task instruction was also evaluated by contrasting a bloc of trials where subjects had to focus on meaning (semantic instruction) and one where they had to focus on case (physical instruction). Results showed that the N400-like ERP was modulated by semantic matching and semantic category, but not by physical matching. The effect of semantic matching was observed only with the semantic instruction, while the effect of category was not modulated by task instruction. These results show that massive repetition could allow, at least in explicit semantic tasks, a drastic simplification of N400 protocols and permit the study of specific categories or individual differences

B89

INFLUENCE OF ANIMACY AND THEMATIC ROLE TYPE ON INTERPRETATION OF DIRECT OBJECT ARGUMENTS IN ACTIVE ENGLISH SENTENCES *Martin Paczynski[1], Gina Kuperberg[1,2], Evan Ruppell[1]; [1]Tufts University, [2]Massachusetts General Hospital* – In two experiments we explored the neural processing associated with the processing of Direct Objects, using Event Related Potentials (ERPs). In experiment one we compared Direct Object noun phrases (NPs) that were strongly prototypical Patients (inanimate) with weakly prototypical Patients (animate). The NPs were presented within a sentence context following verbs selecting for animate (e.g. frisk) or inanimate (e.g. reopen) Direct Object. In normal sentences, a small, transient N400 effect was found for weakly prototypical animate NPs relative to inanimates. In sentences with animacy violations (e.g. frisked the *gate/reopened the *passenger), anomalous NPs evoked a biphasic N400-P600 effect relative to their normal counterparts, that was larger for anomalous inanimate NPs at frontal sites. In experiment two, animacy selecting Agent-Patient verbs (e.g. frisk) were compared with Causer-Experiencer (e.g. please) verbs, thus contrasting a prototypical Direct Object role (Patient) with an atypical role (Experiencer). In normal sentences, Experiencer NPs evoked a large, early, frontal N400 effect compared to Patient NPs, indicating that atypical roles rapidly incur greater integration processing costs. Animacy violations (e.g. frisked the *gate/pleased the *gate) evoked a biphasic N400-P600 which was not modulated by Thematic Role type. Taken together, the two experiments suggest that how prototypical an NP is relative to its Thematic Role has modest influence on semantic integration costs, while the level of prototypicality of a Thematic Role markedly impacts early semantic processing. Additionally, these experiments show that the semantic P600 is not modulated by animacy per se nor Thematic Role type.

B90

THE TIES THAT BIND THE LEXICON: LEXICAL ASSOCIATIVE PROCESSES IN THE CEREBRAL HEMISPHERES *Padmapriya Kandhadai[1], Kara Federmeier[1,2]; [1]University of Illinois, [2]Beckman Institute for Advanced Science and Technology* – This study investigated lexical associative processes in the cerebral hemispheres using the visual half-field technique in conjunction with event-related potentials (ERPs). Participants read pairs of words for comprehension and were told to try to remember the pairs for a later cued recall task. Word pairs were asymmetrically associated (e.g., butcher-meat), allowing a manipulation of associative strength while keeping semantic content relatively constant. In the forward direction (forward pairs), there was a strong association from prime to target and the target was the primary associate of the prime. However, when these pairs were presented in the backward direction (backward pairs), there was a weak association from prime to target. For both hemispheres, ERPs to lateralized targets revealed that N400 amplitudes were graded, smallest to forward pairs and largest to unrelated pairs. This suggests that both hemispheres are sensitive to lexical associative strength. However, there was a P2 enhancement for forward pairs limited to the left hemisphere (LH), indicating that only the LH uses context information to predict upcoming words when there is a strong association from prime to target. Further, enhancement of the late positive complex to the backward targets in the LH suggests that the LH additionally employed controlled processes to reshape and amplify the weak association from prime to target. These results suggest that even though both hemispheres are sensitive to lexical association, they engage in complementary processes to appreciate such associative relationships.

B91

NOMINAL AND PREDICATE METAPHOR PROCESSING IN PARTICIPANTS WITH LEFT AND RIGHT HEMISPHERE LESIONS *Gwen L. Schmidt[1], Eileen Cardillo[1], Alexander Kranjec[1], Anjan Chatterjee[1]; [1]University of Pennsylvania* – The traditional view that people with right hemisphere (RH) lesions have difficulty understanding figurative language such as metaphors is currently under fire. Recent imaging work has provided conflicting results which may be due to various factors including poor stimulus control. Furthermore, metaphor theory and research typically only consider nominal metaphors ('My job is a jail'). However, verbs are frequently used metaphorically in predicate metaphors ('He swept the woman off her feet'). To address these potentially critical factors, we developed a closely-matched set of nominal metaphors, predicate metaphors, and literal sentences with accompanying comprehension questions for testing with participants with strokes (n=32). While participants with LH lesions showed similar performance across conditions, participants with RH lesions were less accurate on metaphors than literal sentences, an effect driven by performance in the predicate metaphors. The residuals from a regression of predicate metaphors on matched literal sentences did not differ between the two groups, while the residuals from a regression of literal sentences on predicate metaphors were significantly different between the groups. Thus it was the differences in literal sentence processing between the groups that drove the effect, and participants with LH lesions had higher scores for metaphors than literal sentences. One possible explanation is that they derive a benefit from an intact right hemisphere which facilitates their processing of metaphors more than literal sentences.

B92

BRAIN MECHANISM OF CHINESE IDIOM COMPREHENSION: EVIDENCE FROM A FUNCTIONAL MAGNETIC RESONANCE IMAGING STUDY *Jie Yang[1], Hua Shu[1]; [1]State Key Laboratory of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China* – Idiom processing has evoked interesting empirical researches and led to theoretical debates regarding the role of the left versus the right hemisphere in the processing of idioms. The current study investigated the brain mechanism of Chinese idiom to identify the neural substrates of idiom processing. During the experiment, participants judged whether there was an italic character in each opaque idiom, transparent idiom, or regular phrase. Group analysis and conjunction analysis showed idioms activated bilateral brain regions, while phrases only activated left regions. ROI analysis showed in the left inferior frontal gyrus the sum signal intensity of opaque idioms was significantly greater than that of transparent idioms and regular phrases, but there was no significant difference between the later two conditions. In the right inferior frontal gyrus, there was clearly a graded effect of the sum signal intensity across opaque idioms, transparent idioms, and phrases, suggesting that this region may be particularly involved in idiom processing. Besides, in left middle temporal gyrus phrases showed significant greater signal intensity than idioms. In sum, the results showed bilateral neural substrates are involved in idiom processing. The left regions might be responsible for general lexical retrieval and semantic integration, while the right regions may play the more important role. This role might be

due to the involvement of the right inferior frontal gyrus in the retrieval of long-term, episodic memory, given that the Chinese opaque idioms require special efforts in organizing and completing a knowledge-based story comprehension.

B93

SEMANTIC INTERFERENCE IN THE POSTCUE NAMING PARADIGM IS A POSTLEXICAL EFFECT: EVIDENCE FROM FMRI *Julia Hocking[1], Katie McMahon[1], Greig` de Zubicaray[1]; [1]fMRI Lab, Centre for Magnetic Resonance, University of Queensland* – In the postcue naming paradigm, participants are shown pictures of two objects and are cued to name one (the target) following their presentation. When the two objects are categorically related, naming latencies are slower compared to unrelated objects. Three different mechanisms have been proposed to account for this effect occurring at pre-lexical, lexical and post-lexical levels of processing. We tested these accounts using event-related functional magnetic resonance imaging with a sparse design at 4 Tesla. Over 50 trials, participants were required to view two superimposed line drawings of real objects (one red, one green). A subsequently presented selection cue - the postcue (a red or green dot) - then indicated which item was to be named. Half the superimposed pairs were categorically related. Following standardized data preprocessing stages in SPM5, we computed the effect of naming in related compared to unrelated trials. At the second, random effects level, naming in the context of related compared to unrelated distractors increased activation in two regions of frontal cortex. The first was in the left pars triangularis of the inferior frontal gyrus - a region thought to be involved in mediating selection among competing alternatives in picture naming tasks. A second cluster was observed in a medial superior frontal gyrus region associated with task switching and response selection. Together, these results indicate that semantic interference during naming in the postcue paradigm occurs at a late stage in the object naming system, subsequent to lexical selection.

B94

AUDITORY CONTEXT EFFECTS IN PICTURE NAMING INVESTIGATED WITH EVENT RELATED FMRI *Greig de Zubicaray[1], Katie McMahon[1]; [1]fMRI Lab, Centre for Magnetic Resonance, University of Queensland* – Naming an object entails a number of processing stages, including retrieval of a target lexical concept and encoding of its phonological word form. We investigated these stages using the picture-word interference task in a sparse design event-related fMRI experiment. Participants named target pictures in the presence of auditorily presented semantically, phonologically or unrelated distractor words, or in isolation. As expected, auditory context effects resulted in BOLD signal changes in left hemisphere regions associated with lexical conceptual and phonological processing, including the mid to posterior lateral temporal cortex. However, contrary to predictions, these BOLD responses manifested as signal reductions for all distractor conditions compared to naming alone. Compared to unrelated words, phonologically related distractors showed further signal reductions in these regions, while only the pars orbitalis of the left inferior frontal cortex showed a selective reduction in response in the semantic condition. We interpret these findings as indicating the word forms of lexical competitors are phonologically encoded, and that competition during lexical selection is reduced by phonologically related distractors due to initial word form features overlapping with those of the target. As the extended nature of auditory presentation requires a large portion of a word to be presented before its meaning is accessed, we attribute the BOLD signal changes observed for semantically related words to mechanisms engaged after target name selection has occurred. In addition, we argue that the signal decreases observed could only be accommodated by production models incorporating lateral inhibition to suppress the activity of competitors.

B95

A PARAMETRIC FMRI STUDY OF QUANTIFIER TYPES: MANY, MOST, AND MORE-THAN-HALF *Yosef Grodzinsky[1], Stefan Heim[2,3,4], Sarah Hautvast[5], Simon B. Eickhoff[2,3,4], Katrin Amunts[2,3,4]; [1]McGill University, Linguistics, [2]INB3-Medicine, Research Centre Jülich, [3]Aachen University, Psychiatry and Psychotherapy, Medical Faculty, JARA, RWTH, [4]Aachen University, Psychiatry and Psychotherapy, Medical Faculty, RWTH, [5] Aachen University, Neurolinguistics, Medical Faculty, RWTH* – Quantifiers are relational terms whose role in semantic composition is critical. They are classified into first-order (some, many) or higher-order quantifiers (most, more-than-half). These types recruit different computational resources: the former require one calculation of set relations (Some As are Bs=A is a subset of B); the latter require additional calculations (Most As are Bs= the intersection between A and B is greater than A-B). First- and higher-order quantifiers recruit distinct brain regions (Troiani et al. 2008; McMillan et al. 2005). We used a novel fMRI design with two objectives in mind: (1) to explore this distinction via a parametric design varying the processing demands within each quantifier condition; (2) to investigate finer distinctions within higher-order quantifiers (most vs. more-than-half) that are treated equally in Generalized Quantifier Theory, although they might be computed differently (Hackl 2008). Participants heard sentences like most circles are blue or more-than-half of the circles are yellow and then saw scenes in which task difficulty was systematically manipulated by varying the proportion of blue and yellow circles. They decided whether the scene matched the sentence. RTs and BOLD response measures were regressed upon the parametric modulation of the proportion of blue/yellow circles. We found RT and BOLD differences for these regressors for first- vs. higher-order quantifiers, and, most importantly, for most vs. more-than-half. Thus, we may have hints for a semantic brain map. This novel paradigm may be useful to elucidate deficits in patients with either linguistic (e.g. primary-progressive aphasia) or formal thought disorders (e.g. schizophrenia).

B96

COMMUNICATIVE STYLE OF A SPEAKER AFFECTS LANGUAGE COMPREHENSION: AN ERP STUDY *Thomas Gunter[1], Stefanie Regel[1], Seana Coulson[2]; [1]Max-Planck-Institute for Human and Cognitive Brain Sciences, Leipzig, Germany, [2]University of California, San Diego* – Contextual and pragmatic knowledge has been shown to influence the interpretation of sentences within discourses. Specifically, this information gains importance when sentences have a figurative, e.g. ironic meaning which has to be derived by means of contextual knowledge. The knowledge about speakers, for example, indirectly adds extra-linguistic information that probably facilitates the interpretation of sentences having a non-literal meaning. In an ERP experiment with two sessions, we investigated when and how such pragmatic knowledge can affect the construction of sentence meanings. In the first session the pragmatic knowledge of two particular speakers was established. One speaker was characterized as being highly ironic and making very frequently ironic statements, whereas the other appeared to be low ironic saying mainly literal sentences. In session 2, the influence of this knowledge was explored when the use of irony was balanced for both speakers. Participants were presented with discourses ending in an ironic or literal sentence expressed either by the high or low ironic speaker. ERPs in session 2 showed a clear interaction of irony and speaker on the P2. Whenever the communicative style of a speaker was congruent with a particular statement, P2 was larger compared to when it was not. Interestingly enough, only for the high ironic speaker a LPC was elicited by ironic statements. These results suggest that pragmatic knowledge about speakers is taken into account when comprehending (ironic) sentences.

B97

THE MODULATION OF SEMANTIC PRIMING BY DISCOURSE AND SENTENCE CONTEXTS DURING SPEECH COMPREHENSION: AN ERP STUDY *Megan Boudewyn[1], Christine Camblin[2], Jon Venezia[3], Lara Polse[1], Peter Gordon[4], Tamara Swaab[1]; [1] UC Davis, Psychology and Center for Mind and Brain, [2]CSU, Division of Social, Behavioral and Global Studies, Monterey Bay, [3]UC Irvine, Cognitive Sciences, [4]UNC, Psychology, Chapel Hill* – This study examined the effects of semantic priming in discourse and sentence level contexts in both the

visual and auditory modalities. Specifically, highly associated words (e.g. tables and chairs) and unassociated words were embedded within auditory three-sentence passages (Experiment 1) and in auditory, visual, and compressed, flat-prosody single-sentence contexts (Experiments 2, 3 & 4). In Experiment 1, the discourse was either congruent or incongruent with the final word in the third sentence (which was either associated or unassociated). ERP results for Experiment 1 show early main effects of discourse congruence and delayed traces of lexical association effects. The same pattern of results was found in auditory sentential contexts (Experiment 2), yet classic N400 effects of lexical priming were intact when the same stimuli were presented as text (Experiment 3). In order to establish whether properties unique to spoken language were leading to speech having a 'context-advantage' over text, we removed prosodic cues as well as compressed the naturally spoken stimuli from Experiment 2 (Experiment 4). However, as in Experiment 2, this yielded a null N400 effect of semantic priming. The pattern of results across all four experiments shows strong N400 evidence for the robust modulation of semantic priming in spoken (more than written) three-sentence discourse contexts and in single sentences. This indicates that although the greater effect of context on semantic priming in speech cannot be attributed to prosodic cues alone, the presence of auditory discourse and even sentential context may still be enough to modulate word-level effects like priming.

B98

FMRI-ADAPTATION EVIDENCE OF OVERLAPPING NEURAL REPRESENTATIONS FOR OBJECTS RELATED IN FUNCTION OR MANIPULATION *Eiling Yee[1], Daniel Drucker[1], Sharon L. Thompson-Schill[1]; [1]University of Pennsylvania* – According to sensorimotor-based theories of semantic memory, different aspects of an object's meaning are stored in physically distal networks, according to the modality in which the information was acquired. We used fMRI adaptation to test this hypothesis, measuring brain activation as participants read pairs of words, on which they later made a semantic judgment. Pairs shared: shape (marble - grape), function (flashlight - lantern), both (pencil - pen), neither (saucer - needle), or were identical (drill - drill). We observed adaptation for pairs similar in both function and shape in left precentral cortex (premotor cortex). Further, we found that (across all pairs) degree of manipulation similarity was correlated with the degree of adaptation in left premotor cortex and in left intraparietal sulcus (involved in guiding actions). This suggests that manipulation information about concepts is encoded in brain regions involved in performing or guiding actions. There were also three regions in which function (but not manipulation) similarity was correlated with degree of adaptation: two in the left temporal lobe (left medial temporal lobe, left middle temporal gyrus) which has been hypothesized to play a role in mutimodal integration, and the left superior frontal gyrus. Unexpectedly, we also found that objects similar in shape showed increased activation (rather than adaptation) in left premotor cortex and left intraparietal sulcus. Overall, we found evidence (in the form of adaptation) that objects that share semantic features have overlapping representations, as well as support (due to the particular regions of overlap) for both sensorimotor and amodal representations.

B99

AN ELECTROPHYSIOLOGICAL INVESTIGATION OF INDIVIDUAL DIFFERENCES IN THE USE OF SENTENTIAL CONTEXT *Edward W. Wlotko[1], Kara D. Federmeier[1,2,3], Marta Kutas[4,5]; [1]University of Illinois, Psychology, [2]University of Illinois, Neuroscience Program, [3]Beckman Institute for Advanced Science and Technology, [4]University of California, Cognitive Science, San Diego, [5]University of California, Neurosciences, San Diego* – Comprehenders differ on a number of dimensions relating to the processes involved in constructing message-level meaning for spoken or written discourse in realtime. In several experiments using similar materials, we investigated how some aspects of verbal ability and/or verbal memory may affect the ease or efficiency of message-level processing. We focused on the sentence level by examining event-related brain potential (ERP) responses to words that completed sentence frames varying in level of constraint. Consistent with prior research, we found that reading span predicted the size of the basic sentence-level expectancy effect on the N400 component of the ERP. We also found that scores on the Magazine Recognition Questionnaire, a measure of exposure to print, predicted the size of a recently-observed late frontal positivity that is larger for unexpected endings in strongly constraining sentence contexts compared to unexpected endings in weakly constraining contexts. We previously linked this positivity to a semantic revision process, needed when a plausible but unexpected word must be integrated into a constraining sentential context that strongly suggests a different word. These results suggest that reading experience may impact the use of predictive contexts in online language comprehension, particularly during reading.

B100

CALLOSAL QUALITY MEDIATES THE BILATERAL PROCESSING ADVANTAGE *Simon Davis[1,2], Jamaur Bronner[2], Norbou Buchler[1,2], Roberto Cabeza[1,2]; [1]Duke University, Center for Cognitive Neuroscience, [2]Duke University, Psychology and Neuroscience* – A number of studies have shown the benefit of interhemispheric processing when tasks become increasingly difficult. This bilateral processing advantage (BPA) occurs in older adults at lower levels of matching demands than in younger adults; this result is consistent with the functional compensation account because it suggests that older adults show the benefits of bilateral processing at levels of task difficulty for which a single hemisphere is largely sufficient in younger adults. Our study sought to use functional MRI and diffusion tensor imaging (DTI) to link age effects on cross-hemispheric matching to the quality of the bilateral processing network in older adults. In the perceptual condition participants matched faces that differed in perceptual similarity, whereas in the semantic condition they matched word pairs that differed in semantic relatedness. Consistent with the functional compensation view, BPA in the semantic and perceptual conditions increased with task difficulty; this pattern was even more pronounced in older adults. A parametric analysis of fMRI data weighted by task difficulty indicated that lateral temporal and fusiform activity tracked task difficulty in semantic and perceptual conditions, respectively, while anterior frontal regions tracked task difficulty in both tasks. Consistent with these fMRI results, DTI data indicated that the quality of callosal fibers connecting these anterior frontal regions showed positive relationship with the BPA. Taken together, these results support the view that the hemispheres cooperate during difficult bilateral tasks and that this effect generalizes to complex semantic and perceptual tasks not previously investigated with this paradigm.

B101

THE EFFECT OF LEXICAL AMBIGUITY ON SPOKEN WORD RECOGNITION USING HOMOGRAPHIC AND HETEROGRAPHIC HOMOPHONES *Jack Rogers[1], William Marslen-Wilson, Matthew Davis; [1]MRC Cognition and Brain Sciences Unit, Cambridge, UK* – Faster visual lexical decisions for semantically ambiguous words versus unambiguous controls have been interpreted as evidence for facilitatory feedback from multiple semantic representations (Rubenstein et al., 1970). Yet, more recent experiments have suggested two opposite effects of lexical ambiguity: polysemous words (twist) with multiple related senses show an ambiguity advantage whereas homographic homophones with multiple unrelated meanings (bark) delay word recognition due to semantic competition (Rodd et al., 2002). However, the homophony/polysemy distinction is subjective and further data is valuable. Assessing responses to spoken words allows us to use homographic (bark) as well as heterographic (knight/night) homophones for which two separate representations exist. In both an auditory lexical decision task and semantic categorisation task using 72 matched homographic homophones, heterographic homophones and single-meaning controls subjects show significantly slowed response times for both groups of ambiguous words versus controls. No significant difference between the homographic and heterographic homophones suggests that the ambiguity disadvantage is

largely due to semantic not orthographic competition. This ambiguity disadvantage is consistent with neural network accounts of word recognition (Rodd et al., 2004); ambiguous spoken words activate multiple semantic representations, which compete during identification. Similarly, neural responses to sentences containing multiple ambiguous words produces increased signal in frontal and temporal regions implicated in comprehending and selecting contextually appropriate word meanings (Rodd et al., 2005). We propose that the neural mechanisms that enable the selection of appropriate semantic attributes of ambiguous words within a sentence also allow semantic information to be selected and integrated for single ambiguous words.

B102

WHAT CONSTITUTES A RELEVANT CONTEXT FOR PROCESSING NEGATION? AN EVENT-RELATED POTENTIAL STUDY *Lea Hald[1], Julie-Ann Marshall[1], Alan Garnham[2]; [1]Canterbury Christ Church University, United Kingdom, [2]University of Sussex, United Kingdom* – Several event-related potential (ERP) studies have found when a sentence includes negation ('A robin is not a TREE/BIRD') the amplitude of the N400 is greater for true sentences ('tree') than for false sentences ('bird'), (Fischler et al., 1983). However, Nieuwland and Kuperberg (in press) have shown that in a context appropriate for negation, false words rather than true words elicit a larger N400. This suggests that the context allows readers to relate the incoming words to the negation information immediately. The current study explores what aspects of context are relevant. Our hypothesis is that at least three factors contribute to the immediate processing of negation. First, whether the negated word is in focus. Secondly, whether the negated word is related to 'the implied set of likely worlds' and thirdly, whether the use of negation adds new information. When all three of these factors are present, a negated word will not elicit a large N400. However, when none of these factors are present, a negated word will elicit a large N400. In an ERP study we have tested this prediction by using a five-sentence discourse context followed by one of five continuations that tease apart the independent but correlated influence of focus, the implied set of likely worlds and new information. Our preliminary results support our hypothesis, when all three of these factors are included in a context, the amplitude of the N400 is smallest compared to when some or all of these factors are missing from the discourse.

B103

'BREAKING' LANGUAGE: A PARADIGM THAT DISSOCIATES SEMANTIC AND PHONOLOGICAL FUNCTIONS IN LEFT POSTERIOR TEMPORAL AND PARIETAL BRAIN REGIONS *Miranka Wirth[1], Ayse At[1], Melanie Fisler[1], Andrea Federspiel[1], Helge Horn[1], Thomas Dierks[1]; [1]University of Bern, Bern, Switzerland* – Previous functional Magnet-Resonance-Imaging (fMRI) findings suggest a dissociation of language (i.e., phonologic and semantic) functions in posterior temporal and parietal brain areas. However, this assumption is mostly derived from analyses that compare activations patterns across different stimuli and subjects groups. In this study we test a simple block-design paradigm that aims to localise language functions connected to posterior brain areas in group and single subject analyses by demanding semantic and phonological judgements to the same word-stimuli. The subjects judged words according to semantic (living?, yes/no) and phonological (2 syllables, yes/no) features via button press. Preliminary data will be presented.

B104

FINDING AN OPTIMAL TASK FOR TESTING LANGUAGE DEFICITS IN ATTENTION-DEFICIT/HYPERACTIVITY DISORDER CHILDREN *Jennifer Edens[1], Fan-pei Gloria Yang[1], Daniel Krawczyk[1, 2]; [1]Center for Brain Health, University of Texas at Dallas, [2]University of Texas Southwestern Medical Center, Psychiatry, Dallas, Texas* – Attention-Deficit/Hyperactivity Disorder (ADHD) has been studied in areas of language abilities in general. Clear lines have not been drawn on whether ADHD language deficits have to do with vocabulary competence, semantic knowledge or inference ability. It is beneficial to design a language task that can assess performance on different types of linguistic stimuli to identify which cognitive factors are of most concern. The goal of our proposed study was to investigate correlations between vocabulary competence/inference ability and figurative language comprehension using computerized presentation of novel and conventional metaphors and literal sentences. Conventionalized sentences (metaphor and literal) only test semantic knowledge whereas novel metaphors test inference ability. In this study the participants were instructed to rate whether the displayed sentence held a positive or negative meaning by pressing the corresponding key. A written task asked for their interpretation of the sentences. Our results indicated that these children performed significantly better in both the conventional metaphors and the literal sentences relative to the novel metaphor condition. Overall they scored equally well on comprehension of conventional and literal sentences. Compared with normal controls they performed significantly worse in all categories. This study can provide insights for research on ADHD children's higher cognitive functions such as reasoning and language processing. This can help to assess whether conventional neuropsychological measures are appropriate for evaluation and diagnosis. These measures have limitations that our computerized tasks could supplement by allowing better control over familiarity of stimuli and identification of specific cognitive deficits in relation to language comprehension.

B105

REAL WORD PICTURE SET NORMED FOR NAME AND STEM COMPLETION *Aaron T. Karst[1], Eric S. Clapham[1], C. Mark Wessinger[1,2,3]; [1]University of Nevada, Reno, [2]Charteroak State College, [3]Northcentral University* – Experimental investigations utilizing picture stimuli many times suffer from a lack of validity because the picture set being employed was never normed. To avoid this problem many individuals either norm pictures themselves or will use a normed picture set available to the public. Stimuli for one such normed set available for public use consists of pictures of black and white line drawings of objects and animals. These pictures are standardized for name and image agreement, which increases the validity of the stimuli and thus any experiment using the stimuli. Though this picture set provides for a great deal of validity for experimental use, the pictures do not contain many real world characteristics such as color, depth or texture. This confound raises the question of whether these pictures are processed in the same manner as one would process the real world, or as efficiently. Attempting to correct for this confound our lab has standardized a variety of real world, full color pictures for name and image agreement. Consequently, this picture set is being standardized in other areas. Among the various subgroups (e.g. furniture) represented within this picture set, it also contains an equal animate/inanimate grouping. Furthermore, all picture names with five or more letters have been normed for completion percentage. This involved adding additional letters to each root forming the first word that came to mind. Such information will prove useful in many experimental studies investigating object and semantic processing.

Poster Session C

Attentional processes: Visual

C1

EARLY ATTENTIONAL PROCESSES AS PREDICTORS OF RESPONSE CONFLICT AND ERROR COMMISSION *John R. Fedota[1], Craig G. McDonald[1], Raja Parasuraman[1]; [1]George Mason University* – Are modulations in early attentional ERP components predictive of modulations in later decision related components and the commission of errors? In the present study we evaluate the relationship between early and late stimulus-related ERP components. Recent evidence suggests that the N2 component indexes response conflict in go/no-go tasks. The ERN, an index of error commission, is also is elicited in go/no-go tasks. If early attentional processes inform later conflict and error processes, changes in N1 amplitude should be reflected in changes in N2 and ERN following response conflict and error commission respectively. Subjects completed a visual go/no go task with a difficult discrimination between targets and non-targets. Blocked task conditions were 80% target-20% non-target (go/no go) or 20% target-80% non-target (oddball). 64 channel EEG was recorded. Behavioral data show subjects had difficulty making the target/non-target discrimination in both the 20/80 and 80/20 target/non-target conditions. Thus, there were adequate numbers of error trials to enable meaningful comparison of correct and error trial ERP waveforms. ERP results showed that reduced N1 amplitude was predictive of error commission in both tasks and with the ERN associated with the go/no go task. Conversely, greater N1 amplitude was associated with correct performance in both tasks and greater pre-response N2 amplitude for the go/no go task. While previous studies have examined conflict and error processing in relation to N2 and response-ERN, our results tie the manipulation of these components directly to the attentional modulation of the earlier N1 component.

C2

INTEGRATING FEATURES ACROSS AND WITHIN CORTICAL STREAMS IN VISUAL SEARCH: DIFFERENTIAL EFFECTS OF AGING AND ALZHEIMER'S DISEASE *William C. Heindel[1], Elena K. Festa[1], Samantha Set[1], Lindsay A. Miller[2], Jennifer D. Davis[3], Brian R. Ott[2]; [1]Brown University, Psychology, [2]Brown University, Clinical Neurosciences, [3]Brown University, Psychiatry and Human Behavior* – The selective disruption of corticortical connections in Alzheimer's disease (AD) should lead to a specific deficit in effectively integrating stimulus features processed within distinct cortical areas. To examine this issue, two visual search tasks identical in their selective attention demands but differing in the demands placed on cross-cortical interactions were developed: Subjects were required to integrate a target's motion with either its luminance contrast (black or white) or its isoluminant color (red or green). Given that luminance and motion information are both processed within the same dorsal cortical stream whereas color identity information is processed within the ventral cortical stream, the motion/color integration task places greater demands on cross-cortical interactions than does the motion/luminance integration task. As expected, healthy elderly participants performed comparably on the two integration tasks, and displayed proportionately larger search times with increasing distractor set size compared to healthy young participants; taken together, these results indicate that aging is associated with a deficit in selective attention but not sensory integration. AD patients, in contrast, not only displayed an additional increase in slope relative to the healthy elderly in both tasks (suggesting a further decline in selective attention), but also showed an additional impairment in the more demanding cross-cortical binding motion/color task that was independent of set size. These findings not only provide further confirmation of a specific sensory binding deficit associated with neocortical disconnectivity in AD, but also provide empirical support for a fundamental distinction between binding and attentional components of feature integration within visual search.

C3

OBJECT-BASED ATTENTION IN PATIENTS WITH LEFT AND RIGHT HEMISPHERE LESIONS *Alexandra List[1,2], Ayelet Landau[1], Joseph Brooks[1], Anastasia Flevaris[1], Francesca Fortenbaugh[1], Michael Esterman[1], Thomas VanVleet[3], Alice Albrecht[1], Bryan Alvarez[1], Lynn Robertson[1,3]; [1]University of California, Berkeley, [2]School of Psychology and Wolfson Centre for Cognitive Neuroscience, Bangor University, UK, [3]Medical Research Service, Veterans Affairs, Martinez* – Since Egly, Driver and Rafal's (1994) pioneering study of object-based attention, their two-object cueing design has been widely used to study space- and object-based attentional orienting. Here, twenty-nine patients with unilateral brain injury (sixteen with RH injury) performed target detection in a modified version of the two-object cueing task. By obliquely orienting the two rectangular objects ±45?, we were able to measure cueing performance separately at midline, in the contralesional field, and in the ipsilesional field. Cues were 64% predictive and always appeared in an upper or lower midline location. For targets appearing at midline locations, RTs were faster at the cued than uncued locations, as expected. When targets appeared laterally to the right or left of fixation, performance was modulated by the configuration of the objects in the display, but in opposite ways on the contralesional and ipsilesional sides. Reaction times (RTs) on the ipsilesional side were in the predicted direction: faster for targets in cued objects than uncued objects. Conversely, RTs to contralesional targets were slower in cued objects than uncued objects. The left and right hemisphere groups did not differ from each other in this respect. In sum, both patient groups revealed contralesional object-based neglect while demonstrating the opposite, but expected, object-based facilitation effect in their ipsilesional field. The current findings will be related to previous studies of lateralized attentional orienting, patients' performance on bedside tests of space- and object-based orienting, and to theories of hemispheric asymmetries in attentional orienting.

C4

ATTENTIONAL CAPTURE BY SIZE DEPENDS ON FEATURE-SPECIFIC TOP-DOWN TASK SETS: EVIDENCE FROM THE N2PC COMPONENT *Monika Kiss[1], Martin Eimer[1]; [1]Birkbeck College London, UK* – The question whether attentional capture by salient but task-irrelevant visual stimuli is determined by top-down task set is still a matter of debate. A recent study (Eimer & Kiss, 2008, J Cogn Neurosci) used the N2pc component of the event-related potential to show that spatially uninformative colour singleton cues capture attention only when targets are defined by their colour but not when they were defined in another dimension (onset or size). Here, we used the N2pc as a marker of attentional capture to investigate the role of feature-specific top-down task sets for the attentional capture by size singletons. In separate blocks, participants searched for a pre-defined size target (a small or large bar among medium-sized bars). Circular search displays were preceded by spatially non-predictive circular cue displays that contained either a small or a large item among medium-sized items. N2pc components and behavioural cueing effects were observed only when the relative size of singleton cues and targets matched (e.g., for small cues when participants searched for small targets), demonstrating that attentional capture is not triggered by any size discontinuity, but is determined by feature-specific top-down task sets that

represent relative size. Interestingly, the absence of an item in the cue display triggered behavioural cueing effects and an N2pc both when participants searched for small and for large targets, suggesting that bottom-up factors can affect attentional capture in such extreme cases of feature discontinuity.

C5

ATTENTIONAL CAPTURE AND AWARENESS *Edmund Wascher[1], Christian Beste[1]; [1]Leibniz Research Centre for Working Environment and Human Factors* – Visual attention might be driven either by intention or by salient events in the visual field. Models like the "biased competition model" assume that these two mechanisms interact with each other, thereby providing the basis for aware representations. Within this framework, a competition of information is assumed to take place in perceptual and higher prefrontal areas. This process brings incoming information in relation to each other and selects those (strongest) elements of relevance that will subsequently propagate to higher cognitive functions. Attentional control is assumed to modulate this process as a kind of processing filter. Thus, also for intention based selection, the competition mechanism might serve as the main substructure. Therefore, manipulating the saliency of irrelevant elements in a display may essentially modulate the processing of attended information. We run two experiments in which participants had to press a button to a luminance change. In some trials, a motion transient of varying strength (implemented by a 90° rotation of a bar with differing aspect ratios) was presented simultaneously with the 40cd-lumimance change. Behavioral data showed that the strength of the task-irrelevant transient modulated the ability of the observer to perceive the luminance transient awarely. Up to 30% errors were committed with the strongest irrelevant stimulus. EEG-recordings support the notion that despite the instruction to attend the luminance transient only, the motion signal captured attention at a first processing step. Intention based attention obviously has to overcome this initial tendency when searching for desired information.

C6

THE NEURAL CONTROL MECHANISMS UNDERLYING MEMORY-GUIDED ATTENTION *Ian C. Gould[1], Mark G. Stokes[1], Kathryn Atherton[1], Anna Christina Nobre[1]; [1]University of Oxford* – The control mechanisms that guide selective attention are typically examined in response to explicit attentional cues. In everyday life, however, the focus of attention is more typically guided according to past experiences than direct instruction. We therefore developed a novel behavioural paradigm to examine the neural substrate of memory-guided attentional orienting. Participants first learn the location of target stimuli hidden within naturalistic scenes. After the target locations have been learned, participants then perform an attention-orienting task. Each experimental trial begins with a cue stimulus, consisting of the memory scene presented without the target stimulus. A test scene is then presented, with a 50% probability of a target stimulus being present at the remembered location. Participants are instructed to use their memories to guide the focus of attention. In a previous fMRI study (Summerfield et al., 2006, Neuron), trials involving memory-guided attention were shown to engage activity in the same dorsal frontoparietal network that is typically associated with explicitly cued shifts of spatial attention, and in the hippocampus. However, it was not possible to isolate target-related processes from cue-related processes. In the present study, we tested and verified the roles of dorsal frontoparietal cortex and hippocampus activity in the neural control of memory-guided attention, by dissociating mnemonic cue-related activity from target-related activity. These results provide additional insights into the functional neural architecture of memory-guided attention, broadening the neuroscientific foundations for a more generalised account of attentional control during real-world behaviour.

C7

VISUAL REALISM AND EMOTION MODULATE ATTENTIONAL PROCESSING: EVIDENCE AT THE P3 EVENT-RELATED POTENTIAL *Bernadette Sibuma[1], Karen Froud[2,3], John Black[2,3]; [1]State University of New York at Oswego, [2]Columbia University, [3]Teachers College* – Emotional content and task relevance have been found to modulate the amplitude of the P3 event-related potential (ERP), however little is known about the effects of the visual realism of images on attentional processes. In this study, we examined the P3 amplitude as elicited by cartoon, computer agents, and photographs of faces with and without emotion (fear, neutral). The experiment was conducted using dense array electroencephalography with twenty-five adult participants. A repeated measures design using two perceptual decision-making tasks examined the effects of visual designs on ERPs. Consistent with previous studies (Kiss & Eimer, 2008), the results showed a significant effect of emotion on the P3 amplitude, with fearful faces increasing P3 positivity. Researchers suggest that fear images, in particular, enhance attention due to a hard wired response to threatening stimuli. Secondly, a significant effect of design was found, with photographs eliciting higher P3 amplitudes in comparison to agents or cartoons. The results suggest increased attentional processing to photographs that could be due to activation of higher cognitive processes, such as discrimination of face identity, which are not active when cartoon or computer agents are perceived. The findings are relevant for the selection and equivalency of stimuli across various neurocognitive experiments, in particular those which occur in simulated environments.

C8

NEURAL CORRELATES OF SUSTAINED ATTENTION *Caroline Hilti[1], Kay Jann[1], Dörthe Heinemann[2], Andrea Federspiel[1], Erich Seifritz[1], Katja Cattapan-Ludewig[1]; [1]University Hospital of Psychiatry, University of Bern, Berne, [2]University Hospital of Neurology, Inselspital Bern, Berne* – All versions of the Rapid Visual Information Processing task (RVIP) - RVIP0, RVIP000 and RVIP3tarseq - require the participant to sustain attention over 16 min. Whereas the RVIP3tarseq is a high demanding task, RVIP000 and RVIP0 are simple tasks especially designed to measure purer forms of sustained attention. We apply a rapid event related paradigm in fMRI to investigate brain regions recruited by these tasks and the correlation between brain activity and behavioural data. 20 right-handed participants responded to specific target numbers in each task. Reaction times (RT) and the number of hits were recorded. Nullevents were interspersed randomly. Random effects GLM analyses were performed, contrasting targets vs. nullevents. RVIP0 shows the most extended and highest activations followed by RVIP000 and RVIP3tarseq. They all activated the visual areas bilaterally and the medial frontal/cingulate area. RVIP0 is the only task that activates the right dlPFC. The inferior parietal lobules bilaterally are activated in RVIP000 and RVIP3tarseq. Furthermore, RVIP3tarseq shows the most extended deactivations in the default mode network, whereas the same areas are only partly/not deactivated in RVIP000/RVIP0. The three tasks differ in the behavioural data and in the magnitude and extent of the (de)activated brain regions. The activation in the medial frontal gyrus might reflect planning and execution of movement. The RVIP0 could be the purest form of a sustained attention task, as it is the only task where the right dlPFC is activated. The default network might only become visible when highly demanding tasks (RVIP3tarseq) are performed.

C9

FEATURE PRIMING IN CHRONIC METHAMPHETAMINE ABUSERS: EVIDENCE FOR SPATIAL DEFICITS *Ruth Salo[1,2], Susan Ravizza[3], Thomas Nordahl[1,2], Lynn Robertson[4,5]; [1]UC Davis Imaging Research Center, [2]UC Davis Medical Center, [3]Michigan State University, [4]University of California, Berkeley , [5]Department of Veteran Affairs, Martinez CA* – Long-term methamphetamine (MA) abusers report problems in focusing attention. These attentional problems may be the result of a deficiency in filtering out irrelevant information. The aim of the current study was to assess

whether MA abusers exhibit greater effects of changes to task irrelevant features compared to healthy participants. 21 chronic MA abusers (mean age = 38+ 7.3 yrs) who were currently drug abstinent (range 1 mos to 4 yrs) and eighteen controls (mean age = 34+ 8.8 yrs) were studied. Subjects identified targets whose features could repeat or switch. The task-relevant feature of the target was letter identity whereas color and/or location were always task-irrelevant. Each trial consisted of a brief presentation of a target and distractor letter. Participants pressed the appropriate key associated with the target letter. Of primary interest in this experiment were effects of switches in the irrelevant features (color and location), when target identity remained constant. All participants were slower when color and location switched, however, MA abusers tended to show a bigger location switching effect than controls ($p < .05$). In contrast, color switching effects did not differ between groups ($F < 1$). These results suggest that chronic MA abusers do not exhibit global impairments of feature processing. Instead, impairments appear to be restricted to situations in which task-irrelevant location features vary. These findings are consistent with other studies that have reported spatial processing deficits in patients with damage to dopaminergic systems. Keywords: methamphetamine, feature processing, spatial attention [K01DA16293-01 to RS].

C10

REDUCED SPATIOTEMPORAL RESOLUTION IN CHILDREN WITH CHROMOSOME 22Q11.2 DELETION SYNDROME (22Q11.2DS) *Elliott A. Beaton[1,2], Margarita Cabaral[1,2], Joel Johnson[1,2], Tony J. Simon[1,2]; [1]Psychiatry and Behavioral Sciences, [2]The M.I.N.D. Institute, University of California, Davis* – Children with 22q11.2DS have cognitive impairments on spatiotemporal attention, arithmetical and numerical tasks. We suggest that early atypical neurodevelopment is deleterious to forming representations and processes necessary for typical function in the spatiotemporal domain. We hypothesize that this results in "spatiotemporal hypergranularity"; diminished attentional capacity, increased crowding, and a decrease in the number of elements that can be individuated. To examine spatiotemporal processing impairments and attention capacity in children (7-14 years) with 22q11.2DS versus typically developing (TD) controls, we used a variant of the Multiple Object Tracking (MOT) task in both the laboratory and during a functional magnetic resonance (fMRI) scan. In both versions, children viewed cartoon animations of 0 to 3 aliens hiding behind corresponding target planets in a field of 7 total identical planets. For 12 seconds, the 58 by 58 pixel planets moved at 60 or 120 pixels per second in non-overlapping or occluding motion within a 770 square pixel field. The child reported, via touch screen or button press, whether a planet concealed a target. In the non-scanner task, children with 22q11.2DS but not TD children showed significant decreases modeled capacity as number of targets and speed of motion increased. In the fMRI task, neural activation in children with 22q11.2DS during active object tracking overlapped with but was dissimilar to the canonical frontoparietal network evident in TD controls. Decreased tracking capacity with increased load and atypical functional activation indicate anomalous development of cortical, subcortical, and limbic temporal and spatiotemporal processing circuits in children with 22q11.2DS.

C11

MODULATION OF BRAIN ACTIVATION TO BACKWARD MASKED EMOTIONAL FACES BY TRAIT EMPATHY AND MINDFULNESS *Kit Elam[1], Josh Carlson[2]; [1]Southern Illinois University at Carbondale, [2]State University of New York at Stony Brook* – Research has shown that individual differences in anxiety modulates brain activation to subliminally presented threatening emotional stimuli in the amygdala. In empathy research, overt emotional scenes activate limbic areas such as the insula, inferior and medial frontal areas, and cingulate areas. Mindfulness, the purposeful attention to the self and surroundings, has been associated with increased emotional processing. However, individual differences in empathy, mindfulness, and subliminal emotion processing have yet to be assessed. The purpose of this experiment was to investigate how brain activation to backward masked emotional stimuli is related to individual differences in empathy and mindfulness. In the current study, event-related fMRI data was collected while participants viewed backward masked emotional faces. During each trial subjects viewed a fixation cross for 1000ms followed by a happy, fearful, or neutral face for 33ms, which was immediately masked with a neutral face for 100ms. Subjects completed the Interpersonal Reactivity Index as a measure of empathy and the Kentucky Inventory of Mindfulness Skills. Scores from both questionnaires were found to covary with activation in relation to fearful and happy faces. Activation to backward masked happy faces was found to covary with empathy and mindfulness in facial recognition, limbic, medial frontal, and cingulate regions. Fewer areas were found to covary with fearful faces, primarily the thalamus and temporal pole. These results suggest that even backward masked emotional faces activate brain regions involved in empathy. In addition, this activation was predicted by individual differences in empathy and mindfulness.

C12

COGNITIVE CONTROL OF ATTENTION: NEUROIMAGING EVIDENCE SUPPORTING USE OF THE DISTRACTOR CONDITION SUSTAINED ATTENTION TASK IN TRANSLATIONAL RESEARCH *Elise Demeter[1], Luis Hernandez-Garcia[2], Sally K. Guthrie[3], Rachel Engelmann[4], Stephan F. Taylor[5], Martin Sarter[4], Cindy Lustig[4]; [1]University of Michigan, Neuroscience Program, [2]University of Michigan, FMRI Laboratory, [3]University of Michigan, College of Pharmacy, [4]University of Michigan, Psychology, [5]University of Michigan, Psychiatry* – The dSAT (distractor condition sustained attention task) was originally developed to investigate the neural bases of attention and top-down control in rats. Recent neuropsychological studies validated its use in healthy humans (Demeter et al., 2008). The Cognitive Neuroscience Treatment Research to Improve Cognition in Schizophrenia (CNTRICS) initiative chose the dSAT as a candidate task to investigate attentional control in schizophrenia (Nuechterlein et al., in press). As part of continuing validation we report evidence on the neural correlates of dSAT performance in healthy adults. For each task trial, the participant indicates the presence or absence of a brief, centrally-presented signal. The standard (SAT) condition uses a static grey background; the distraction (dSAT) condition increases attentional challenge by using a strobing (10 Hz) background. Continuous arterial spin labeling (ASL) perfusion functional magnetic resonance imaging (fMRI) of this task in healthy humans ($n = 16$) shows that SAT performance activates regions in bilateral middle frontal gyri, paracingulate and cingulate gyri, and motor and somatosensory regions. The dSAT condition impairs performance and results in extensive right frontal and right parietal activation. Comparison of the dSAT and SAT conditions while controlling for the visual stimulation produced by the dSAT reveals increased activation in right middle frontal gyrus and right frontal pole. These results confirm the general view that sustained attention performance and top-down control of such performance is mediated via a right hemispheric frontal-parietal network. Thus, this evidence supports the usefulness of the dSAT for translational research.

C13

COVERT ORIENTING OF ATTENTION TO A SALIENT DISTRACTOR CAN BE SUPPRESSED DURING VISUAL SEARCH *John McDonald[1], Vincent Di Lollo[1]; [1]Simon Fraser University* – Recent electrophysiological studies of visual search in humans and monkeys have fueled a long-standing debate about the ability of salient visual objects to capture attention. Evidence from event-related potentials (ERPs) indicates that salient-but-irrelevant pop-out items (distractors) capture attention when humans search for less salient pop-out items (targets)(Hickey et al., 2006), whereas evidence from cellular recordings indicates that salient distractors can be ignored when monkeys search for less-salient targets (Ipata et al., 2006). Although the experiments were similar, the

color of the distractor varied randomly in the human ERP study but was fixed in the monkey study. The purpose of the present study was to determine whether advanced knowledge of the distractor helps to guide visual search in humans. We hypothesized that observers can establish a suppressive filter based on a single stimulus feature to reduce the interference from predictable visual distractors. To investigate this issue, we recorded ERPs to search displays containing a target shape singleton and a distracting color singleton whose color was fixed in each block. Crucially, the predictable distractor singleton elicited an ERP component called the distractor positivity (PD), which has been associated with attentional suppression (Hickey, Di Lollo, & McDonald, in press). This finding differed markedly from the ERP results obtained in a related ERP study (Hickey et al., 2006), wherein unpredictable distractor singletons elicited an ERP component associated with attentional deployment (N2pc; Luck & Hillyard, 1994). This demonstrates that while unpredictable distractors capture attention, observers can suppress attentional capture by predictable distractors.

C14

INDIVIDUAL DIFFERENCES IN VOLUNTARY AND INVOLUNTARY ATTENTION *Ayelet Landau[1], Deena Elwan[1], Sarah Holtz[2], Han Duong[3], Prinzmetal William[1]; [1]UC Berkeley, CA, [2]Head-Royce School, [3]Southern California College of Optometry* – The present study examined whether voluntary and involuntary attention manifest differently in people with differences in impulsivity (measured with the Barratts Impulsivity survey). We proposed that high and low impulsive participants would display different amounts of voluntary and involuntary attention. We used the spatial-cueing paradigm to assess attention. In each trial a peripheral cue (the thickening of a rectangle) was displayed, followed by a letter target. Participants were required to identify the target (F or T). Targets could either appear in the cued location (valid trials) or in the uncued location (invalid trials). We used two different manipulations to probe voluntary and involuntary attention. The first was the time elapsing between the cue onset and the target onset (SOA). Targets were separated from cues by either 40 or 400 ms. This manipulation was motivated by the finding that involuntary attention is typically transient while voluntary attention takes longer to build up. In addition, the peripheral cues were either predictive of cue location (i.e., mostly valid trials) or non predictive of cue location (i.e., equal probability for valid and invalid trials). While predictive trials probe voluntary and involuntary attention, non predictive trials summon only involuntary attention, since target location is random with respect to cue location. The different SOAs and predictability manipulations were performed in separate blocks within subjects. We found that participants with high impulsivity scores exhibited larger involuntary attention effects whereas participants with low impulsivity scores, exhibited larger voluntary attention effects.

C15

SELECTIVE ATTENTIONAL IMPAIRMENTS IN CHILDREN WITH CHROMOSOME 22Q11.2 DELETION SYNDROME *Heather M. Shapiro[1], Yukari Takarae[2], Elliott A. Beaton[1], Joel Johnson[1], Tony J. Simon[1]; [1]M.I.N.D. Institute, University of California, Davis, [2]Center for Mind and Brain, University of California, Davis* – Children with chromosome 22q11.2 deletion syndrome (22q11.2DS) demonstrate a variety of impairments on tasks involving spatial attention. These include poorer endogenous but less impaired exogenous orienting, delayed inhibition of return, and more impaired space- versus object-based attention compared to similarly aged typically developing (TD) children. To explore this further, we used an "Endogenous-Exogenous" cueing experiment to examine the differential effects of cue type, meridian crossing, and cue presentation time in 34 children with 22q11.2DS and 25 TD children (all aged 7-14 years). The task included both exogenous (luminance change in a peripheral box with 50% valid/invalid probability for an upcoming target) and endogenous (a central arrow with 65/35% valid/invalid probability for an upcoming target) cues. The time lapse from cue to target, or stimulus onset asynchrony (SOA), was either 200 or 750 ms. Cues oriented attention to equidistant locations either above and below or to the left and right of a central fixation. Overall, children with 22q11.2DS showed larger invalidity costs on endogenously but not exogenously cued trials compared to TD children. Effects were modulated by SOA length and whether orienting required crossing the horizontal or vertical meridians. Both groups produced inhibition of return, which was also modulated by SOA length and which meridian was crossed. Integrated with our other cognitive and neural findings, these results significantly clarify the specific neurocognitive basis of attentional impairments in children with 22q11.2DS.

C16

PERCEPTUAL GROUPING DURING MULTIPLE OBJECT TRACKING *Andrew McCollough[1], Trafton Drew[1], Edward Vogel[1]; [1]University of Oregon* – Previous research has suggested that perceptual grouping may significantly aid performance in Multiple Object Tracking (MOT) tasks. That is, observers may track multiple items by spontaneously grouping disparate items into a single virtual object. According to this hypothesis a virtual polygon is initially created and then updated during tracking, with the vertices of the polygon consisting of the tracked elements.(Yantis 1992) Recently our lab has demonstrated an ERP component, the CDA, sensitive to the number of successfully tracked items in a MOT task such that the amplitude of the component increases with increasing set size up to the individual subject's tracking capacity (Drew & Vogel 2008 J. Neuroscience). Here, we investigated whether a real or virtual polygon between targets in a tracking task would enhance behavioral performance and reduce tracking load (as indexed by a reduction in amplitude of the CDA). We found that the the presence of actual grouping lines between three targets in a bilateral tracking task reduced tracking load when the lines were present as compared to when they were absent. These result suggest that perceptual grouping does play a role in tracking but this may be restricted to situations when there are strong bottom-up cues for grouping.

C17

ATTENTIONAL PRIORITIZATION:THE INFLUENCE OF EXPERTISE ON HOW JOURNAL ARTICLES ARE READ *Lisa M. Meschino[1], Michael G. Reynolds[2], Daniel Smilek[1], Grayden Solman[1]; [1]University of Waterloo, [2]Trent University* – Critical to efficient and effective reading is the ability to prioritize what is of central and peripheral importance from text-based sources. The modular format of journal articles is designed to favor this kind of prioritization by standardizing the areas of central and peripheral interest and promoting selective reading. Our study examined how expertise with the journal article format influences attentional prioritization. Participants viewed two 6-page articles from the journal, Psychological Science. They were given only five minutes to read each article and each article was followed by a comprehension test. An eye monitor tracked eye movements and recorded the location, frequency, and duration of each fixation. Participants were divided into two groups based on their expertise with the text format: 1) a novice group of undergraduate students and 2) an expert group of graduate students. Our results showed that experts had higher comprehension scores than did novices and that there were substantial differences between the two groups in the frequency and location of their fixations. Experts and novices differed in how they attended to the abstract, introduction, methods, figures and discussion, with some variance across journal articles. The findings suggest that novices are less able than experts to identify and locate the important information in the article. Therefore, expertise with text format includes knowledge of what content is of central importance and where to look for it, and this knowledge guides overt attention in a top-down fashion.

C18

THE EFFECTS OF TMS OVER THE POSTERIOR PARIETAL OR DORSOLATERAL PREFRONTAL CORTEX ON THE ATTENTION NETWORK TASK *June Hung[1], Vincent Walsh[2], Jon Driver[2]; [1]Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Taiwan, [2]Institute of Cognitive Neuroscience, University College London, UK* – Arousal, spatial orienting, and conflict resolution represent varieties of attentional functions. These functions seems partially dissociated and usually require separate tasks to measure each. The attention network task is a modified flanker task that consists of three possible flankers (neutral, congruent, and incongruent) preceded by four possible types of cueing (no cue, central cue, double cue, or spatial cue), which allows measurements of the cognitive processes involving conflict resolution, along with those concerning alerting and spatial orienting. Here we investigated the roles of the posterior parietal cortex (PPC) and dorsolateral prefrontal cortex (DLPFC) in these three dimensions of attentional function. Seven healthy participants performed the attention network task before and after 1-Hz repetitive transcranial magnetic stimulation (rTMS) over the left/right PPC and DLPFC. The results showed that, after 1-Hz rTMS over the left/right PPC or left DLPFC for 600 s, all post-rTMS behavioral measures were not significantly different from the pre-rTMS baseline. After 1-Hz rTMS over the right DLPFC, however, accuracy in performing the flanker task was significantly decreased; this effect was only apparent for incongruent-flanker trials that set the highest demand for conflict resolution. Correspondingly, right DLPFC rTMS significantly increased a reaction-time derived parameter, conflict effect (prolongation in reaction times for incongruent-flanker trials relative to those for congruent-flanker ones), without affecting other parameters reflecting alerting or orienting effect. Right DLPFC is thus important in resolving conflict or competition between visual stimuli to achieve visual selectivity.

C19

INDIVIDUAL DIFFERENCES IN MULTIPLE MODES OF VOLUNTARY VISUAL ATTENTION *Marcia Grabowecky[1], KatieAnn Skogsberg[1,2], Joshua Wilt[1], William Revelle[1], Satoru Suzuki[1]; [1]Northwestern University, [2]Centre College* – Extensive research has characterized what can be prioritized by attention (e.g., a location, an object, a color, or a motion), and how attention can act (e.g., focused, distributed, or sustained). Neuroscientific approaches have identified both distinct and overlapping patterns of brain activity associated with different modes of attention, suggesting inter-relationships among attention mechanisms. To understand how the many hypothesized attention mechanisms work together to support behavioral goals, it is essential to understand these inter-relationships. To this end, we examined inter-correlations among representative voluntary attention skills by administering an attention battery consisting of 10 common voluntary attention tasks to over 250 participants. Eight of these tasks (except for two Eriksen-flanker-type tests) had sufficient reliability, so we examined their relational structure by performing cluster (using the ICLUST algorithm; Revelle, 1979) and multidimensional scaling (MDS) analyses on their correlation matrix. Results suggested that these tasks formed four distinct clusters of attention skills, (1) rapidly deploying attention, (2) persistently maintaining attention (vigilance), (3) spatially shifting attention or tracking with attention, and (4) attending to global patterns and objects or grouping with attention. In the MDS, the first two clusters defined an axis interpretable as a transient-sustained axis, and the latter two clusters defined an axis interpretable as a spatiotempral-discrete-global axis. Prior investigations of the neural substrates of some of the attention battery tasks appear consistent with this clustering. Finally, we will demonstrate the utility of the attention battery for investigating group differences in attention abilities using sex differences as a test case.

C20

DO VISUAL SPATIAL ATTENTION-VISUOMOTOR INTERACTIONS EXTEND TO LOCOMOTIVE MOVEMENTS? AN ERP STUDY OF SENIOR FALLERS VS. NON-FALLERS *Lindsay Nagamatsu[1,3], Patrick Carolan[1], Teresa Liu-Ambrose[2,3], Todd Handy[1,3]; [1]The University of British Columbia, Psychology, [2]The University of British Columbia, Physical Therapy, [3]The Centre for Hip Health* – Visual-spatial attention has been found to have a central function in visuomotor planning associated with reach and grasp type movements. Our main question was whether this link between motor abilites and visual-spatial attention extends to other types of movement, such as walking, and how it may apply to successful movement through the environment. Because of methodological problems associated with recording event-related potentials (ERP's) during movement, we used a population with deficits in locomotion in order to answer this question. Using a between-groups design, we recorded event-related potentials in a canonical spatial cuing task performed by two groups of senior (aged 65+ years old) participants: those with a recent history of falls (> 2 falls in the past 12 months), and those with no such history (0 falls in the past 12 months). In terms of attentional control systems in cortex, we found no significant differences in function between groups. However, in terms of attentional factilitation of cortical processing, we found that fallers manifest specific abnormalities in the sensory/perceptual processing of targets in the left visual field. Our findings thus suggest that fallers have specific deficits in visuocortical systems associated with attentional enhancement of events on the left side of visual space. These findings are consistent with the hypothesis that visual-spatial attention and visuomotor abilities are critical for successful locomotion through the environment.

C21

SPATIAL TOPOGRAPHY OF HUMAN PREFRONTAL AND PARIETAL CORTICES *Trenton Jerde[1], Adam Riggall[1], Clayton Curtis[1,2]; [1]NYU, Psychology, [2]Center for Neural Science, NYU* – We used fMRI to map the spatial topography of the frontal and parietal cortices in humans. To define topographical maps in these higher order association areas, we used modified versions of standard retinotopic methods that tax spatial attention processes. We induced traveling waves of neural activity across cortex in topographical areas with working memory (WM) and motion discrimination (MD) tasks. In the WM task, subjects maintained fixation while faces were presented one at a time circling the visual periphery and indicated when the same face was presented consecutively (one-back). In the MD task, subjects maintained fixation while attending to circular apertures containing varying levels of coherently moving dots. Dot apertures were presented one at a time and circled the visual periphery; subjects indicated the direction of coherent dot motion by pressing a button. By adjusting the percentage of dots moving in the same direction, a staircase procedure kept subject performance at 75% accuracy. Fixation during both tasks was quantified by eye tracking. For both tasks, data were analyzed with standard phase-encoded retinotopic mapping methods. When using WM and MD tasks, similar topographical maps of contralateral space were found in dorsal and ventral prefrontal cortex and in posterior parietal cortex, as well as in early visual areas. Moreover, these topographic areas showed evidence of contralateralized persistent activity during the maintenance of covert spatial attention. Therefore, discrete areas of association cortex are spatially topographic and can be defined by systematic shifts in the locus spatial attention.

C22

THE ALLOCATION OF EARLY VISUAL ATTENTION DURING SMOOTH PURSUIT EYE MOVEMENT *Javier Lopez-Calderon[1], Kathya Torquati[2], Johanna Kreither[3], Francisco Aboitiz[1]; [1]Departmento de Psiquiatria, Pontificia Universidad Catolica de Chile, [2]Dipartimento di Scienze Cliniche e Bioimmagini and ITAB, Istituto di Tecnologie Avanzate Biomediche, Università "G. D'Annunzio", Chieti - Italy, [3]Escuela de Psicología, Universidad San Sebastián, Chile* – Recent studies suggest that the control of voluntary eye movements relies on specific target selection and decision making pro-

cesses. In particular, the accuracy of smooth pursuit eye movements (SPEMs), which maintain the image of a moving target on the fovea, depends strongly on attentional mechanisms. Nonetheless, the specific nature of the link between visual attention and SPEMs remains to be elucidated. Previous studies have elegantly demonstrated a biased allocation of attention to an area just in front of a constant-speed pursued target. This has been accomplished by measuring the latency and accuracy of saccadic eye movements, or manual reaction times, to stimuli appearing near the location of the moving target. As a further step in this line, we explored the spatial allocation of attention during horizontal sinusoidal SPEMs, using pattern reversal visual evoked potentials (prVEPs), elicited by retinotopically selected bilateral patches in the periphery of a pursued target. Our findings show a higher V1/V2 global response for the pursued right-going compared to left-going movement. Additionally, we found a higher contralateral V1/V2 response for the right-going movement, suggesting an ahead-biased allocation of attention. We discuss a direction-of-reading effect hypothesis.

C23

EARLY AND LATE PRE-STIMULUS ENHANCEMENTS FOR EXPECTATION OF FEARFUL AND NEUTRAL FACES IN FUSIFORM FACE AREA *Tracy Jill Doty[1,2], Shruti Japee[1], Martin Ingvar[2], Leslie Ungerleider[1]; [1]NIMH/Laboratory of Brain and Cognition, [2]Karolinska Institutet, Clinical Neuroscience* – The expectation of a behaviorally relevant stimulus can lead to faster and more accurate behavioral responses. Neuroimaging studies have shown that the anticipation of an upcoming visual stimulus enhances activity in visual processing areas even before that stimulus appears. However, few studies have investigated the effect of emotion on this anticipatory activity, and none has studied the expectation of emotional faces. In this event-related fMRI study, we manipulated valence expectation by presenting face images, within 50-trial runs containing different proportions of fearful:neutral faces: 80:20, 50:50, and 20:80. Before each run, subjects were explicitly told the ratio of fearful to neutral faces, and subjects were instructed to categorize each face as fearful or neutral on each trial. A red fixation cue preceded each face by 4 seconds. Behavioral data demonstrated that subjects were significantly faster to categorize the expected face type. A robust early (2-4 seconds post-cue) increase in BOLD activity was found in bilateral fusiform face area (FFA) prior to the presentation of an infrequent fearful face (compared to other trials). While this early activation in response to the cue did not confer a reaction time advantage (subjects were as slow to categorize infrequent fearful as infrequent neutral faces), it may represent a preparatory bias for infrequent emotional images. In contrast, consistent with behavioral data, a late (6-8 seconds post-cue) enhancement was seen in bilateral FFA during certain expectation trials (80:20 and 20:80) as compared to uncertain expectation trials (50:50). This late pre-stimulus enhancement may represent preparatory top-down signals.

C24

SLOW-WAVE AND OSCILLATORY MARKERS OF ANTICIPATORY BRAIN ACTIVITY DURING VISUAL SPATIAL ATTENTION AND THE PERCEPTUAL BIASING OF SENSORY CORTEX *Tineke Grent-t-Jong[1,2], Marty G. Woldorff[1]; [1]Center for Cognitive Neuroscience, Duke University, [2]Utrecht University, Psychopharmacology, Netherlands* – Two scalp-recorded electrophysiological markers of visual-location-specific anticipatory brain activity -- the slow-wave ERP-component termed the Biasing-Related-Negativity (BRN) and the event-related power decreases (ERDs) in alpha-band oscillatory activity -- have been reported in the literature as reflecting a state of increased excitability of sensory cortical areas (baseline-shift or biasing hypothesis) that results in improved perceptual sensitivity. However, the possibility that they might reflect different frequency components of the same underlying brain mechanism has never been directly tested. The current study attempts to fill this gap by using three variants of a visual spatial-cueing paradigm to test (a) whether the contralateral BRN and alpha-ERDs respond similarly to different task manipulations, (b) whether their activity levels correlate across the delay period, and (c) whether they similarly affect perceptual processing of the expected stimulus. The results indicated that none of these criteria for accepting the hypothesis of corresponding functional significance were met. The behavior of the contralateral BRN activity was the most consistent with the biasing hypothesis, in that this component was sensitive to the manipulation of expected perceptual difficulty of the target and its activity level correlated with the amplitude of the target N1 sensory component. In contrast, the contralateral alpha-ERDs responded more to motor-preparation instructions and motivational aspects of the task and affected later target processing stages (P3 amplitude). Generally, alpha oscillatory changes appeared to be more indicative of the strength of spatial attention at a particular point in time, rather than reflecting expectancy-driven biasing activity for future processing.

C25

ELECTROPHYSIOLOGICAL EVIDENCE FOR THE TOP-DOWN MODULATION OF ATTENTIONAL ORIENTING ELICITED BY CENTRAL NUMBER CUES *Jelena Ristic[1], Barry Giesbrecht[1]; [1]University of California Santa Barbara* – It has been reported that central numbers elicit an automatic shift of attention to the location corresponding to their relative spatial position on a left-to-right mental number line (Fischer et al 2003). Behaviorally, this effect is revealed as facilitated responses for left targets precued by a small number (e.g., 1) and right targets precued by a large number (e.g., 9). However, because the effect emerges late, about 700ms post-cue, it has been argued that instead of reflecting automatic orienting, it may reflect orienting that is controlled in top-down manner. Here we examined attentional effects of central number cues on visual cortical processing as indexed by the P1 event-related potential (ERP) component. Participants completed a cuing task in which centrally presented digits (3 or 9) served as attentional cues. The numbers were either uninformative or informative of the target location. Analysis of target-evoked ERPs revealed that when the number was uninformative, P1 magnitude was modulated in a manner that is consistent with the mental number line. However, this pattern reversed in the informative condition where the spatial location cued by the number contradicted the left-right number line, such that the P1 was largest for left targets cued by a large digit (9) and right targets cued by a small digit (3). These data indicate that the perception of digits may initially bias visual processing according to the mental number line. However, dovetailing with past data, the resulting attentional effect appears to depend on the spatial mental set adopted by observers.

Emotion

C26

VARIATIONS IN TREK1 GENOTYPE LINKED TO ANTIDEPRESSANT RESPONSE ARE ASSOCIATED WITH POTENTIATED NEURAL RESPONSE TO REWARDS IN HUMANS *Daniel Dillon[1], Ryan Bogdan[1], Jesen Fagerness[3], Avram Holmes[1], Roy Perlis[2,3], Diego Pizzagalli[1]; [1]Harvard University, Psychology, [2]Depression Clinical & Research Program, Massachusetts General Hospital and Harvard Medical School, [3]Psychiatric and Neurodevelopmental Genetics Unit, Center for Human Genetic Research, Massachusetts General Hospital* – The TREK1 gene has been linked to a depression-resistant phenotype in rodents and antidepressant response in humans. However, the mechanisms underlying these links are unclear. Because TREK1 is expressed in reward-related basal ganglia regions, it has been hypothesized that TREK1 genetic variation may be associated with anhedonic symptoms of depression. To test whether TREK1 genetic variation influences reward processing, we genotyped healthy individuals (n = 32) who completed a monetary incentive delay task during functional magnetic resonance imaging. Three of four TREK1 genotypes previously linked to positive

antidepressant response were associated with potentiated basal ganglia responses to gains, but did not influence activity elicited by penalties or no change feedback. Furthermore, the total number of "protective" TREK1 alleles possessed by individuals was positively correlated with responses to gains in several other regions of the mesocortical reward network, including the dorsal anterior cingulate cortex, orbitofrontal cortex, and mesial prefrontal cortex. These results indicate that variation in TREK1 genotype is associated with individual differences in neural responses to rewards, and suggest that variation in reward processing could mediate the association between TREK1 and antidepressant response in humans.

C27

THE EFFECTS OF ACUTE STRESS ON ATTENTIONAL CAPTURE BY ALCOHOL-RELATED CUES IN SOCIAL DRINKERS *Ryan Giuliano[1], Natalie Ceballos[2], Nicole Wicha[1,3], Reiko Graham[2]; [1]University of Texas, San Antonio, [2]Texas State University, [3]University of Texas Health Sciences Center, San Antonio* – Alcohol is often consumed to ameliorate the stress of everyday life. The purpose of this study was to examine the neurophysiological correlates of alcohol-related attentional processes among social drinkers before and after exposure to stress using a 3-stimulus oddball paradigm. Participants (N = 34) were randomly assigned to either an alcohol target (respond to alcohol pictures, ignore other objects or nonsense shapes) or an object target condition (respond to object pictures) while event-related potentials (ERPs) were measured before and after stress induction. Behavioral results indicated that overall, responses to both alcohol and object targets were faster after stress induction. These results were mirrored by changes in the peak latency of the P300, which peaked earlier as a result of stress, irrespective of target type. Amplitude analyses were also conducted after taking latency differences across conditions into account. Regardless of stress, P300 amplitudes were largest for targets, but this was mediated by a target by condition interaction. Amplitudes were larger for targets in the alcohol condition, whereas there was no significant difference between targets and non-targets (alcohol images) in the object condition, suggesting that alcohol images captured attention, regardless of stress or target status. Interestingly, there was a stress by condition by hemisphere effect: the P300 for alcohol targets was bilateral before stress but right-lateralized after stress, supporting the role of right parietal regions in emotion-related arousal (Heller, 1993). Overall, results suggest that stress appears to affect both controlled and automatic processing of alcohol related images.

C28

GOAL INDUCEMENT AND EMOTION CONTROL: THE EFFECTS OF CONSCIOUS AND NONCONSCIOUS GOAL REGULATION ON THE RESPONSE TO EMOTIONAL STIMULATION *Sanda Dolcos[1,2], Keen Sung[1,2], Ekaterina Denkova[1,2], Florin Dolcos[2,3]; [1]University of Alberta, Psychology, Canada, [2]University of Alberta, Psychiatry, Canada, [3]Centre for Neuroscience, University of Alberta, Canada* – The ability to regulate emotions is an important coping mechanism in the face of emotionally stressful situations. While previous emotion regulation (ER) studies have focused mainly on conscious/deliberate regulation, recent evidence suggests that non-conscious/automatic regulation could prove as effective while being less costly (Bargh & Williams, 2007). However, it is not clear whether both types of ER are equally effective in controlling varying intensities of emotional challenge. The present study used an experimental design that manipulated both the goal to regulate emotion (conscious vs. nonconscious) and the intensity of emotional challenge (high vs. low). Different groups of participants were either explicitly instructed or non-consciously primed to suppress their response to pictures with varying degrees of emotional content selected from the International Affective Picture System. Participants rated the emotional content of negative and neutral pictures, while skin conductance (SC) responses to viewing the pictures were also recorded. Analyses of behavioural data suggest that both deliberate and automatic ER decreased the subjective response to low-intensity emotional pictures. However, only deliberate ER was effective in suppressing the response to high-intensity emotional pictures. Preliminary analyses of the SC data are consistent with the subjective rating findings. This study suggests that while automatic ER might be less effortful and less costly, it might also be less effective in the face of highly challenging negative situations. The findings are relevant for understanding mood and anxiety disorders, in which emotion dysregulation is often among the core debilitating features.

C29

SEX-RELATED DIFFERENCES IN EMOTION REGULATION STRATEGIES IN COPING WITH SOCIAL ANXIETY: A COMBINED PERSONALITY AND BRAIN IMAGING INVESTIGATION *Florin Dolcos[1,2], Sanda Dolcos[1,2,3], Ekaterina Denkova[1], Gloria Wong[1,2]; [1]University of Alberta, Psychiatry, Canada, [2]University of Alberta, Canada, Centre for Neuroscience, [3]University of Alberta, Psychology, Canada* – The study investigated the role of individual variation in emotion regulation (ER) strategies in response to trait and state social anxiety (SA). The relationship between the habitual use of two ER strategies (i.e., reappraisal and suppression) and trait SA was first investigated using the Emotional Regulation Questionnaire (ERQ) and the Liebowitz SA scale (LSAS). Correlation analyses on data from 86 participants (49 females) identified a negative relationship of LSAS scores with ERQ-Reappraisal (ERQ-R), but a positive relationship with ERQ-Suppression (ERQ-S). Interestingly, while the former relationship was driven by women, the latter was driven by men. These findings suggest that reappraisal is overall a more effective strategy in coping with SA, and that habitual suppression tends to be inefficiently engaged by men. These findings were next confirmed on a smaller sample (N=18, 10 females) in which SA was transiently induced by viewing angry faces presented as task-irrelevant distracters during a working memory (WM) task. This investigation also revealed that ERQ-R predicts enhanced WM performance in the presence of transiently induced SA in men but not in women. Functional MRI data were also recorded while participants performed the WM task, and preliminary analyses suggest that these sex-related differences in the engagement of ER strategies are linked to dissociable involvement of cognitive control brain regions (e.g., anterior cingulate) in response to transient anxiety-inducing distraction in men and women. Collectively, these findings suggest that women and men engage different ER strategies and brain mechanisms in coping with trait and state SA.

C30

EMOTIONAL DISTRACTION MODULATES THE IMPACT OF TASK DIFFICULTY ON PERFORMANCE IN A PERCEPTUAL TASK *Andrea Shafer[1], Dmitriy Matveychuk[1], Todd Penny[1], Roberto Cabeza[2], Florin Dolcos[1]; [1]University of Alberta, [2]Duke University* – An important open question in the emotion literature concerns the impact of task-irrelevant emotional distraction on perceptual processing. According to Lavie (2005), task-irrelevant distracters have a differential impact on task-relevant processing depending on the "processing load" of the main task - i.e., low-perceptual load is susceptible to distraction whereas high-perceptual load eliminates distracter processing. It is unclear, however, whether these effects are also found when the distracters are emotionally-charged. Possibly because of their relevance for survival, emotional stimuli can "capture" attention and reallocate processing resources from processing goal-relevant information to processing irrelevant emotional information. Thus, it is possible that processing of distraction is not eliminated by high perceptual load if the distracters are emotional. This idea was investigated using a shape detection (SD) task in which participants made decisions on the orientation of vertical and horizontal pictures with varying degrees of emotional content. Task difficulty was manipulated by varying the ratio of the horizontal vs. vertical sides, which thus influenced the difficulty in deciding whether the pictures were clearly rectangles (with vertical/horizontal orientation) or closer to squares (with uncertain vertical/horizontal orientation). Preliminary analyses showed that the response speed in the SD task was modulated by both task difficulty and emotional content. Specifically, the

longest reaction times were recorded when the orientation was difficult to identify and the content of the pictures was emotional. These findings shed light on the impact of task-irrelevant emotional distracters on perceptual processing, and have relevance for understanding clinical conditions associated with exacerbated susceptibility to emotional distraction.

C31

ALMOST HUMAN: NEURAL ACTIVATION TO AVATAR AND HUMAN EMOTIONAL FACIAL EXPRESSIONS *Matthias Wieser[1], Antje Gerdes[1], Paul Pauli[1], Peter Weyers[1], Felix Breuer[2], Andreas Mühlberger[1]; [1]University of Würzburg, [2]Magnetic Resonance Bavaria (MRB)* – Facial expressions of emotions are important in nonverbal communication. While previous studies have mostly relied on facial images of humans, the effects of computer-generated (avatar) emotional faces compared to natural emotional faces on brain activation were investigated in the present study. Twenty-two healthy subjects (ten females) viewed blocks of facial expressions (anger, fear, happinnes and neutral) and scrambled faces in a blocked design, while their brain activation was measured by means of 1.5 T BOLD fMRI. Activations in emotional networks including amygdala, insula, ACC were apparent in response to both avatar and human emotional faces, but the response was significantly stronger especially to human faces of anger in the amygdala. Behavioral data indicate that avatars are rated as less arousing compared to human faces, which might be an explanation of the weaker brain responses. However, as there was an emotional modulation of brain activity present, we suggest that avatars could be a useful tool in neuroimaging studies of facial expression processing because they elicit comparable activations in emotional areas similarly to human faces, yet have the advantage of being highly manipulable and fully controllable. This allows for creating innovative research designs with dynamic facial expressions. However, further investigations are needed to clarify the differences between natural and artificial stimuli and the influence of trait variables like social anxiety.

C32

OPPOSING PATTERNS OF BRAIN ACTIVITY IN PERCEPTUAL AND EXECUTIVE BRAIN REGIONS LINKED TO INDIVIDUAL VARIATION IN SOCIAL ANXIETY: AN FMRI INVESTIGATION *Ekaterina Ninova[1], Gloria Wong[2], Kristen Sabourin[3], Keen Sung[1], Sanda Dolcos[4,1], Florin Dolcos[1,2]; [1]University of Alberta, Psychiatry, Canada, [2]University of Alberta, Center for Neuroscience, Canada, [3]University of Alberta, Biomedical Engineering, Canada, [4]University of Alberta, Psychology, Canada* – Mood and anxiety disorders are often characterized by increased susceptibility to emotional distraction. However, the underlying neural circuitry associated with individual differences predicting the response to emotional challenge remains unclear. Here, we investigated the relationship between brain activity in response to anxiety-inducing task-irrelevant distraction (i.e., angry faces) and individual variation in indices of social anxiety (SA). Event related fMRI data were recorded while 18 healthy subjects performed a working memory (WM) task with angry face distracters presented during the delay between the memoranda and probes. Trait SA was also measured with the Liebowitz Social Anxiety Scale (LSAS). Analysis of fMRI data revealed dissociable patterns of brain activity in perceptual (fusiform face area-FFA) and executive (dorsolateral prefrontal cortex-dlPFC) brain regions linked to the nature of distraction and individual variation in SA. Specifically, anxiety-inducing distraction enhanced activity in the FFA while disrupting activity in the dlPFC. Moreover, activity in these regions also showed opposing patterns of co-variation with the trait SA, reflected in positive (FFA) vs. negative (dlPFC) correlations with the LSAS scores. Collectively, these findings provide support for the idea that enhanced activity in perceptual brain regions in response to task-irrelevant emotional distraction may lead to disrupted activity in executive brain regions, and that these effects are mediated by individual variation in the sensitivity to anxiety-inducing stimulation. These findings have implications for understanding alterations in the neural circuitry underlying emotion-cognition interactions in clinical SA, in which exacerbated response to anxiety-inducing social contexts leads to debilitating effects on social behavior.

C33

TRAIT ANXIETY AND IMPOVERISHED PREFRONTAL CONTROL OF ATTENTION *Sonia Bishop[1]; [1]University of California, Berkeley* – Many neurocognitive models of anxiety emphasize a hyper-responsive threat-detection system centered on the amygdala, with recent accounts incorporating a role for prefrontal mechanisms in regulating attention to threat. The current study investigated whether trait anxiety is associated with a much broader dysregulation of attentional control. Volunteers performed a response conflict task under conditions posing high or low demands on attention. High trait anxious individuals showed reduced prefrontal activity and slower target identification in response to processing competition when the task did not fully occupy attentional resources. The relationship between trait anxiety and prefrontal recruitment remained after controlling for state anxiety. These findings indicate that trait anxiety is linked to impoverished recruitment of prefrontal attentional control mechanisms to inhibit distractor processing even when threat-related stimuli are absent. Critically, this deficit is observed when ongoing task-related demands on attention are low, potentially explaining the day-to-day difficulties in concentration associated with clinical anxiety.

C34

THE IMPACT OF METHYLPHENIDATE ON EARLY EMOTIONAL PROCESSES IN ADULT PATIENTS WITH ATTENTION DEFICIT HYPERACTIVITY DISORDER (ADHD) *Eva Woidich[1], Annette Conzelmann[1], Ron F. Mucha[1], Peter Weyers[1], Christian P. Jacob[1], Paul Pauli[1]; [1]University of Würzburg* – Background: Emotional- motivational dysfunctions are very likely important in the pathophysiology of attention-deficit/ hyperactivity disorder (ADHD). Although symptoms like hyperactivity and impulsivity seem to be closely related to emotional- motivational functions, few studies about this topic can be found. Even fewer studies examined the influence of methylphenidate on emotional processes, though methylphenidate is the first class medical treatment in ADHD since 1937. Methods: 13 adult ADHD- patients took part twice. During both investigations, objective (affect- modulated startle response) and subjective (valence and arousal ratings) reactions to positive, neutral and negative visual stimuli were affiliated. Every subject had to cope with the same task twice- once without and once after the intake of their own methylphenidate supplement. Results: During the exposure of high arousing visual stimuli and after the intake of methylphenidate, all 13 patients showed improved affective startle- modulation in response to positive and negative pictures. Affective valence and arousal ratings did not differ between both examinations. Conclusion: These findings indicate some positive impact of methylphenidate on early emotional processes in adult ADHD- patients. Results suggest that this improvement is independent of subjective parameters.

C35

INVESTIGATING SEROTONIN'S ROLE IN LINKING BEHAVIOURAL INHIBITION TO PUNISHMENT *Molly Crockett[1], Luke Clark[1], Trevor Robbins[1]; [1]Behavioural and Clinical Neuroscience Institute, Experimental Psychology, University of Cambridge* – Serotonin (5-HT) has been implicated in a wealth of psychiatric disorders, including depression, anxiety, and obsessive-compulsive disorder, but its functions in regulating both normal and abnormal behaviour remain poorly understood. Two hypotheses dominate the literature: one suggests that 5-HT signals punishments, and the other proposes that 5-HT facilitates response inhibition. It has recently been suggested that 5-HT is responsible for linking inhibition to punishment, potentiating behavioural suppression in anticipation of negative outcomes. However, existing data cannot rule out either the punishment or the inhibition hypothesis. In this study, we temporarily lowered brain 5-HT levels in healthy human volunteers using the acute tryptophan depletion (ATD) procedure. We employed a novel version of the Go/No-Go task that independently tested the ability to

inhibit responses and the ability to adjust behaviour in response to rewards and punishments. Twenty-two healthy volunteers completed the task, once following ATD and once following placebo. On placebo, volunteers adjusted their response speed in line with feedback valence, speeding up in response to rewards and slowing down in response to punishments. ATD abolished punishment-induced slowing in a context-sensitive manner, while preserving basic response inhibition and the ability to track changes in reward and punishment contingencies. Additional analyses indicate that ATD removed a bias that was present at the start of the placebo session, but was then attenuated, presumably by learning. These data support the hypothesis that 5-HT promotes a bias to inhibit behaviour in the face of potential punishments, rather than simply signalling punishment or facilitating general inhibition.

C36

A ROLE FOR THE VENTROLATERAL PREFRONTAL CORTEX AND VENTRAL BASAL FOREBRAIN IN TRACKING PROXIMITY TO THREAT AND ANXIETY *Leah Somerville[1], Paul Whalen[1], William Kelley[1]; [1]Dartmouth College* – Previous research identifying the neural substrates of emotion processing has typically treated threat as a categorical stimulus, either present or absent from the environment. An associated question that has received less scientific attention is whether an individual's relative level of threat or safety in a given context is represented continuously in the brain. During fMRI scanning, 50 participants viewed a threat line fluctuating in height, with the height of the line representing risk for earning subsequent electrical shocks. The line trajectory was set to vary such that equal amounts of time were spent at different proximities to the threat (categorized as low, medium, and high), as well as times when the threat (e.g., earning the shock) was earned. Random-effects group analyses identified brain regions with increasing responses as the proximity to the shock threshold increased. Regions demonstrating this pattern include the left and right ventrolateral prefrontal cortex extending into the anterior insula, and the left and right ventral basal forebrain. When examining individual differences, we observed that these regions showed an exaggerated response profile in individuals with greater dispositional anxiety. The present findings suggest that these regions may continuously monitor changes in arousal state, and may subserve hyperarousability in potentially threatening situations commonly experienced by anxious individuals.

C37

INTEROCEPTION FOR MENTALIZING: HEARTBEAT-EVOKED BRAIN POTENTIAL SHOWS AMPLITUDE MODULATION IN AN 'EYES TASK' *Hirokata Fukushima[1,2], Satoshi Umeda[1]; [1]Keio University, [2]Japan Society for the Promotion of Science* – Interoception is a visceral perception or a sensation of the physiological condition of the inner organ (Craig, 2002). Here we investigated whether interoceptive processing in the central nervous system is employed to understanding others' mental states, and it is increased in the individual who was engaged in a mentalizing task. As a neural index of this processing, we examined a pattern on the surface electroencephalogram (EEG), termed heartbeat-evoked potential (HEP). This is a deflection on the brain potential contingent to the most prominent peak of the electrocardiogram (ECG), and which is thought to reflect cortical processing of cardiac afferent input (Schandry et al., 1986). Being measured EEG and ECG, twenty-one healthy adults participated the experiment where they attended to either the mental or physical features of a series of images showing the eyes of other people. Results showed increased HEP amplitude in mentalizing trials compared to non-mentalizing trials. This pattern was observed on the left and medial frontal electrodes around 250-300 ms latency after the R-peak of the ECG. Furthermore, the mean amplitude in this period was found to be associated with a subscore of empathy questionnaire (Interpersonal Reactivity Index; Davis, 1983). The present study suggests the possibility that the external social cognition involves the internal self-monitoring of the bodily states.

C38

RATING AND SEARCHING FOR OCD-CONCERN RELATED IMAGES: ABNORMAL AND NORMAL PROCESSING IN OCD PATIENTS *Sharon Morein-Zamir[1], Martina Butt[1], Naomi Fineberg[2,3], Trevor Robbins[1], Barbara Sahakian[1]; [1]University of Cambridge, [2]Queen Elizabeth II Hospital, [3]University of Hertfordshire* – Whether Obsessive Compulsive Disorder (OCD) is associated with an increased attentional bias to emotive stimuli remains controversial. Additionally, though depression is the main comorbidity of OCD, it is unclear whether it modulates abnormal emotional processing. To examine whether attentional bias may be restricted to individualized concern-related information we employed a visual search task with OCD-relevant images. Following individual ratings of 100 images, the idiosyncratic most positive and negative scenes were selected for each individual. Participants then searched for their positive images amongst their negative distracters, and their negative images amongst their positive distracters. The search task was administered to nondepressed OCD patients, depressed OCD patients and healthy controls (n=18 per group). Whilst the rating values were similar, both OCD groups were slower than controls to rate the images in terms of pleasantness. Visual search performance did not differ between the groups, although the OCD depressed group exhibited a general slowing. All groups demonstrated an attentional bias whereby negative targets were detected faster amongst positive distracters as compared to positive targets amongst negative distracters. A second experiment using pre-selected negative and positive images replicated the visual search results, with no group differences in attentional bias. OCD rating performance following the search now indicated both slower and more negative scoring values. Results indicate that OCD patients, regardless of their depression state, process OCD-relevant scenes differently from controls depending on task demands and previous exposure. The results have implications for the development of emotional responses to concern-related materials in OCD.

C39

FUNCTIONAL CONNECTIVITY OF THE DORSOLATERAL PREFRONTAL CORTEX DURING A FACIAL EXPRESSION VS. IDENTITY N-BACK TASK *Maital Neta[1], Erika Ruberry[1], Paul Whalen[1]; [1]Dartmouth College, Psychological & Brain Sciences* – Facial expressions of emotion are a critical aspect of our social interactions as human beings. Just as important is the identity of the individuals, as this creates the context in which these expressions will be interpreted. Therefore, it is crucial that we monitor both identity as well as expression information and maintain this information in memory. Participants performed an N-back task in which they either tracked the expression or the identity of the same set of face stimuli. During both the expression and identity tasks, we found a significant increase in activity in dorsolateral prefrontal cortex (DLPFC), an area that has been shown to be critical for working memory. Functional connectivity analyses revealed that activity within this region of the DLPFC was coupled with the amygdala during the facial expression N-back, but coupled with the fusiform gyrus during the face identity N-back. Finally, the connectivity of these regions in each task was significantly correlated with accuracy on those trials. Based on these findings, there is evidence for two separate neural circuitries, both involving the DLPFC, supporting working memory for two distinct aspects of face processing/memory.

C40

AMYGDALA VOLUME CORRELATES POSITIVELY WITH FEARFULNESS IN NORMAL HEALTHY GIRLS: AMYGDALA VOLUME AS AN ENDOPHENOTYPE FOR INTERNALIZING DISORDERS? *Ellen A.A. van der Plas[1], Aaron D. Boes[1], John Wemmie[1], Peg Nopoulos[1]; [1]University of Iowa, Psychiatry* – Research into the neural underpinnings of fear and fear-related pathology highlight the role of the amygdala. For instance, bilateral damage to the amygdaloid complex is associated with decreased appreciation of danger and recognition of fear in humans and non-human primates, whereas enlarged amygdala vol-

ume is associated with syndromes such as anxiety disorders and depression. It is unknown whether amygdala volume and fearfulness are directly related in the absence of pathology. To address this issue, we examined the correlation between normal fearfulness and amygdala morphology in 116 healthy children and adolescents (60 boys, 56 girls, age 7-17). Based on the structure-behavior relationship suggested by lesion- and pathological fear studies, we predicted to find a positive correlation between fearfulness and amygdala volume. Fearfulness was measured using the parent ratings on the Pediatric Behavior Scale (Lindgren et al., 1987) and amygdala volumes were determined by manual tracing. Partial correlation analyses indicated a significant positive correlation between right amygdala volume in girls ($r = .29$, $p < .05$). This relationship was more robust and significant for both the left and right amygdala when analyses were limited to girls with a positive nuclear family history of depression ($r = .63$ and $r = .58$ respectively, both $ps < .05$). In boys there was no significant relationship, which may suggest that biological mechanisms and their interactions with the environment differ between sexes. Given the role of the enlarged amygdala volume in pathology, these findings may indicate that variation in amygdala morphology marks susceptibility to internalizing disorders.

C42

UNDERSTANDING THE EFFECTS OF UNPLEASANT DISTRACTERS DURING A FACIAL WORKING MEMORY TASK *Anne Richards[1], Virginia Hon[1], Sammy Aung[1], Richard Hernandez[1], Parveen Hussain[1], Sam London[1], Richard Maddock[1]; [1]University of California, Davis* – This study investigated the effects of emotion on working memory (WM) and how these effects are related to individual differences, physiological arousal, emotion regulation, and brain activation. We used a facial memory task with unpleasant and neutral distracters. Block instructions alternated between "Regulate Emotions" and "Respond Naturally". We recorded memory accuracy, skin conductance and several individual difference questionnaires from 109 undergraduates. Regulation instructions did not affect working memory performance, so we combined both block types for all analyses. A paired t-test shows improved WM accuracy on trials with unpleasant distracters ($n=109$, $t=6.581$, $p<.0001$, two-tailed). This facilitation of WM is significantly related to low state anxiety ($n=109$, $r=.326$, $Z=3.486$, $p=.0005$). A Wilcoxon Signed Rank test shows that higher arousal measured by skin conductance response to unpleasant distracters predicts better memory accuracy following unpleasant distracters ($n=80$, $Z=1.962$, $p<.05$, two-tailed). A separate group of 20 subjects participated in an fMRI study using a version of the same task. In a contrast between unpleasant and neutral distracters, we found that fMRI activity in the left mid-VLPFC (BA 45) correlated with WM facilitation by unpleasant distracters (cluster-level $p<.05$). In summary, unpleasant distracters unexpectedly improved facial WM accuracy. This effect correlated with low state anxiety and with fMRI activity in the left mid-VLPFC, an area associated with cognitive control in memory. WM accuracy following unpleasant distracters was positively correlated with skin conductance responses to the unpleasant distracters. Thus, emotional distracters can lead to improved working memory via a mechanism influenced by arousal, anxiety, and cognitive control.

C43

MODULATORY EFFECT OF VOICE ON CONSCIOUS AND NONCONSCIOUS PROCESSING OF EMOTIONAL BODY LANGUAGE *Bernard M.C. Stienen[1], Akihiro Tanaka[1], Beatrice de Gelder[1,2]; [1]Cognitive and Affective Neurosciences Laboratory, Tilburg, The Netherlands , [2]Martinos Center for Biomedical Imaging, Massachusetts General Hospital and Harvard Medical School, Charlestown, Massachusetts* – Previous studies have shown that affective processing of faces is still possible in absence of visual awareness. Recent results of our group have shown that emotional body language is also processed even if a target body is masked after a short SOA and not consciously visible. As emotional events have multiple correlates and are simultaneously perceived by several sensory systems in naturalistic settings, emotional information conveyed by other modalities (e.g. voice) can affect the processing of conscious and nonconscious processing of emotional body language. In the present study, we investigated the effect of emotional voice on conscious and nonconscious processing of emotional body language. A target body (happy or anger) and a mask were presented at 12 different SOAs varying from -50 to +133 milliseconds. Emotional voice (happy or anger) was presented with the onset of the target body. Participants were instructed to ignore the voices and to do two tasks successively. The first task was to categorize the expression of the target body and the second task was to indicate whether they had seen the body or not. Results revealed that emotional voice facilitated categorization of the target body when the emotional valence was congruent between body and voice, whereas it interfered with categorization when the emotional valence was incongruent. Voice did not affect the responses when the body was not presented, while it did affect when the body was presented. These results have implications for multisensory and nonconscious processing of emotion.

C44

THE PROCESSING OF EMOTIONAL PROSODY IN ALEXITHYMIA *Katharina Goerlich[1], Sander Martens[1], André Aleman[1]; [1]BCN Neuroimaging Center Groningen, University Medical Center Groningen, University of Groningen, The Netherlands* – In the present study, we used event-related potentials (ERP's) to test the hypothesis of aberrant automatic processing of emotional speech in Alexithymia, a personality trait associated with difficulty to interpret emotions. High-scorers on Alexithymia were compared to low-scorers on this personality trait and to a control group with middle scores on Alexithymia. Volunteers watched a silent video while nonsense syllables spoken in neutral emotion (standard) and four different emotional intonations (deviants) were presented in an oddball paradigm. High-scorers on alexithymia were found to show diminished amplitudes of ERP components indicating pre-attentive, automatic detection of changes in emotional prosody. The results of this study suggest that people with Alexithymia show differences in processing emotion conveyed by speech already at very early, automatic processing stages, reflecting a dimished sensitivity to emotional prosody in this personality trait.

C45

HOW THE BRAIN RESPONDS TO SEEING FEARFUL BEHAVIOR IN THE REAL WORLD *Jan Van den Stock[1,2], Beatrice de Gelder[1,3]; [1]Laboratory for Cognitive and Affective Neuroscience, Tilburg University, the Netherlands, [2]Old Age Psychiatry, University Hospitals Leuven, Belgium, [3]Martinos NMR-MGH Center, Harvard Medical School* – Recent studies have examined the role of surrounding contextual information on the processing and recognition of objects, as well as the respective neural mechanisms. There are only a few studies focussing on the mechanisms involved in contextual influence on perception of social stimuli. Although the processing of faces seems to have a 'privileged' status, recent data reports that the early components of the neural processing of faces are influenced by the emotional content of the contextual information. An object category that displays several behavioral and neurofunctional similarities with faces, comprises whole bodies. We used functional Magnet Resonance Imaging (fMRI) to investigate the neural correlates of perceiving emotional whole body expressions in either emotionally congruent or incongruent contexts. We presented fearful and neutral whole body expressions in a fearful, neutral or scrambled context, creating realistically compound stimuli. The stimuli were presented in a blocked design while blood oxygenation level depended brain scans were acquired (3 Tesla). Participants were required to perform an oddball detection task on the presentation of an inverted stimulus. The experiment consisted of four runs with each 31 blocks. In one block, eight stimuli were presented for 800ms with an interval of 350ms. In 10% of the blocks, an oddball stimulus was presented. Finally, a functional localiser for the perception of faces, bodies, houses and tools was performed. The

results show that activity in brain areas that are associated with perception of bodies or perception of scenes, are influenced by the emotional information conveyed by the respective stimuli.

C46

NEURAL CIRCUITRY UNDERLYING EMOTIONAL VS. COGNITIVE CONFLICT AND CONTROL: FACIAL EXPRESSIONS AS A MODEL BEHAVIOUR *Kimberly S. Chiew[1], Bethany G. Edwards[1], Todd S. Braver[1]; [1]Washington University in St. Louis* – Recently, the neural basis of emotional control has become a topic of empirical interest; however, overlaps and differences in the neural circuitry underlying emotional and cognitive control have yet to be systematically established. We have identified emotional facial expressions as actions modulated by both emotional and cognitive influences: thus, their use as performance measures in emotional control tasks may provide greater ecological validity than previous tasks, using arbitrary behavioural responses, have permitted. In this study, we examined brain activity during emotional and cognitive versions of the AX-Continuous Performance Task (AX-CPT), a cue-probe task used to examine controlled processing and conflict. Participants responded via facial expressions (smiling or frowning) to emotional probes (IAPS images) or unemotional probes (letters, numbers and symbols). In both tasks, trial frequency and contextual cues introduced a bias towards the target cue-probe combination that leads to two forms of conflict in non-target trials: top-down (i.e., cue-driven) vs. bottom-up (i.e., probe-driven). However, in the emotional condition, the conflict was further amplified by the incongruency between the required facial expression and the emotional valence of the picture. A mixed block/event fMRI design enabled separation of sustained and event-related neural correlates of task activity. The results address the question of whether affective brain regions (e.g., ventral striatum, orbitofrontal cortex, amygdala) are selectively engaged in the emotional conditions, and further whether conflict in this condition engages regions associated with cognitive control (e.g., anterior cingulate cortex and lateral PFC) but in anatomic locations distinct from those activated in the cognitive condition.

C47

ANXIETY AFFECTS LUMINANCE DISCRIMINATION IN THE RIGHT HEMISPHERE *Caroline Crump[1], Eran Zaidel[1]; [1]University of California, Los Angeles* – Key features of anxiety include an attention bias toward negative, emotional stimuli and heightened autonomic response to threat. Both negative emotions and autonomic responses are selectively associated with the normal right hemisphere. Consequently, we predicted that the right hemisphere of anxious participants will have a distinct information processing profile, different from the left hemisphere of an anxious participant and from the right hemisphere of a nonanxious participant. We compared the perceptual differences between college students who rated high and low on the Spielberger State-Trait Anxiety Inventory. Participants received identical copies of a color square (the target) and an emotional word in each visual hemifield. Following a brief delay, they received two probes: one identical to the target, the other equally often of a lighter or darker luminance. Participants were required to indicate with a keypress which probe test matched the target. We predicted that anxious participants would more often choose the probe with the lower luminance and that this effect should be selective to left hemifield probes. Both predictions were correct. The results implicate the right hemisphere in anxiety and show a perceptual bias toward the darker (more negative) stimuli. It remains to be determined whether the bias toward darker stimuli occurs in the perceptual stage, reflects short-term memory, or is due to a late-stage response programming bias. The results suggest new, nonverbal measures of anxiety. They also suggest that the right hemisphere is the proper target for both measuring and controlling anxiety.

C48

FURTHER EVIDENCE FOR AN EPISTASIS BETWEEN 5-HTT AND BDNF FROM SELF REPORTED ANXIETY RELATED TRAITS *Tina B. Lonsdorf[1,2], Armita Golkar[1,2], Martin Schalling[1], Arne Öhman[1,2]; [1]Karolinska Institutet, [2]Stockholm Brain Institute* – Anxiety related traits have been associated with several genetic polymorphisms. The s-allele of an insertion/deletion (5-HTTLPR) in the serotonin transporter (5-HTT) promoter is associated with higher neuroticism, amygdala reactivity and morphological alterations. The met-allele of a polymorphism (BDNFval66met) in the Brain-derived neurotrophic factor (BDNF) prodomain has been associated with lower scores on anxiety related traits. A study by Pezawas et al. (2008) demonstrated a biological epistasis between BDNFval66met and 5-HTTLPR. The morphological phenotype of 5-HTTLPR s-allele carriers, reduced gray matter volume of the subgenual anterior cingulate, could be compensated by the presence of a BDNF met-allele. We tested this epistasis at the level of self reported traits. 349 healthy individuals, genotyped for 5-HTTLPR and BDNFval66met, filled in the Swedish University Scales of Personality (SSP). Both 5-HTTLPR and BDNFval66met genotype had a main effect on the subscale Stress Susceptibility (SS): 5-HTTLPR s-carriers and BDNF val-carriers reported higher SS than individuals homozygous for the 5-HTTLR l- allele, p=0.04, and the BDNF met-allele, p=0.032. Furthermore there was evidence for an epistasis effect: 5-HTTLPR s-carriers that also were homozygous for the BDNF met-allele reported significantly less SS than 5-HTTLPR s-carriers that also carried a BDNF val-allele, p=0.011. Our data indicate that the BDNF met/met genotype seems to protect against the adverse effect of the 5-HTTLPR s-allele also on the level of self reported traits.

C49

GENETIC SUSCEPTIBILITY TO DEPRESSION AND SELECTIVE ATTENTION FOR NEGATIVE AND POSITIVE INFORMATION: PRELIMINARY FINDINGS *Iris van Oostrom[1], Barbara Franke[2], Maaike Verhagen[1], Annemarie Van der Meij[1], Jan Buitelaar[1], Constance Vissers[1], Armand van Oosterwijck[1], Joost Janzing[1]; [1]Donders Institute for Brain, Cognition and Behaviour, Psychiatry, The Netherlands, [2]Radboud University Nijmegen Medical Centre, Antropogenetics, Nijmegen, The Netherlands* – According to the cognitive theory of depression, individuals susceptible to depression attend selectively to negative information and filter out positive information. Goal of the study was to examine the relationship between candidate genetic susceptibility factors for major depressive disorder (MDD) and selective attention for negative or positive information in formerly depressed patients, their unaffected relatives and unaffected controls. Formerly depressed female patients having at least one first-degree relative with a history of MDD (n=23), unaffected female relatives (n=20) and female healthy controls screened for lifetime MDD (n=10) were administered the emotional Stroop task using negative, positive and neutral words. Attentional biases were calculated using the difference in reaction times (RT's) between neutral and negative or positive words. The CIDI was used to assess current and lifetime diagnosis of MDD. All participants were genotyped for polymorphisms in the 5-HTT/SLC6A4 gene (5-HTTLPR), BDNF (Val66Met) and COMT (Val158Met). Patients and family members demonstrated non-significantly (p=0,09) longer RT's for negative compared to neutral words (m=5,67;sd=26,78), while controls demonstrated shorter RT's for negative compared to neutral words (m=-13,39; sd=46,04). Groups did not demonstrate differences with regard to positive bias. At the genetic level, no significant differences were observed in attentional biases between groups based on genetic polymorphisms. Findings suggest that formerly depressed patients and their unaffected family members tend to focus more on negative information than controls. Our non-significant findings may be due to small sample sizes and/or the restricted contribution of single polymorphisms. We suggest to use larger sample sizes in future studies.

C50

ATTENTIONAL REDEPLOYMENT AS AN EFFECTIVE EMOTION REGULATION STRATEGY *Martin Herrmann[1,2], Andreas Mühlberger[2], Alexandra Rebhan[2], Maike Georgs[2], Paul Pauli[2], Andreas Fallgatter[1]; [1]University of Würzburg, Psychiatry, Psychosomatics and Psychotherapy, [2]University of Würzburg, Psychology* – Recent studies have shown that cognitive reappraisal can be used as an effective emotion regulation strategy, leading to decreased amygdala activity and to a reduction of the late positive potential (LPP) in the EEG. Van Reekum and colleagues (2007) tested the possibility that people use attentional redeployment rather than, or in addition to, reappraisal as a strategy to regulate emotion. Indeed they found that subject show a reduced viewing of the emotion-eliciting stimulus when they were instructed to decrease the emotional response. Another study (Dunning and Hajcak, in press) showed that cues leading the visual attention to a non emotional focus within unpleasant images can also reduce the LPP. Both studies suggest that attentional redeployment might be an effective emotional regulation strategy, which should be tested in our study. Therefore we instructed our subjects (n=20) to lead their attention to a non emotional or emotional focus within the displayed images and recorded the event-related EEG potentials with 21 scalp electrodes. As hypothesized we found a reduction of the LPP over Pz while focusing to a non emotional part of the pictures, leading to the suggestion that simply to instruct the subjects not to look at the emotional part of a picture is a useful emotion regulation strategy for healthy subjects.

C51

MOOD AFFECTS SYNTACTIC PROCESSING: EVIDENCE FROM P600 *Constance Vissers[1], Daniele Virgillito[2], Dan Fitzgerald[1], Anne Speckens[1], Indira Tendolkar[1], Iris Van Oostrom[1], Dorothee Chwilla[3]; [1]Donders Institute for Brain, Cognition and Behaviour, Psychiatry, [2]Scuola Superiore di Catania, Catania, Italy, [3]Donders Institute for Brain, Cognition and Behaviour* – A P600 effect has been reliably reported after syntactic violations (Osterhout et al., 1992) and more recently also to several kinds of semantic anomalies (Kuperberg, 2007). To our view the P600 effect reflects a more general process of reanalysis, triggered by a strong conflict between a highly expected and an unexpected linguistic element (Vissers et al. 2008). In this study we explored the interaction between syntax and emotion. To this aim, we investigated the effects of emotional state on P600. EEG was recorded while female participants (31) read sentences half of which contained subject-verb agreement errors ('The crook who shot[plural] at the cops...') and correct sentences ('The cops who shot[plural] at the crook...'). Mood was manipulated between participants by presenting short film clips that either displayed fragments from a happy movie or a sad movie. The main results were as follows: After watching the happy film clips participants scored significantly higher on a 9 point-mood scale than after watching the sad film clips ($p < .01$). The clips thus effectively induced the intended mood. For P600, measured between 600 to 800 ms, an interaction of syntax with mood was present for both the midline and for the lateral sites (ps < .02).). The interaction revealed a broad bilaterally distributed P600 effect for the happy mood condition, and a strong reduction of a P600 effect for the sad mood condition. Hence, syntactic processing is affected by mood in healthy subjects. This modulation of syntax by mood challenges modular views of language processing.

C52

DISPOSITIONAL MINDFULNESS AND NEURAL SYSTEMS UNDERLYING REAPPRAISAL OF NEGATIVE EMOTION *Gemma Modinos[1], Johan Ormel[2], André Aleman[1]; [1]BCN Neuroimaging Center, University of Groningen, Groningen, The Netherlands, [2]Interdisciplinary Center of Psychiatric Epidemiology, University Medical Center Groningen, Groningen, The Netherlands* – Research with functional magnetic resonance imaging (fMRI) has played a crucial role in seeking to determine the neural substrates of the cognitive regulation of negative emotional responses. However, little is known about how activity in these regions is modulated by individual differences in the tendency to respond emotionally or to regulate emotion. Mindfulness, an enhanced attention to and awareness of current experience, is at the core of meditation practices, and is known to reduce negative affect and promote well-being. The influence of dispositional mindfulness skills, thought of as a form of self-regulation, on the neural systems supporting the cognitive control of emotion remains unknown. To examine the relationship between mindfulness and reappraisal-related neural structures, we imaged 18 healthy subjects (mean age = 20.56; 7 females) while performing a reappraisal task in a 3T MRI scanner. Subjects viewed neutral and negative emotional pictures under three conditions - attend-neutral, attend-negative, reappraise-negative - and provided in-scan emotion experience ratings. Dispositional mindfulness skills were assessed prior to scanning through self-report. When individual mindfulness scores were incorporated in the analysis of brain activity associated with reappraising compared to attending to negative pictures, we observed that mindfulness significantly predicted increased activity in the amygdalae, insula, and dorsal prefrontal cortex. These results suggest a direct link between mindfulness and the neural substrates of emotion processing and its cognitive control, and provide novel neuroscientific support to the potential usefulness of mental training in the effective regulation of negative affect.

C53

MOTOR SYSTEM CONTRIBUTIONS TO SOCIAL INTERACTION SKILLS: EVIDENCE FROM EEG ACTIVITY IN THE MU FREQUENCY RANGE *Anat Perry[1], Shlomo Bentin[1,2], Nikolaus F. Troje[3]; [1]Hebrew University, Psychology, Jerusalem, Israel, [2]The Interdisciplinary Center of Neural Computation, Hebrew University, Jerusalem, Israel, [3]School of Computing, and Centre for Neuroscience Studies, Psychology, Queen's University, Kingston, Canada* – Motor actions suppress the EEG activity over the sensory-motor cortex, in a frequency range between 8-13 Hz, a range labeled Mu rhythms. Mu-suppression is induced not only by actual movements but also while the participant observes actions executed by someone else. This characteristic of Mu rhythms putatively associates them with the Mirror-Neurons System, which has been implicated in humans with social skills abilities and ToM. Further evidence for association between mu rhythms and social skills comes both from studies of individuals with Autistic Spectrum Disorders, and from a few studies with typical participants. These studies showed different mu rhythms modulations depending on the degree of social content of an observed human action. We further explored the basic relation between mu rhythms and social interaction. Specifically, using point-light biological motion, we manipulated the observer's task while keeping the stimuli identical across tasks. In separate blocks EEG was recorded while observers were instructed to process either the gender or the emotion or the intention of a moving pattern revealing the same biological motion of humans. The participants also completed two questionnaires - The Interpersonal Reactivity Index, and The Empathy Quotient. Mu suppression was found in all conditions relative to a baseline consisting of a moving circle. The suppression was modulated by task, strengthening the proposed association between mu rhythms and social interaction skills. Significant correlations between mu suppression and the scores on the personality scales unveiled theory-based individual variability in the activation of the mu-suppression mechanism.

C54

SITUATED CONCEPTUALIZATION OF EMOTION AND ABSTRACT CONCEPTS *Christine Wilson[1], Lisa Feldman Barrett[2,3], W. Kyle Simmons[4], Lawrence Barsalou[1]; [1]Emory University, Psychology, [2]Boston College, Psychology, [3]Harvard Medical School, Psychiatric Neuroimaging Research Program, Massachusetts General Hospital, [4]National Institutes of Mental Health, Laboratory of Brain and Cognition* – Evidence increasingly suggests that the human conceptual system is situated and dynamic. From this perspective, situational content, such as setting, event, and thematic information, shapes concepts dynamically, including emotion concepts like fear and anger. This approach to emotion concepts motivates

different questions than traditional views that focus instead on trying to identify a diagnostic biological pattern in the body and brain for each emotion category. To investigate whether situational context shapes emotion concepts dynamically, we developed an fMRI paradigm in which a mental state concept is processed in physical situations (where participants imagined being in physical danger brought on by their own poor judgment) and in social situations (where participants imagined being socially evaluated in an unfair manner by another individual). Two emotion concepts (fear, anger), and two abstract concepts (plan, observe), were assessed in each situation type. On a given trial, participants listened to the description of a situation, heard one of the four mental state words, and rated how easy it was to experience the mental state in the situation. We predicted that different activation patterns would occur for the same mental state concept in the two situation types. Results support these predictions, indicating that conceptualizing an emotion or abstract concept is a context-sensitive, dynamic process.

C55

DIFFERENTIAL NEURAL RESPONSES TO EMOTIONAL STIMULI ASSOCIATED WITH MOOD CONGRUENT VS MOOD INCONGRUENT DELUSIONS *Ayana Gibbs[1], Paul Fletcher[2], Anthony David[1]; [1]Institute of Psychiatry, King's College London, [2]University of Cambridge* – Delusions in psychosis have been divided into those that arise from underlying mood disturbance (mood congruent - MC) and those arising in the absence of mood abnormalities (mood incongruent - MI). Abnormal responses to emotional stimuli may play a role in the formation of delusional beliefs. However this role may differ for MC compared to MI delusions. To investigate this, fMRI data were collected while participants (8 MC, 9 MI and 15 controls) viewed 46 aversive-arousing pictures and 46 neutral pictures. In the AVERSIVE > NEUTRAL contrast MC patients demonstrated a similar pattern to controls with activation in visual cortical areas and limbic areas, while the MI group demonstrated activity in ventral striatal regions. In the alternate NEUTRAL > AVERSIVE contrast there was a pattern of ventral striatal activation in the MC group, mirrored to a lesser extent in the controls, suggesting relative suppression of striatal responses to aversive pictures. Between group comparisons of the AVERSIVE > NEUTRAL contrast revealed increased activation of the ventral striatum in MI relative to MC patients. Taken with the within group findings, this suggests that the MI group may be less effective at suppressing activity in this reward-associated region in the presence of a non-rewarding or aversive stimulus. There was also increased activation of the precuneus in MC relative to MI patients. These findings suggest that abnormal patterns of brain activation to emotional stimuli may play a role in the formation of mood congruent and mood incongruent delusions however the neural mechanisms may differ.

C56

EARLY AND LATE EFFECTS OF EMOTIONAL WORDS AND FACES IN THE EVENT-RELATED BRAIN POTENTIAL *Annekathrin Schacht[1], Julian Rellecke[1], Werner Sommer[1]; [1]Humboldt-University at Berlin, Psychology* – Several studies have shown emotional stimuli to involuntarily draw attentional resources, resulting in a preferential and sustained processing. The underlying neural mechanisms are suggested to be reflected in two different components of event-related brain potentials (ERPs): the early posterior negativity (EPN) and the late positive potential (LPC). However, as yet it remains mostly unclear, under which boundary conditions emotional processing depends on the availability of central attentional resources and specific stimulus characteristics. In a series of experiments, we investigated the time course of emotion effects in word and face processing by using ERPs. In line with studies on affective picture processing, both EPN and LPC components - distinguishable in their scalp topographies and latencies - were elicited by emotional words and facial expressions, although their emotional meaning was irrelevant for the tasks. Importantly, EPN effects appeared later to words than faces, but showed comparable scalp distributions in both domains, and were independent of the level of processing. Moreover, the EPN to angry faces appears to benefit from the withdrawal of central resources by an additional task. In contrast, LPC effects were modulated by a variety of different factors and dependent on specific task demands. Furthermore, these late emotion effects appeared at comparable latencies but with different scalp distributions to words and faces, indicating contributions of domain-specific brain systems. These results indicate both ERP components to reflect different mechanisms of emotional processing at early and late stages.

C57

RECOGNIZING EMOTIONS FROM OUR OWN FACES: HOW GOOD ARE WE? *Bhismadev Chakrabarti[1], Jorrit de Kieviet[1,2], Zanna Szlachta`[1,3], Simon Baron-Cohen[1]; [1]Autism Research Centre, University of Cambridge, [2]Vrije University, Amsterdam, The Netherlands, [3]MRC Cognition and Brain Sciences Unit, Cambridge, UK* – Background: Our own face has special status as an instrument for interacting with the external social world, using expressions of emotion that we rarely see. Humans, from birth, perceive expressions of emotion in the faces of others but have limited visual experience of their own emotion expressions (via mirrors and film). In two experiments we tested emotion recognition from one's own face compared to those from others' faces. Sample and Method: 34 volunteers were photographed making expressions of five basic emotions, and tested one week later using their own face and those of unknown others (taken from a standardized stimuli set), in an emotion recognition task. Results: In Experiment 1, people were quicker to correctly recognize all emotions from their own face, compared to others' faces. In Experiment 2 replicated these results, using a set of morphed faces between self and others, and showed that the degree of self-similarity in a faces is positively correlated with speed of accurate emotion recognition. Conclusions: This is the first demonstration of a self-effect in relation to basic emotion recognition from faces. The results are consistent with an account based on simulation theory and have possible clinical implications for conditions marked by difficulties in self and emotion processing, such as autism spectrum conditions.

C58

CUE-DEPENDENT NEURAL REPRESENTATIONS OF VOCAL AFFECT PERCEPTION *David Leitman[1], Tim Campellone[1], Daniel Ragland[2], Daniel Wolf[1], James Loughead[1], Jeffery Valdez[1], Cameron Carter[2], Bruce Turetsky[1], Daniel Javitt[3,4], Ruben Gur[1]; [1]Brain Behavior Laboratory, Neuropsychiatry Section, [2]Imaging Research Center, UC DAVIS, [3]Nathan S Kline insititute for Psychiatric Research, [4]New York University, Psychiatry* – Affective communication through vocal tone (prosody) is a core channel of interpersonal interaction, which, like its facial analogue, relies on gestural changes. Such vocal changes involve modulation of specific aspects of the speech signal including perceived pitch, voice intensity, and spectral energy. The stage in the information processing cascade where perception and integration of these cues occur in the brain is the topic of intensive debate. Using functional magnetic resonance imaging, we show that right primary and secondary auditory cortices are already sensitive to valence-related vocal features. These auditory regions in conjunction with limbic regions show a reciprocal pattern of activation with inferior frontal gyrus. The balance of activation is determined by the degree of cue salience in an emotion-specific manner.

C59

EARLY EXPERIENCE AND CHANGES IN BRAIN STRUCTURE AND FUNCTIONS FOR MATERNAL LOVE *Pilyoung Kim[1,2], James Leckman[2], Linda Mayes[2], Michal-Ann Newman[3], Ruth Feldman[4], James Swain[2]; [1]Human Development, Cornell University, [2]Child Study Center, Yale University, [3]Howard University, [4]The Leslie and Susan Gonda Brain Science Center, Bar-Ilan University, Israel* – Early experience such as maternal care can influence development of stress reactivity and the ability to bond with others. Animal studies suggest that early maternal care is related to heightened stress reactivity in the hippocampus. Maternal care may also have long-term effects on brain areas related to social competence and attachment. To examine whether early experience may affect neurologi-

cal correlates of maternal love, we studied effects of perceived quality of maternal care in childhood on brain structure and functional responses to salient infant stimuli among human mothers in the first postpartum month. Higher maternal care in childhood was linked to larger gray matter volumes in the superior and middle frontal gyri, orbital gryrus, superior temporal gyrus and fusiform gyrus. These areas have been found to be important for social information processing. Furthermore, in response to infant cries, mothers with higher maternal care in childhood showed increased activations in the dorsolateral prefrontal cortex, middle frontal gyrus, superior temporal gyrus, and fusiform gyrus; whereas mothers with lower maternal care showed increased hippocampal activations. The areas with greater brain activations were considerably overlapping with the areas with larger gray matter volumes among the high maternal care group. These findings suggest an association between maternal care in childhood and neurobiological substrates of stress reactivity, social attachment, further maternal love in human mothers.

C60

NEURAL SUBSTRATES OF FEAR EXTINCTION DUE TO EXPOSURE THERAPY *Katherina Hauner[1], Susan Mineka[1], William Revelle[1], Ken Paller[1]; [1]Northwestern University, Psychology* – Specific phobias, characterized by excessive and unreasonable fear of an object or situation, are the third most prevalent of all mental disorders. Exposure therapy for specific phobias can lead to fear extinction, usually within two hours of treatment. The neural mechanisms by which this remarkable clinical outcome is accomplished are not currently understood. The chief goal of the present study was to identify the functional neuroanatomical substrates of fear extinction following exposure therapy in a group of participants meeting diagnostic criteria for spider phobia. An additional goal was to determine the extent to which extinction and habituation (a non-associative decrease in fear due to repeated stimulus presentation) are neuroanatomically distinct. Before treatment, neural correlates of phobic fear were obtained as differential fMRI responses to alternating sequences of phobic images (spiders) versus neutral images (moths), particularly in the amygdala. A detection task performed during all scanning required subjects to maintain attention to all stimuli. Neural correlates of habituation were obtained using repeated phobic images. Participants then completed a 2-hour exposure therapy session (or 2-hour sham therapy session), followed by a subsequent fMRI session during which they viewed a novel set of phobic and neutral images. Results yielded pre- versus post-treatment changes in the processing of phobic versus neutral stimuli. These findings are relevant for hypotheses regarding neurocognitive mechanisms for fear extinction, which appears to involve both changes in the perception of fear and in the strategic use of fear inhibition. Ramifications for neurobiological models of fear extinction will be discussed.

Higher level cognition: Executive functions

C61

SEPARATE SYSTEMS IN ATTENTIONAL SWITCHING AND SELECTION: EVIDENCE FROM FMRI *Benjamin O. Turner[1], F. Gregory Ashby[1]; [1]University of California, Santa Barbara* – In the Wisconsin Card Sorting Test (WCST), subjects learn to sort cards using a series of simple one-dimensional rules. Perseverative responding on this test is a classic symptom of frontal dysfunction. Even so, perseverative errors on the WCST could be due to a failure to select the appropriate dimension that needs attending, or to a failure to switch attention from the current dimension to the newly selected dimension. The present study used a modified version of the WCST in which errors of selection and switching had separate observable effects. Healthy normal college students performed this modified WCST in a rapid event-related fMRI experiment, experiencing approximately 100 rule changes over the course of the scanning session. The results strongly supported the hypothesis that selection and switching are separate neural and cognitive processes. For example, relative to rule switching, rule selection was associated with increased activation in anterior cingulate cortex and in the striatum. Further, these areas were shown to be components in partially-overlapping networks that mediated the selection and switching operations. Overall, the results were generally consistent with the COVIS model of category learning, which proposes that selection is mediated by a network that includes the anterior cingulate and the prefrontal cortex and that switching is mediated by a reduction in the prefrontal activation of the striatum.

C62

NEURAL NETWORKS THAT MONITOR RESPONSE UNCERTAINTY *Erick J. Paul[1], David Smith[2], F. Gregory Ashby[1]; [1]University of California, Santa Barbara, [2]University at Buffalo, State University of New York* – Humans and some animals (but not all) display the ability to monitor uncertainty about the environment, and to cope with such uncertainty by escaping or by seeking more information. In most categorization and discrimination experiments, participants are forced to make a decision on each trial regardless of their uncertainty. Some paradigms, however, have been designed specifically to elucidate the nature of uncertainty monitoring during such tasks. Researchers have successfully observed strategic use of uncertainty (or escape) responses from humans and some animals, but the neural substrates of uncertainty monitoring are not entirely known. Using fMRI, the present study sought to detect active brain regions related to uncertainty in a categorization task. Human subjects were asked to categorize visual patterns according to whether the pixel density was sparse or dense; they were also allowed to use an uncertain response on every trial. Correct responses were rewarded, incorrect responses were punished, and uncertainty responses allowed participants to escape to the next trial. On trials when uncertain responses were given, we identified activity unique to uncertainty responses and unrelated to task difficulty. This network included areas of bilateral frontal cortex, anterior cingulate cortex, and right posterior insular cortex, which have been implicated in state monitoring, self-awareness and attention. These results help to describe the neural components of uncertainty and metacognition and may clarify what distinguishes humans and animals that can consistently use uncertainty responses from those that cannot.

C63

INFLUENCE OF CONFLICT SIZE AND ERROR TYPES ON POST-ERROR SLOWING *Carolin Dudschig[1,2], Ines Jentzsch[1]; [1]University of St Andrews, [2]Universität Tübingen* – In order to achieve optimal performance, people are able to adjust their response threshold on a trial-to-trial basis, becoming increasingly faster until committing an error and slowing down immediately after the error. Such adjustments are usually explained by shifts along the speed-accuracy trade-off function, triggered by conflict in previous trials (Botvinick et al., 2001). Some researchers assume that conflict is particularly large in error trials, especially when the erroneous and correct responses are similar (e.g. left foot instead of left hand, see Gehring & Fensick, 2001). However, the influence of conflict strength on post-error slowing, and the link between the error-related negativity (ERN) and post-error slowing, is still unclear. In two experiments conflict size and its influence on post-error slowing and on the ERN were investigated. If conflict strength determines post-error slowing, slowing should increase the more response features are shared by the erroneous and correct response. We found the ERN and post-error slowing to increase with increasing conflict, but only when different effectors (hand, foot) were involved. When only hand responses were required (hand, finger), the data did not follow the predictions of the conflict strength hypothesis. We conclude that the conflict account as well as the relationship between ERN amplitude and post-error slowing is limited to specific task settings.

C64

INDIVIDUAL VARIABILITY IN WORKING MEMORY CAPACITY PREDICTS SUCCESS IN ATTENTION-RELATED PROCESSING OF VISUAL STIMULI *Jesse J. Bengson[1,2,3], George R. Mangun[1,2,3,4]; [1]Center for Mind and Brain, University of California, Davis, [2]University of California, Davis, [3]University of California, Davis, Psychology, [4]University of California, Davis, Neurology* – We investigated the hypothesis that working memory capacity (WMC) supports a subject's ability to generate expectancies for the characteristics of upcoming stimuli. In a cuing paradigm (Handy et al., 2001) participants were cued to expect both the location and orientation of a square-wave grating stimulus. Performance in the cuing task was measured as the difference in reaction time (RT) and accuracy between validly cued orientations and invalidly cued orientations at validly versus invalidly cued spatial locations. The Operation Span (OSPAN) task (Turner & Engle, 1989) indexed variations in subjects' WMC. The design included two between-subjects conditions: a response cued condition, in which the grating orientation cue also cued the hand of response, and a feature cued condition, in which the orientation cue did not predict the hand of response. A total of 111 subjects were tested. In the response-cued condition, independent of WMC, we found that RTs were faster for validly cued orientations, at both validly, ($t(54) = 10.599$, $p < .000$), and invalidly cued spatial locations, ($t(54) = 5.501$, $p < .000$). In contrast, in the feature-cued condition, the benefits of cueing were observed at validly cued spatial locations only for those subjects in the top third of WMC, ($t(17) = 4.134$, $p = .001$). In conclusion, these findings show that the ability to develop expectancies for complex stimuli is critically dependent on individuals' WMC. As a result, individuals with higher WMC are better able to utilize selection mechanisms to enhance performance under demanding perceptual conditions.

C65

EFFECTIVE AND STRUCTURAL CONNECTIVITY OF THE EXECUTIVE AND MOTIVATIONAL CORTICOSTRIATAL LOOPS UNDERLYING FEEDBACK PROCESSING *Dan Lopez-Paniagua[1], Carol Seger[1]; [1]Colorado State University* – Previous research indicates that feedback is crucial for successful category learning. The head of the caudate and ventral striatum have been shown to be sensitive to feedback across different types of learning, including category learning. Several cortical areas work collectively with these striatal regions; the head of the caudate connects with prefrontal and posterior parietal cortex to form the 'executive' corticostriatal loop, while the ventral striatum connects with orbitofrontal and mediofrontal cortex to form the 'motivational' corticostriatal loop. In this study, both effective and structural connectivity of the executive and motivational loops were examined. First, BOLD responses associated with feedback processing were measured during trial and error learning in a categorization task. Diffusion tensor mapping (DTM) identified frontostriatal pathways between regions implicated in feedback processing. Effective connectivity between striatal and cortical regions sensitive to feedback was then assessed using Granger Causality Mapping (GCM). Directed influence was observed from ventral striatum to mediofrontal cortex, from mediofrontal cortex to the head of the caudate, which in turn exerted directed influence on lateral prefrontal, posterior parietal cortex, and posterior regions of the caudate. The effective and structural connectivity results of the present study provide further insight as to how the striatum and cortex interact to subserve feedback processing. In particular, GCM results demonstrate that information from one corticostriatal loop can be relayed to another loop in a "feed-forward" fashion, and are consistent with animal models showing that interactions between loops occur in a ventroanterior to laterosuperior direction beginning in the ventral striatum.

C66

DISSOCIABLE COMPONENTS OF COGNITIVE CONTROL: AN ELECTROPHYSIOLOGICAL INVESTIGATION OF RULE-SWITCHING *Matthew Waxer[1], J Bruce Morton[1]; [1]The University of Western Ontario, Psychology* – Rule-switching is thought to involve distinct preparatory and response-related processes. The current study investigated these potentially dissociable aspects of cognitive control by mean of high-density event-related potentials (ERP's). Adult (n=20) participants performed a deductive rule-switching task with distinct preparatory and response-related trial periods. To investigate differences in preparatory processes underlying rule-switching, we compared ERP's in the preparatory period of switch trials and repeat trials. To investigate differences in response-related processes underlying rule-switching, we compared ERP's in the response period of conflict trials and non-conflict trials. Participants were slower and more error-prone on switch trials and conflict trials than on repeat trials and non-conflict trials. There was no interaction between switching and conflict. Analysis of ERP's time-locked to the preparatory period revealed a late negativity over frontal sensors whose amplitude was greater on switch than repeat trials. Source localizations of these ERP data with Low Resolution Electromagnetic Tomography (LORETA) revealed increased current density activations of the anterior cingulate cortex (ACC), left dorsolateral prefrontal cortex (DLPFC), and left parietal cortex for switch trials relative to repeat trials. Analysis of ERP's time-locked to the response-period revealed a fronto-central N2 whose amplitude was greater on conflict than on non-conflict trials. Distributed cortical source localizations of these data with LORETA revealed increased current density activations of the ACC for conflict relative to non-conflict trials. These findings provide further insight into differences in dissociable processes involved in rule-switching.

C67

WHO TO MARRY OR TO CHOOSE AS A FRIEND?: EFFECT OF SOURCE INFORMATION AND SOCIAL CONTEXT ON THE BRAIN MECHANISMS OF PERSON-PREFERENCE JUDGMENT *Motoaki Sugiura[1,2], Risa Funayama[2], Yuko Sassa[1,3], Hyeonjeong Jeong[1,4], Keisuke Wakusawa[1,5], Kaoru Horie[6,7], Shigeru Sato[6,7], Ryuta Kawashima[1,3]; [1]IDAC, Tohoku University, Sendai, Japan, [2]Faculty of Education, Miyagi University of Education, Sendai, Japan, [3]RISTEX, JST, Kawaguchi, Japan, [4]Japan Society for the Promotion of Science, Tokyo, Japan, [5]Graduate School of Medicine, Tohoku University, Sendai, Japan, [6]Graduate School of Intercultural Studies, Tohoku University, Sendai, Japan, [7]LBC Research Center, Tohoku University, Sendai, Japan* – Person preference is critical to the dynamics of our society. In making judgments, the face and behavior are two important sources of information, and choice of spouse and of friends are different decisions. We used functional magnetic resonance imaging to identify brain areas involved in person-preference judgment, based on paired information in two contexts. Normal subjects were shown pictures of two different faces of the opposite sex (Fa), or shown one actor performing two different routine behaviors (Bh). Each subject selected the person they would prefer to marry (Mr) or to be a friend with (Fr). As a control task, brightness of the picture was judged. All the preference-judgment conditions activated the anterior cingulate and caudate nucleus more than the control task. The Bh condition activated the bilateral temporoparietal junction and anterior temporal sulcus more than the Fa condition. Activation in the right ventral striatum and left amygdala was conspicuous in the FaMr condition. Activation in the right dorsolateral and medial prefrontal cortices was prominent in the BhMr condition. Our results showed that, in addition to the common decision-making mechanism, person-preference judgments recruit different brain areas, depending on the type of source information and social context. Behavior-based judgment involves the neocortical networks for social perception. Choice of a spouse, which is of critical evolutionary importance, recruits the limbic networks in face-based judgment and the neocortical cognitive integration and inhibition networks in behavior-based judgment, presumably reflecting different evolutionary stages, when the two types of source information were relevant to the judgment.

C68

INDEPENDENT MODULATORS OF REGIONAL EEG ALPHA SUB-BAND POWER DURING A WORKING MEMORY TASK *Julie Onton[1], Scott Makeig[1]; [1]University of California, San Diego* – Previous studies have suggested that upper and lower alpha-band power are sepa-

rately regulated during certain cognitive processes. A shortcoming of those studies was that alpha power was summed across several scalp channels. Here we show that alpha sub-bands are, indeed, separately regulated and occur within single EEG independent component or source domains. EEG data from a "two-back" working memory task was first decomposed by extended-infomax independent component analysis (ICA) to isolate temporally independent EEG activities from the signal mixtures recorded at the scalp channels. Activation time series of brain-generated independent component (IC) processes were transformed into log spectrograms using 4-cycle (at 4 Hz) to 42-cycle (at 125 Hz) wavelets moved at 50-ms intervals through each stimulus-response trial. The mean log power spectrum over all time windows was removed for each IC, leaving spectral fluctuations from the mean log spectrum in each window. Spectral data from all ICs were reduced by principal component analysis (PCA), and then again decomposed by ICA to separate the spectral data into a log mixture of independent modulator processes (IMs) with maximally distinct spectral profiles across ICs and frequencies. Some of the resulting IM templates accounted for activity in distinct alpha sub-bands. Because each IM template was associated with IM time weights for each trial and latency, we could test whether these alpha sub-band modulators had different mean time courses relative to task events and whether the patterns of alpha power modulation were brain-region specific.

C69

THE EFFECTS OF EXPECTED VALUE AND RISK LEVEL ON BEHAVIORAL AND ELECTROPHYSIOLOGICAL RESPONSES IN A MODIFIED IGT *Nai-Shing Yen[1,2], Chang-Hao Kao[1], I-Chen Chou[1], Hui-Kuan Chung[1]; [1]Psychology, National Chengchi University, Taipei, Taiwan, [2]Research Center for Mind, Brain, and Learning, National Chengchi University, Taipei, Taiwan* – The somatic maker hypothesis (SMH) proposed that decision making is a process that depends on emotion and deficits in emotional signaling will lead to poor decision making (Damasio, 1994). An Iowa Gambling Task (IGT) was used to support SMH. In the IGT, somatic maker (i.e. anticipatory SCR) is interpreted as correlates with the bad decks, and it operates as an alarm to make subjects withdraw from bad decks. Compared with normal controls, patients with VMPFC damage showed less anticipatory SCR and chose more cards from bad decks. However, the bad decks in IGT are also more risky decks. Thus, another factor which may influence the performance on the IGT is risk level (Dunn et al., 2006). In order to further clarify the SMH, the expected values and risk levels were manipulated in a modified IGT. In good decks, the immediate gain and delayed loss are smaller, which leads to positive expected values. In bad decks, the immediate gain and delayed loss are larger, which leads to negative expected values. The risk level was manipulated by the magnitude of coefficient of variation. Behavioral data, SCR and alpha activity in the EEG were collected. In our modified IGT, a significant interaction between decks and risk levels was found. Participants chose more cards from bad decks in high risk condition and chose more cards from good decks in low risk condition. Furthermore, the anterior alpha activity showed the same pattern as the behavioral data. But the anticipatory SCRs were not. Therefore, the SMH is not supported.

C70

A FUNCTIONAL MAGNETIC RESONANCE IMAGING STUDY OF LIST-WIDE VS. ITEM-SPECIFIC CONTROL IN THE STROOP TASK *Julie Bugg[1], Bethany Edwards[1], Todd Braver[1]; [1]Washington University in St. Louis* – The magnitude of Stroop interference is smaller when attentional conflict occurs frequently, as in a mostly incongruent condition. In a previous study using a state-item fMRI design, we found that decreases in list-wide proportion congruence (the percentage of congruent trials within a list) were selectively associated with increased state-related activation of right ventrolateral prefrontal cortex. We interpreted this sustained pattern as reflecting increased utilization of proactive control: expectancy-driven attentional adjustments that biased attention away from word reading even prior to stimulus onset. While recent behavioral evidence suggests a single control mechanism may underlie both the list-wide and item-specific proportion congruence effect (i.e. smaller interference for mostly incongruent items in a 50% congruent list), this idea has not been tested using fMRI. In the current study, we used a state-item fMRI design to examine the degree to which similar or dissociable neural activation patterns characterize list-wide and item-specific proportion congruence effects. Participants (N = 20) were scanned while performing Stroop trials in blocks for which proportion congruence was manipulated in a list-wide manner (mostly congruent, mostly incongruent, mostly neutral, and equal ratio) as well as in an item-specific manner (list = equal ratio). Both types of proportion congruence manipulations influenced behavioral interference effects. The imaging results address whether these manipulations differentially affect activity in control regions, including the anterior cingulate cortex and lateral prefrontal cortex response to conflict. We consider several explanations for our findings including the role of stimulus repetition.

C71

MOTIVATIONAL INFLUENCES ON INHIBITION-RELATED BRAIN ACTIVITY *Lauren Leotti[1], Tor Wager[1]; [1]Columbia University, Psychology* – The stop-signal paradigm provides a sensitive measure of response inhibition (SSRT) that is assumed to be independent of strategic and motivational biases. However, our recent work has shown that SSRT varies systematically when adopting different strategic tradeoffs between speed and accuracy. The present study examines stop-signal performance in 14 participants in a mixed-block/event-related design, which allowed us to separate responses on stop and go trials (phasic changes) with sustained strategy-related activity (tonic changes). Consistent with previous studies, successful inhibition of responses to the stop-signal was associated with increased activity in inferior frontal cortex (IFC) and striatum. Controlling for activity due to phasic responses, we observed tonic increases in response inhibition-related regions (right IFC) when subjects adopted an accuracy bias and tonic increases in motor preparation regions (basal ganglia, substantia nigra, motor cortex) when subjects adopted a speed bias. Furthermore, strategy-induced differences in tonic activity predicted differences in phasic response on successful inhibition trials. Greater tonic activation of right IFC (accuracy > speed) predicted greater phasic activation of the globus pallidus on successful stop trials. Greater tonic increases in the substantia nigra (speed > accuracy) predicted less phasic activity in control regions in the lateral PFC. Collectively, the results suggest that strategic shifts alter the recruitment of regions involved in response inhibition and response selection. Separating the influences of motivation from inhibitory processes is important for understanding the neural bases of inhibitory control in normal cognition and in populations with presumed inhibitory deficits.

C72

REGULATORY FOCUS AND EXECUTIVE FUNCTIONS *Brian D. Glass[1], J. Vince Filoteo[2], Arthur B. Markman[1], W. Todd Maddox[1]; [1]The University of Texas at Austin, [2]VA San Diego Healthcare System & University of California, San Diego* – Executive functions (EF) encompass cognitive processes that allow flexible and adaptive behavior in the face of novel or changing situations. The anterior cingulate cortex (ACC) and head of the caudate nucleus have been proposed as critical brain regions in rule based tasks involving set shifting (Maddox & Ashby, 2004; Monchi et al., 2006). The Wisconsin Card Sorting Task is the gold standard measure of EF in cognitive assessment and has been used extensively in experimental settings. We test the hypothesis that EF is affected by the interaction of global incentive structure and the local task reward structure in a group of normal participants. This prediction is based on the possibility that the ACC is differentially activated by the interaction between global incentive structure and local task components (Cunningham et al., 2005). Global incentive structure was manipulated by requiring participants to earn a raffle entry (promotion focus) or keep a raffle entry from being revoked (prevention focus). Reward structure was framed as maximizing point

accrual (gains structure) or minimizing point reduction (losses structure). A regulatory mismatch (promotion-losses, prevention-gains) is predicted to impair cognitive flexibility relative to regulatory fit (promotion-gains, prevention-losses). As predicted, participants in a regulatory mismatch showed worse EF than participants in a regulatory fit. These findings suggest that accurate assessment of EF must consider motivational and task reward factors that could be influenced by various neural systems, and have important implications for the relationship between executive function and regulatory focus.

C73

NEUROCOGNITIVE CORRELATES OF ERROR INDUCED POSITIVITIES REVEALED BY MEG *Päivi Helenius[1], Marja Laasonen[2,3], Laura Hokkanen[2], Ritva Paetau[4], Markku Niemivirta[5]; [1]Brain Research Unit, Helsinki University of Technology, Finland, [2]Helsinki University, Psychology, [3]Helsinki University Central Hospital, Phoniatrics, [4]Helsinki University Central Hospital, Pediatric Neurology, [5]Education, Helsinki University* – The cognitive and physiological processes related to successful Go/NoGo task performance and error detection were investigated using magnetoencephalography (MEG) and event-related potentials (ERPs at Fz, Cz, Pz). Our stimuli were visual arrays composed of 5 items (apples and animals). The relative position of items was randomized between successive stimuli presented once every 2 seconds. The 12 participants were instructed to make a rapid manual response to a target stimulus (wolf facing a pig) and avoid responding to a non-target stimulus (17%) (wolf facing an apple). Erroneous responses elicited an ERP component peaking 60 ms after button press and an enhanced positivity peaking around 230 ms (error positivity, Pe). The infrequent non-target stimuli evoked a more negative going deflection 390 ms after stimulus onset and a more positive going deflection at 530 ms (late positive component, LPC) compared to the target stimuli. The Pe and LPC components were coupled with functionally and temporally equivalent activation in the MEG channels. This activation was localized bilaterally in the posterior temporal cortex. In the response-locked averages, the temporal activity was enhanced if errors were committed. In the stimulus-locked averages, the activation was also enhanced after infrequent non-target stimuli and delayed for the initially miscategorized non-targets accompanied with erroneous response. Thus, the results suggest that the cortical correlates of LPC and Pe are not specifically related to commission of an error, but these components, and bilateral temporal cortices, are more generally involved in conflict resolution and memory updating triggered by the incoming stimuli.

C74

ASSOCIATING EVENT-RELATED BRAIN DYNAMICS WITH EVENT CONTEXT *Scott Makeig[1], Julie Onton[1]; [1]University of California San Diego* – Active human agents both create and respond to events in 'real' time without the luxury of delay. Ongoing EEG source signals and their event-related perturbations index processes that maintain or adjust the distribution of attention between sensory, mnemonic, and imaginative processes in response to the perceived significance of events --- which may be heavily influenced by the context in which they occur. To determine from the data themselves which event contexts are linked to which brain dynamics changes, we decomposed event-related log spectrograms from maximally independent EEG components (IC) processes time locked to delivery of auditory feedback signals in a 'Two-back with feedback' visual working memory paradigm. Before decomposition of the (frequencies * latencies by trials) matrix for each IC, we appended a matrix of 'answers' to 19 questions about the trial context, in the form of a (questions by trials) matrix of ('yes|no') 1s and -1s. Maximally independent components of the joint data matrix gave independent factors (IFs) comprising a log spectral time/frequency modulation template, a loading on each of the questions, plus a weight specifying the relative effect of the template in each trial. Sorting the individual trial context vectors by their IF trial weights revealed significant across-trials trends, even for IFs predominantly linked to relatively simple event contrasts. Context ICA decomposition appears likely to allow new insights in the connection between events in context and the complex spatiotemporal patterns of local cortical field synchrony that produce the ongoing EEG.

C75

THE ROLE OF OVERALL VALENCE IN EVALUATIVE DECISION MAKING *Andries Van der Leij[1], Steven Scholte[2], Ap Dijksterhuis[1]; [1]Behavioural Science Institute, Radboud University Nijmegen, [2]University of Amsterdam, Psychology* – Evaluative decision making, for instance deciding which of two political opinions to prefer, involves forming a relation between the alternatives and one's internal values and goals, a comparison between the alternatives, and a choice. The characteristics of these goal-directed decisions change when both alternatives are judged as positive or negative, the former leading to a decision in terms of anticipated benefits and the latter to a decision in terms of costs ('Which alternative will benefit/harm me the most?'). It has been shown that the evaluative judgment of a stimulus (e.g. self-referential processing) involves activation of the anterior frontomedian cortex. However, the neuronal underpinnings of decision making between multiple evaluative stimuli are still largely unknown. We hypothesized that the potential harmfulness of choosing the wrong alternative between two negative options would be associated with additional prefrontal activity. We used functional magnetic resonance imaging to investigate the neuronal processes underlying these types of decisions. While scanned, participants made dichotomous choices between political statements. In a behavioral session the participants rated each statement on a negative to positive visual analogue scale, which allowed for estimation of the overall valence of the choices. When contrasted with choices between two positive statements, choices between two negative statements led to the activation of the frontopolar cortex. These data support the notion that the differences in overall valence of evaluative decisions are associated with differences in brain activation patterns and suggest a special role of the most frontal regions in choosing between undesirable alternatives.

C76

IS YOUR ERROR MY CONCERN? AN EVENT-RELATED POTENTIAL STUDY ON OWN AND OBSERVED ERROR DETECTION IN COOPERATION AND COMPETITION *Ellen de Bruijn[1], Daniel von Rhein[1], Harold Bekkering[1]; [1]Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen, the Netherlands* – For successful goal-directed behavior it is essential for humans to continuously monitor one's actions and detect errors as fast as possible. EEG studies have identified an error-related ERP component known as the error-related negativity or ERN. Theories on error monitoring propose a direct relation to reward processing. Whenever an error is made, the outcome of an action turns out to be worse than expected, resulting in a loss of reward and hence eliciting the ERN. However, as own errors are always associated with a loss of reward, disentangling whether the ERN is error- or reward-dependent has proven to be an extremely difficult endeavor. Recently, an ERN has also been demonstrated following the observation of other's errors. An important difference with own errors is that other people's errors can be associated with loss or gain depending on the cooperative or competitive context in which they are made. We conducted an ERP study to disentangle whether the ERN is error- or reward-dependent. Eleven pairs (N=22) of participants performed and observed a speeded-choice reaction task in two contexts. Own errors were always associated with a loss of reward. Observed errors in the cooperative context also yielded a loss of reward, but observed errors in the competitive context resulted in a gain. The results showed that the ERN was present following all types of errors independent of who made the error and the outcome of the action. Consequently, the current study demonstrates that the ERN is error-specific and not dependent on reward.

C77

FUNCTIONAL CONNECTIVITY OF THE DORSOLATERAL PREFRONTAL CORTEX IN CHILDREN WITH AUTISM

SPECTRUM DISORDERS: A FUNCTIONAL MRI STUDY OF WORKING MEMORY *Benjamin E. Yerys[1], Alicja U. Kreczko[1], Kathryn F. Jankowksi[1], Philip S. Lee[2], Peter Daniolos[1], John VanMeter[3], Lauren Kenworthy[1], Chandan J. Vaidya[1,2], William D. Gaillard[1,3]; [1]Children's National Medical Center, Washington, DC, [2]Georgetown University, Washington, DC, [3]Georgetown University Medical Campus, Washington, DC* – Functional connectivity studies of working memory in adults with ASD have yielded reduced neural synchrony between neural regions expected to support task performance. No studies to date have examined functional connectivity of working memory networks in children with ASD. The current study included 24 children (12 with ASD and 12 age, IQ, and gender matched controls) who completed an N-back working memory task (2-back and 1-back blocks) at 3T using echo planar imaging. The left and right dorsolateral prefrontal cortex (BA 9/46; DLPFC) served as seeds, given their importance in working memory. The time series of seed locations were extracted via MarsBar and entered as a covariate of interest in a whole-brain voxel-wise regression in SPM5. Within the control group, the expected fronto-striatal loop was observed with both DLPFC seeds. In contrast, the ASD group exhibited atypical increased prefrontal connectivity. Taken together, these findings extend atypical functional connectivity to include working memory networks in childhood samples of ASD.

C78

NEURAL CORRELATES OF REWARD-BIASED PERCEPTUAL DECISION-MAKING *Kartik Kesavabhotla[1], Shruti Japee[1], Aurora Ramos[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, NIMH, NIH* – Studies suggest that higher-level cortical areas may compute perceptual decisions by comparing outputs of different pools of selectively tuned lower-level sensory neurons. A factor that may influence this decision-making process is the reward value associated with making a particular response choice. To study the effect of incentive on the decision-making process, we conducted an fMRI study, in which 19 subjects performed a face-house categorization task involving noise-degraded stimuli and multiple levels of monetary reward. Two noise levels: 46% and 58% were used for degradation of images. To study the effect of incentive, four reward levels were used: No Reward, Equal Reward, High Face Reward (higher reward for correct face than house), and High House Reward (higher reward for correct house than face). Behavioral data showed that subjects shifted their decision criterion towards the more profitable response choice, especially at the higher noise level. Preliminary fMRI data showed that frontal regions, such as BA9/44, were generally more engaged when subjects processed noisy stimuli and when their decisions were influenced by reward. Specifically, these regions showed greater activity during high house compared to equal reward trials. Furthermore, when subjects incorrectly identified a face as a house (i.e., decision aligned with reward-induced bias toward houses), differential activity (high house relative to equal reward) in this region was negatively correlated with the magnitude of decision-criterion shift (for high house relative to equal reward trials). These results indicate that frontal regions may combine reward-induced response bias with sensory evidence when computing perceptual decisions.

C79

SEARCHING FOR THE MAJORITY: ALGORITHMS OF VOLUNTARY CONTROL *Jin Fan[1,2], Kevin G. Guise[2], Xun Liu[2], Hongbin Wang[3]; [1]Mount Sinai School of Medicine, Psychiatry, [2]Mount Sinai School of Medicine, Neuroscience, [3]University of Texas Health Science Center at Houston, School of Health Information Sciences* – Voluntary control of information processing is crucial to allocate resources and prioritize the processes that are most important under a given situation; the algorithms underlying such control, however, are often not clear. We investigated possible algorithms of control for the performance of the majority function, in which participants searched for and identified one of two alternative categories (left or right pointing arrows) as composing the majority in each stimulus set. We manipulated the amount (set size of 1, 3, and 5) and content (ratio of left and right pointing arrows within a set) of the inputs to test competing hypotheses regarding mental operations for information processing. Using a novel measure based on computational load, we found that reaction time was best predicted by a grouping search algorithm as compared to alternative algorithms (i.e., exhaustive or self-terminating search). The grouping search algorithm involves sampling and resampling of the inputs before a decision is reached. These findings highlight the importance of investigating the implications of voluntary control via algorithms of mental operations.

C80

ERROR SWITCH COST AS GOAL NEGLECT: FAILURE OF VOLUNTARY TOP-DOWN CONTROL AND ITS RELATION TO FLUID INTELLIGENCE *Koki Ikeda[1], Ryo Tamura[2], Toshikazu Hasegawa[1]; [1]University of Tokyo, [2]Saitama Gakuen University* – Altmann proposed the randomized-runs task switching paradigm, where a run consists of several trials, and a task cue is presented only in the first trial of a run but not in the following trials (Altmann & Gray, 2008). Subjects are required to execute the same task throughout a run. When the task assigned in a run differs from the previous one, it is defined as a "switch" run. In this paradigm, "latency" switch cost (or "switch cost" as commonly termed) is observed only in the first trial of a run, whereas "error" switch cost occurs all through a run and only after switching. Apparently, there are two distinct mechanisms that underlie these two types of switching cost, but only few attempts have been made to understand the nature of error switch cost. In this study, we explored several aspects of this phenomenon. First, we showed that error switch cost was eliminated either by explicit error feedback or voluntary effort to reduce error. Secondly, individual differences in error switch cost were correlated with the psychometric scores of fluid intelligence. These results suggested that error switch cost closely resembles a phenomenon called "goal neglect," which was found in frontal damaged patients (Duncan et al., 1996). Possible mechanisms underlying this phenomenon are discussed.

C81

FRONTAL EEG POSITIVITIES DURING A SIMPLE STERNBERG TASK PREDICT TASK ERROR RATE IN OLDER ADULTS *William Tays[1], Jane Dywan[1], Lesley Capuana[1], Sidney Segalowitz[1]; [1]Brock University* – There is evidence that enhanced frontal activation in older adults during cognitive tasks may serve a compensatory role in sustaining high level performance. We have recently shown that a Sternberg short-term memory task with familiarity-based interference manipulations produced a unique frontal positivity in the ERP waveforms of older adults rather than the interference-based negativities typically observed in the young. However, in contrast to the compensation account, these positivities were related to higher error rates on the task. We hypothesized that these interference-related positivities in older adults may represent a strong response to familiarity that does not easily resolve itself, thus making older adults more susceptible to familiarity-based interference. In the present study, we recorded EEG responses of younger and older adults in a simple Sternberg task without interference manipulations such that familiarity would be beneficial to performance. We hypothesized that frontal positivities in older adults in this circumstance would be predictive of enhanced performance. In contrast to expectations, unique frontal positive activations in older adults appeared to once again predict poor Sternberg memory accuracy thus replicating previous work. These data suggest that deviations from the medial prefrontal negativities that emerge in younger adults during the Sternberg task may represent a less efficient form of information processing which is inconsistent with the compensatory frontal activation reported in imaging data.

C82

CONTROLLING MENTAL IMAGERY: BRAIN ACTIVITY UNDERLYING MENTAL IMAGE GENERATION AND INHIBITION *Courtney Clark[1,2], Adam Safron[1], Ken Paller[1]; [1]Northwestern University, [2]St. Andrews University* – A pink elephant! Upon reading this, does a Dumbo-like image pop into your mind's eye? Through sheer will power, could you prevent that elephant from entering your visual consciousness? To explore the extent to which people can avoid visual imagery on command, we studied two conditions. In the IMAGE condition, subjects were asked to form vivid visual images for the referents of 96 concrete, highly imageable spoken nouns. In the REFRAIN condition, subjects were asked to focus attention on the sound of each of 96 similar words and not to think of anything visual at all. EEG data were collected so that we could analyze a specific brain potential associated with visual imagery in prior experiments (e.g., Gonsalves & Paller, 2000ab). EEG results suggested that subjects were successful at inhibiting imagery, in that occipital potentials were larger in the IMAGE than in the REFRAIN condition, with maximal amplitude differences about 800 ms after spoken-word-onset. Given that different views of imagery control were provided by EEG measures and self-assessments (subjective ratings, attention-control questionnaire, and visual imagery ability), it is unclear which method provides the best account of whether the mind's eye is full or empty, and of the ability to achieve control of mental imagery. More work will be needed to cohesively relate subjective measures to EEG measures, but these EEG methods nonetheless provide a new way to investigate the degree of control people have over this sort of visual imagery that normally comes to mind so swiftly and naturally.

C83

A COMMON ROLE FOR LEFT INFERIOR FRONTAL GYRUS (BA45) IN PROACTIVE AND SEMANTIC INTERFERENCE IN A WORKING MEMORY TASK? *Alexandra S. Atkins[1], Patricia A. Reuter-Lorenz[1], John Jonides[1], Marc G. Berman[1]; [1]University of Michigan, Psychology* – – Proactive interference (PI) in short-term item recognition tasks causes participants to be slower to correctly reject familiar negative probes that were members of the memory set on a recent trial (see Jonides & Nee, 2006). Numerous brain imaging studies of this recent-probes task have shown increased activations in left inferior frontal gyrus, BA45, associated with this form of familiarity-based PI (Jonides et al., 1998; Nelson et al., 2003). Using a short-term variant of the Deese, Rodeiger and McDermott false memory paradigm, we recently demonstrated within-trial semantic interference and false recognition in response to lure probes using semantically themed memoranda (Atkins & Reuter-Lorenz, 2008). In this task, subjects are slower to correctly reject lure probes that are semantically related to items in the memory set compared to non-related negative probes. Given the importance of left BA45 in mediating interference related to familiarity, we predicted this region might also mediate the processing of semantically related lures. Here we present results from an event-related fMRI investigation which show increased activation in left BA45 associated with the correct rejection of lure vs. unrelated negative probes presented 3 seconds following study of 4-item semantically themed memory set. ROI analyses indicate a positive relationship between the magnitude of semantic interference and BA45 activity. Findings suggest left BA45 may serve a common role in both familiarity-based PI and semantic interference in working memory tasks.

C84

THE INFLUENCE OF PROPORTION CONGRUENCY ON STROOP INTERFERENCE IN THE PRESENCE AND ABSENCE OF AWARENESS *Chris Blais[1], Eddie H. Nahabet[1], Silvia A. Bunge; [1]University of California, Berkeley, Helen Wills Neuroscience Institute* – The magnitude of the Stroop effect increases as the proportion of congruent trials in a block increases. The most common interpretation of this finding is that participants detect and use the contingency between the color and the word to optimize performance. Accordingly, many accounts assume that participants are aware of the proportion of congruent trials. The present investigation directly assesses the role of awareness of the proportion of congruent trials on the magnitude of the Stroop effect, using principles from psychophysics. Participants performed 228 blocks, each containing 100 Stroop trials. The number of congruent trials in each block varied from 5 to 95, in increments of 5. Following completion of each of these 2-3 minute blocks, participants were asked (1) were there more congruent trials than incongruent trials, (2) are you sure, and (3) out of the 100 trials, how many were congruent. The results reveal a strong linear relationship between (a) the size of the Stroop effect and the proportion of congruent trials and (b) the estimated number of congruent trials and the actual number of congruent trials. Assuming that the confidence ratings are an accurate measure of awareness, these results indicate that an entirely "unaware" mechanism can drive the proportion congruency effect, given the fact that participants were only confident of the proportion at the extremes (i.e., >85 and <20).

C85

RESPONSE INHIBITION MEDIATED BY PREFRONTAL CORTEX DISTINGUISHES HEAVY SMOKERS FROM 'CHIPPERS' *V. Viswanath Venugopalan[1], Marco Leyton[1,2], Lesley K. Fellows[1]; [1]Montreal Neurological Institute, McGill University, [2]McGill University* – Addiction to tobacco is the largest preventable cause of death in the world. Not everyone who smokes, though, becomes addicted. A subset of smokers retain better control over their cigarette use, typically smoking no more than 4 or 5 cigarettes per smoking day and not necessarily smoking everyday. We hypothesized that these cigarette 'chippers' would be less impulsive, or exert better inhibitory control (or both), compared to heavy smokers. These possibilities were tested in 27 addicted smokers (12.4±2.1 cigarettes/day) and 27 chippers (3.3±1.3 cigarettes/day) matched for age, gender and education. Group assignment was based on the combined score on two self-report measures of the degree to which individuals can control their smoking behavior. Prefrontally-mediated inhibitory control was measured with the stop-signal task, and in terms of commission errors in a working memory task. Two aspects of impulsivity, temporal discounting and risk-taking, were tapped with a standard delay-discounting task for money, and the Balloon Analog Risk Task (BART), respectively. Participants were tested twice, once while smoking at their usual rate, and once after an 18 h withdrawal period. The groups differed significantly on both measures of inhibitory control: chippers had faster stop-signal reaction times, and made fewer errors of commission on the working memory task. The groups performed similarly on the two measures of impulsivity. Abstinence did not substantially affect performance on any of the tasks. These findings suggest that individual differences in prefrontally-mediated response inhibition may be an important protective factor in retaining control over cigarette use.

C86

TO GRIP OR NOT: ACTION VALUATION BASED ON PHYSICAL EFFORT AND MONETARY GAIN *Irma Triasih Kurniawan[1], Deborah Talmi[2], Wako Yoshida[2], Ben Seymour[2], Nick Chater[1], Raymond J. Dolan[2]; [1]University College London, Cognitive, Perceptual, and Brain Sciences Research [2]University College London, Wellcome Trust Centre for Neuroimaging* – Contemporary decision making focus on incentives that determine the value of an action, but little is known how values are discounted by physical effort. Animal and recent human studies suggest that effort costs influence action choices and that the Anterior Cingulate Cortex (ACC) is crucial in integrating effort and reward. Using functional magnetic resonance imaging, we investigated how our brain calculates the physical effort involved in gripping against the monetary benefit attained by that grip action. We employed a choice task wherein eighteen healthy participants (Mean age 23; SD = 3.4) chose to do nothing or to exert effort by gripping for a sum of money. Choices were followed by the execution of the selected actions. We manipulated effort (low and high) and reward (low and high) levels, and tested if participants' willingness to grip is influenced by effort, reward, and the integration of effort and reward. We assessed BOLD responses in regions implicated in action valuation,

namely the ACC and the striatum. Behaviourally, we found main effects of effort and reward; as expected, participants were more willing to grip when the gain is higher and when the effort is less. The neural results of this paper extend animal findings about calculating action costs and benefits and provide insights about the role of effort costs in amotivation symptoms such as apathy.

C87

EFFECTS OF CONVERSATION COMPLEXITY OF CELL PHONE CONVERSATIONS ON DRIVING: ERP LAB AND ON-ROAD DRIVING STUDIES *Sean Seaman[3,2,1], Li Hsieh[2,1], Richard Young[2,4]; [1]Wayne State University, Communication Sciences and Disorders, [2]Wayne State University, Institute of Cognitive and Applied Neuroscience, [3]Wayne State University, Psychology, [4]Wayne State University, School of Medicine, Psychiatry and Behavioral Neurosciences* – How does the complexity of a conversation affect driving performance? Previous work (Hsieh et al., 2008; Bowyer et al., 2008) has revealed that small, reliable effects of conversation on driving performance can be observed using simulators, but data concerning the kind of conversation - and the specific effects on driving performance it may have - has been lacking. We addressed this research gap in a series of studies designed to measure driving performance while engaged in a secondary conversation task. In the first study, we looked at simulator responses to visual events during a live conversation task. The cognitive complexity of the conversation was manipulated to reflect two naturalistic levels of speech complexity. In addition to measuring behavioral measures of driving performance, such as reaction times to visual stimuli and lane maintenance, we also measured ERPs and subjective workload estimates. In the second study, we took the task on-road to evaluate the effects of live speech, and its varying levels of complexity, in a real-world driving task. Here, we also measured driving performance (in terms of visual event reaction times and lane maintenance), ERPs, and subjective workload estimates. These studies reveal a pattern of the subtle ways in which different conversation demands can interact with the network of cognitive processes that underlie proficient driving performance.

C88

PAYING ATTENTION WHEN IT COUNTS: THE EFFECT OF MOTIVATION ON FMRI ACTIVITY DURING ATTENTIONAL CONTROL *Tracy L. Luks[1], Ashley Kopec[2], Corby L. Dale[1], Gregory V. Simpson[1], Anthony Kaveh[3]; [1]University of California, San Francisco, [2]Carroll University, [3]University of California, Berkeley* – Attentional control is the goal-driven allocation of attention to task-appropriate stimuli and responses, and away from distractions. Motivation is the ability to anticipate and appreciate the consequences of behavior, such as rewards or punishments. We examined interactions between neurobiological systems underlying motivation and attentional control using a Rewarded Counting Stoop task during an fMRI scan. Subjects made a button press response indicating the number of lines of text presented. The content of the text could be neutral, number words congruent with the number of lines of text, or number words incongruent with the number of lines of text. Subjects were notified at each block start that performance would (Reward Condition) or would not (No Reward Condition) be rewarded (25 cents per correct response within 500msec, indicated at the end of each Reward block). Relative to the No Reward condition, Stroop task performance in the Reward condition was associated with greater activation of striatum, thalamus, insula, orbitofrontal cortex, right dorsolateral prefrontal cortex and the intraparietal sulcus area. During Incongruent trials, greater activity occurred in anterior cingulate cortex and orbitofrontal cortex in the Reward than the No Reward condition. During Congruent trials, there was greater activity in the pre-supplementary motor area in the Reward than the No Reward condition. These results suggest that motivation modulates attentional control via increased activity in orbitofrontal and anterior cingulate cortex, as well as increasing arousal and sustained attention by increasing activity in thalamus and right dorsolateral prefrontal cortex.

C89

EFFECTS OF EMOTIONAL SPEECH TONE OF CELL PHONE CONVERSATIONS ON DRIVING: ERP LAB AND ON-ROAD DRIVING STUDIES *Li Hsieh[1,2], Sean Seaman[1,2,3], Richard A. Young[1,4]; [1]Wayne State University, Institute of Cognitive and Applied Neuroscience, [2]Wayne State University, Communication Sciences and Disorders, [3]Wayne State University, Psychology, [4]Wayne State University, School of Medicine, Psychiatry and Behavioral Neurosciences* – We present an investigation into multitasking, using an ecologically valid task: a simulation of driving while conversing on a hands-free cellular phone. Specifically, we look at what factors influence multitasking performance; in this case, we investigated emotional prosody. Recent investigations into the visual processing of emotional stimuli are suggestive of overall enhanced processing of visual information in emotionally-salient contexts. Because the majority of investigations into the effects of phone conversation on driving performance have used emotionally neutral conversation contexts, they may be lacking ecologically validity and wrongly assessing the impact of speech on performance. We used behavioral, ERP and other measures to assess performance and physiological differences between two types of multitasking situations. We employed a validated event-detection paradigm with lane-tracking to measure driving performance. Participants viewed a video recording of a driving scene while using a foot pedal to respond to visual events occurring in the periphery of the display. Lane-tracking was employed to ensure participants were engaged with the video recording. RTs to visual events were recorded, and ERPs were averaged on these events. Behavioral analyses showed the expected pattern of events occurring during simulated conversations being associated with slightly longer RTs. However, this effect was moderated by the emotional tone of the conversation; events occurring during angry conversations were responded to significantly faster than events occurring during neutral conversations, and were only marginally slower than events occurring in absence of conversation. ERP analysis confirms this distinction between events occurring during angry and neutral events.

C91

RESPONSE INHIBITION AND THE INFERIOR FRONTAL GYRUS: ARE THERE TASK DIFFERENCES IN LATERALIZATION? *Diane Swick[1,2], Victoria Ashley[1], And Turken[1]; [1]VA Northern California Health Care System, [2]University of California, Davis* – An influential theory holds that motor response inhibition is strongly lateralized to the right prefrontal cortex (PFC), based on evidence from neuroimaging and neuropsychology (Aron et al., 2004). The human lesion evidence is based entirely on results from the Stop-Signal RT task, where patients with lesions in right IFG, but not left IFG, were impaired in SSRT. However, we recently reported that 12 patients with focal damage in left IFG and insula showed response inhibition deficits in the Go/NoGo task, particularly when responses were more prepotent (90% vs. 50% Go probability; Swick et al., 2008). This raises the possibility that the two tasks might be tapping different elements of response inhibition. Here, we present new data from patients with R PFC lesions in GNG. Three of the four had increased numbers of missed Go trials, suggesting a deficit in sustained attention rather than response inhibition. This pattern was exaggerated in the patient with the most extensive RIFG damage. This patient also had increased NoGo errors in the 50/50 condition but not the 90/10 condition, which does not suggest impairment in response inhibition alone. We also conducted separate meta-analyses of neuroimaging results from GNG (620 foci) and SSRT (130 foci) using the Activation Likelihood Estimation method (Laird et al., 2005). Activations in SSRT were actually more bilaterally represented in PFC and insula than in GNG. Combined, these results demonstrate the importance of obtaining behavioral data from both GNG and SSRT in the same groups of patients and the same fMRI experiments.

C92

LOAD EFFECTS ON ENCODING, MAINTENANCE, AND RETRIEVAL PROCESSES IN YOUNGER AND OLDER ADULTS *Brian Gordon[1,2], Carrie Brumback[3], Gabriele Gratton[1,2], Monica Fabiani[1,2]; [1]University of Illinois Urbana-Champaign, [2]Beckman Institute, [3]University of California Irvine* – Neuroimaging research indicates that tasks utilizing working memory (WM) draw upon a complex cortical network including sensory areas and several regions of frontal and parietal cortex. These regions are involved in different elements of task performance including information encoding, maintenance, and retrieval. Most neuroimaging methods are limited to attaining either high spatial resolution or high temporal resolution. Here we use a brain imaging method with high spatial and temporal resolution, the event-related optical signal (EROS), to measure brain activation during each of these phases in a highly-practiced, fast-paced memory search task. Experimental manipulations included load (2-6 items) and age (young: 18-30; old: 65-85). By incorporating both spatial and temporal information, it was possible to locate areas in prefrontal cortex that show sustained activity during the maintenance interval dissociated from areas in anterior parietal, occipital and prefrontal cortex that show responses during encoding then again during retrieval. The activity was graded both in both latency and amplitude during encoding, and amplitude alone during maintenance and retrieval phases. The older adults showed a more widespread and bilateral pattern of activity than younger adults. The data support the idea that a network of dorsal fronto-parietal structures is involved in maintaining information in WM (Corbetta & Shulman, 2002).

C93

INTERACTIONS BETWEEN TOP-DOWN COGNITIVE CONTROL AND BOTTOM-UP MNEMONIC EVIDENCE IN PRIMING AND DECISION-MAKING *Elizabeth Race[1], Gwen Lawson[2], Anthony Wagner[1,2]; [1]Stanford University, Neurosciences Program, [2]Stanford University, Psychology* – Multiple levels of learning from past experience can have dissociable neural and behavioral consequences during subsequent decision-making. Specifically, recent fMRI data (Race et al., 2008) indicate that stimulus processing is facilitated by learning at three distinct representational levels, with dissociable patterns of BOLD repetition suppression obtained for conceptual learning, stimulus-decision associative learning, and stimulus-response associative learning. While these data demonstrate that different levels of learning yield neural 'benefits' during subsequent decision-making, mnemonic information may also produce behavioral and neural 'costs' when goals change. Indeed, Race et al. reported that neural processing demands increased when a previously learned response was no longer goal-appropriate. However, this neural 'cost' was not accompanied by behavioral (RT) evidence for response-switch costs, raising the possibility that response-switch costs may be offset by stimulus-level facilitation. To investigate this possibility, the current study manipulated top-down preparatory control (cue-to-stimulus interval, CSI), providing a means of temporally separating the influences of learning at distinct levels of representation. Behavioral priming (RT facilitation) due to stimulus-decision learning was observed at both short (300ms) and long (1100ms) CSIs, as was priming due to stimulus-response learning when current responses were congruent with the previously learned response. By contrast, incongruent responses produced an RT cost after short CSI, whereas there was no evidence for stimulus-level facilitation nor response conflict after long CSI. Collectively, these results suggest that retrieval of learned stimulus-response associations occurs rapidly, but that increased top-down preparatory control can reduce the influence of stimulus-response mnemonic conflict to enable faster, task-appropriate responding.

C94

INVESTIGATING THE UNDERLYING COGNITIVE PROCESSES OF THE N-BACK TASK: A REGRESSION STUDY *Martin Buschkuehl[1], Susanne Jaeggi[1], Marc Berman[1], Kirti Thummala[1], Courtney Behnke[1], John Jonides[1]; [1]University of Michigan, Psychology* – Recently, we were able to show that a 4-week long training intervention with a dual n-back task leads to improvements in fluid intelligence. Although the n-back task is widely used, especially in studies involving functional brain imaging, surprisingly little is known about the cognitive processes that are involved in this task. Although many researchers have hypothesized the processes required to successfully perform an n-back task, there are few studies that have examined these hypotheses operationally. Furthermore, there are no published studies that have investigated the processes engaged by the dual n-back task that we used to show training effects on fluid intelligence. Consequently, we have little knowledge about the processes underlying dual n-back training which eventually promote transfer to fluid intelligence. In this study, we used multiple hierarchical regression analyses to account for n-back performance with tasks representing different constructs such as working memory capacity, interference resolution, task switching, processing speed, and fluid intelligence. Our results show that dual n-back task performance is best predicted by fluid intelligence and processing speed providing further evidence for the close relationship between fluid intelligence and n-back performance. Our data shed light on the nature of the observed transfer effects that we obtained previously.

C95

GLUTAMATE AND GLUTAMINE, NOT WHITE MATTER INTEGRITY, UNDERLIE THE ANTERIOR CINGULATE'S ROLE IN EXECUTIVE FUNCTION *David Ruhl[1,2,3], Charles Gasparovic[1,4], Arvind Caprihan[1], Mollie Monnig[3], Paul Mullins[1,5], Jessica Pommy[3], David Hampton[3], Per Lysne[3], Robert Thoma[1,2]; [1]Mind Research Network, [2]University of New Mexico, Psychiatry, [3]University of New Mexico, Psychology, [4]University of New Mexico, Neurology, [5]University of Bangor, School of Psychology* – Functional neuroimaging studies have implicated the anterior cingulate (AC) in executive functioning, but the mechanisms by which this is supposed to occur remain unclear. To investigate this issue, several measures of AC structure and function were assessed with respect to neuropsychological test scores. Neuropsychological measures, high-resolution structural, diffusion-tensor imaging, and single-voxel MR spectroscopy (MRS) data of the anterior cingulate were collected in thirteen healthy individuals. Gray matter thickness (GM) and fractional anisotropy (FA; a measure of white matter integrity) in bilateral cingulate gyri tracts were computed. GM and FA values for the area within the spectroscopy voxel (GMv & FAv) were also derived to facilitate intermodal comparisons. Glx, a composite measure of glutamate and glutamine, was quantified from MRS data. Linear regression revealed a significant negative relationship between Glx and an executive function score derived from the Trail Making Test (TMT A-B), such that higher Glx levels were associated with better executive performance (adj R-square = .63). Neither age, nor Full Scale IQ moderated this relationship. FAv and GMv were also entered into the regression, but did not account for significant additional variance in TMT B-A. No other MRS-derived metabolite concentrations were predictive of executive function. Collectively, these results suggest that it is specifically glutamate and glutamine content, and not gray or white matter structure that mediate the cingulate's contribution to executive functioning.

C96

THE NEURO-ECONOMICS OF AGING IN POLITICAL PREDICTION *Kanchna Ramchandran[1], Dhananjay Nayakankuppam[2], Joyce Berg[2], Eric Axelson[3], Daniel Tranel[1], Antoine Bechara[4], Natalie Denburg[1]; [1]University of Iowa, Neurology, [2]Tippie College of Business, University of Iowa, [3]University of Iowa, Psychiatry, [4]University of Southern California, Psychology* – As America ages, its elderly have a strong voice in political prediction polls and in political outcomes. Deficits in predic-

tion among older adults would affect how they engage and influence politics. Older adults (90% male; M=74.0 years, SD=5.6) were asked to predict the winners of the Presidential primary elections in a repeated measures (Jan, Feb, March, and April 2008) experiment involving the Iowa Electronics Market (IEM). Participants traded shares (amongst themselves) of candidates in the primaries race as if they were market stocks. During the nominee race, their task was to weigh candidates' ability to win the nomination and assign share price. Their performance was compared against the simultaneous, primary election market administered by the IEM, involving approximately 1000 younger, experienced traders (90% male; M=45.8 years, SD=14.4.) Of the older adult sample, approximately 50% had been characterized as poor and 50% as strong decision-makers. Brain MRI volumetric data was available on a subset of the older adult sample. Data revealed that the older adult, strong, decision-makers were comparable to the younger traders in accurately predicting the winning nominees and their share prices. Both samples outperformed the older adult poor decision-makers. Prediction accuracy and rate of updating information were predicted by caudate (p = .02) and putamen (p = .0002) volumes respectively, in older adults. We conclude that a subset of older adults may suffer from prediction deficits that correlate with striatal volume. These findings imply deficits in how older adults may pick political candidates and invest in stock markets.

C97

EXAMINING THE NEURAL EFFECTS OF CONFLICT ADAPTATION DURING WORKING MEMORY *Amishi Jha[1], Pauline Baniqued[1], Ling Wong[1], Kartik Sreenivasan; [1]Center for Cognitive Neuroscience, University of Pennsylvania* – Distracting information can cause conflict at many levels along the information processing stream. Increases in cognitive control following conflict typically lead to decreases in the subsequent behavioral costs of conflict. This "conflict adaptation" effect is thought to be subserved by anterior cingulate cortex (ACC) activity on high conflict trials which signals the need for increased cognitive control. Conflict adaptation has been investigated in paradigms (e.g., Stroop and flanker) in which the need for cognitive control is punctate. In the current study, we investigated if conflict adaptation would occur when conflict occurred at the representational level and the need for cognitive control was sustained. Participants (n = 26) performed a working memory delayed-recognition task during fMRI recording. Representational conflict was manipulated by presenting distracting items during the delay that shared many or few perceptual features with the memory items (high conflict [HC] and low conflict [LC] trials, respectively). Accuracy increased following HC relative to LC trials. Random-effects fMRI analysis revealed a compatible pattern in the ACC; activity was greater following HC trials than following LC trials. Additionally, we investigated the magnitude of the conflict effect (LC accuracy - HC accuracy) and found reduced conflict effects following HC trials. This corresponded to larger neural control effects following HC trials in the inferior frontal gyrus, previously shown to be preferentially activated by HC trials. Our results demonstrate relatively long-lasting conflict adaptation effects in the context of working memory, and suggest a common neural profile for the sequential recruitment of control across tasks.

C98

DISSOCIATING CONTROL OVER TASK SET VERSUS CONTROL OVER SPEED-ACCURACY EMPHASIS IN PREFRONTAL CORTEX *Vincent Van Veen[1], Sheila Loharuka[1], Mark DEsposito[1]; [1]University of California, Berkeley* – People are able to control whether they place emphasis on speed during task performance, or accuracy. Modulation of this speed-accuracy tradeoff (SAT) is thought to be obtained by the modulation of baseline activity in decision-related brain regions; speed emphasis is associated with an increase in baseline activity, such that less neural "evidence" is needed to reach the decision threshold during speed emphasis. In this study, we compared the control of SAT to the control over task set. In a 4T MRI scanner, participants performed a Simon task, in which a red or green square was presented to the left or right of fixation. Prior to each Simon stimulus, a cue was presented instructing the participants to emphasize speed or accuracy, and whether to respond to the color or location of each Simon stimulus with a left or right hand button press. Preparing to make a response based on location is more automatic than making a response based on color; therefore, making a response based on color requires more task control. Thus, task set and SAT were independently modulated. We replicated our previous results concerning SAT (e.g., Van Veen et al., 2008); speed emphasis, compared to accuracy emphasis, was associated with increased baseline activity and reduced transient response-related activation, in SMA, premotor and parietal cortices, while SAT control was associated with left prefrontal activation. In contrast, control over task set was associated with right prefrontal activation. Thus, different prefrontal regions are required for these different types of control.

C99

INTERNAL PERFORMANCE MONITORING INTERACTS WITH EXTERNAL SITUATION *Shun Itagaki[1], Kazuo Hiraki[1]; [1]The University of Tokyo* – External information provides us clues in understanding social and emotional situations, as exemplified by when we understand others' emotion by their facial expressions. Additionally, internal processing such as performance-monitoring is essential for one to adapt to the environment. It has been unknown how they interact with each other, independently of incentive effects. To investigate this issue, we evaluated event-related potential (ERP) components called error-related negativity (ERN), which is elicited by error responses in choice response task such as the flanker task and thought to reflect performance-monitoring that derives from the anterior cingulate cortex activities. Participants (N=13) performed face flanker task constructed by central target and flanker distracters. Stimuli were either Angry and Neutral faces (AN condition) or Smile and Neutral faces (SN condition). The results of ERPs time-locked to choice responses showed a clear ERN for error responses, regardless of stimulus congruency. We found that the ERN was more sensitive to the error responses in the presence of relatively positive emotional stimuli than negative ones. In AN condition, a larger ERN was elicited when the central target was neutral expressions than angry ones. On the other hand, positive expressions elicited a larger ERN than neutral ones in SN condition. These results suggest that the ERN reflects multiple monitoring functions, which are associated not only with the mismatch-detection between the goal and the actual performance, but also with the evaluation of external emotional valence. We conclude that the performance-monitoring function reflected by the ERN interacts with the external situation.

C100

EXAMINING THE LIFESPAN EFFECTS OF REPRESENTATIONAL CONFLICT DURING WORKING MEMORY *Anastasia Kiyonaga[1], Ling M. Wong[2], Amishi P. Jha[1]; [1]University of Pennsylvania, Center for Cognitive Neuroscience, [2]University of California, Davis* – It is well-established that behavioral performance following task conditions of high conflict is better than task performance following low conflict, in healthy young adults. This 'conflict adaptation' effect is subserved by anterior cingulate cortex (ACC) signaling the need for increased cognitive control to be implemented by lateral prefrontal cortex (Egner, 2007). In the current study we investigated: 1) If conflict adaptation is observed during working memory tasks when the need for cognitive control is sustained over longer intervals; 2) If the influence of conflict on subsequent cognitive control differs over the lifespan. Three groups of volunteers (adolescents (N=86), young adults (N=46), and older adults (N=44)) were recruited to perform a working memory delayed-recognition task in which conflict was manipulated. Distracting items were presented during the delay which either shared many or few perceptual features with the memory items (high conflict [HC] and low conflict [LC] trials, respectively). Consistent with previous results, overall task accuracy was highest in young adults, followed by adolescents, and lowest within older adults. Importantly, young adults demonstrated reliable conflict adapta-

tion effects, such that current trial accuracy was greater on trials preceded by HC vs. LC trials. In contrast, accuracy was worse on trials following HC vs. LC trials in adolescents and older adults. These results suggest that recruitment of cognitive control in response to conflict has a developmental trajectory that may follow the integrity of the prefrontal cortex during normal lifespan development.

Higher level cognition: Other

C101

UNDERSTANDING AND EMPATHIZING WITH DISSIMILAR OTHERS: A CASE STUDY OF A CONGENITAL AMPUTEE *Lisa Aziz-Zadeh[1], Tong Sheng[1], Lei Liew[1], Henryk Bukowski[1], Hanna Damasio[1], Antonio Damasio[1]; [1]University of Southern California* – How do individuals born without limbs understand actions performed by others with limbs they themselves have never had? In such individuals, which neural processes correlate with empathy for pain when observing pain in limbs that the congenital amputees are missing? Using fMRI we studied an individual born without arms and legs (DD), in two conditions: action observation and observation of physical pain. In the action observation condition, DD saw videos of normal individuals performing simple actions using their foot, hand, and mouth. Some actions were possible for DD, albeit with the mouth rather than the hand or foot; other actions were impossible for DD. We found that, like normal controls, DD showed activity in premotor and parietal regions for action observation of the hand, foot and mouth. However, when DD observes actions impossible for her, she additionally activates the bilateral superior frontal and bilateral cingulate regions. This may indicate that for impossible actions, regions involved in reasoning and conflict processing are also recruited. In the pain empathy condition, DD observed others receiving an injection in the mouth, upper arm and hand. In normal individuals, these stimuli usually activate components of the "pain matrix" (insula, ACC, and SI/SII). DD displays a similar pattern but with no activity in SI/SII for the hand condition, and increased activity in SI/SII for the mouth condition. This finding indicates that sensory experience is essential for activating SI/SII during pain observation. Broader implications for how we process actions and empathize with physically dissimilar others are discussed.

Poster Session D

Higher level cognition: Problem solving

D1

ROSTROLATERAL PREFRONTAL CORTEX INTEGRATES BOTH SEMANTIC AND VISUOSPATIAL RELATIONS *Carter Wendelken[1], David Chun[1], Silvia A. Bunge[1,2]; [1]Helen Wills Neuroscience Institute, UC-Berkeley, [2], UC-Berkeley, Psychology* – The ability to reason with complex relational structure is a central feature of higher-level human intelligence. Recent fMRI studies have implicated rostrolateral prefrontal cortex (RLPFC) is in a key component of this capacity: the ability to perform second-order relational processing, or relational integration (Christoff et. al. 2003, Bunge et. al 2005, Wendelken et. al. 2008). These studies, involving different tasks and different kinds of stimuli, have variously shown activation in left or right RLPFC, dorsally in some cases and more ventrally in others. We have speculated that differences in the specific locus of activation within RLPFC may be due to privileged access of some areas to information from a particular stimulus domain (Wendelken et. al. 2008). However, in its strongest form, the theory that RLPFC supports processing at the highest levels of complexity suggests that this region should be domain-neutral. We set out to test for domain generality or specificity of RLPFC activation by collecting fMRI data from subjects as they performed two versions of a relational matching task, one involving semantic relational judgments and another involving visuospatial relational judgments. Preliminary evidence (N=12) indicates that both semantic and visuospatial tasks strongly engage the same region of left RLPFC. In addition, right RLPFC is strongly activated by the integration of visuospatial relations, but only weakly activated by the integration of semantic relations. These findings support the hypothesis that RLPFC implements processing at the highest level of abstraction, far removed from the input domain.

D2

INTUITION AND INSIGHT PROBLEM SOLVING *Azurii Collier[1], Mark Jung-Beeman[1]; [1]Northwestern University* – Often when failing to solve insight problems, people report some idea of the solution or that the problem is solvable, but cannot explicitly access the idea. We investigated whether intuition would relate to overnight incubation effects and solvers' ability to make coherence judgments when working on Compound Remote Associate (CRA) problems, where they view three words and must think of another word that forms a compound word with each of the trial words (crab, sauce, pine; solution- apple). When investigating incubation, on Day 1, participants (n=48) attempted to solve 96 CRAs. For problems that were unsolved, participants reported whether they had a tip of the tongue (TOT). On Day 2, participants were given each of the problems they did not solve on Day 1, and 48 new problems. Participants were more likely to solve a new problem compared to an unsolved Day 1 problem. Interestingly, on Day 2, participants were more likely to solve old problems if they reported a TOT for those problems on Day 1. We investigated whether intuition would relate to solvers' ability to judge whether a CRA was coherent or incoherent. Participants (n=43) had 5 seconds to judge the coherence of a problem and afterwards were asked for the solution. There was a significant association between participants' judgments and the coherence of the problem. Of the unsolved problems, participants had a significantly greater percentage of hits and correct rejections than false alarms. This suggests solvers' intuition showed some sensitivity to discriminate between coherent and incoherent problems.

D3

COMPARING EVIDENCE FOR MULTIPLE HYPOTHESES RECRUITS THE LEFT MIDDLE TEMPORAL GYRUS AND THE LEFT INFERIOR FRONTAL GYRUS *Jennifer Whitman[1], Todd Woodward[2]; [1]University of British Columbia, [2]Provincial Health Services Authority* – To determine the cause of an event, one must consider multiple hypotheses and evaluate the strength of the evidence supporting each. Next, one must compare this information to determine the hypothesis most strongly supported by the available evidence. We investigated the brain regions involved in this comparison using fMRI in a probabilistic reasoning task. Each trial of this task showed one visibly empty lake and two upstream lakes filled with black fish and white fish. On each trial either a black or a white fish jumped from the otherwise empty downstream lake. This fish could have come from either the lefthand or the righthand upstream lake. On evidence evaluation trials, participants rated the strength of evidence for just one of the hypotheses (e.g. the likelihood of a black fish coming from the lefthand upstream lake). On evidence comparison trials, participants rated the likelihood of one of the potential explanations being correct rather than the alternate explanation (e.g. the likelihood that the jumping black fish came from the lefthand rather than the righthand upstream lake). Regions more active in the evidence comparison condition than in the evidence evaluation condition included the left middle temporal gyrus, which has been shown to play a role in making comparisons in word problems (i.e. taller / shorter, better / worse). We also found clusters in primary visual cortex, which may reflect elaborative visual processing of the two lakes, and the left inferior frontal gyrus, thought to be involved in selecting among competing representations.

D4

INVESTIGATION OF FUNCTIONAL CONNECTIVITY IN A VISUO-SPATIAL REASONING TASK USING GRANGER CAUSALITY *Ehsan Shokri Kojori[1], Michelle McClelland[1], Michael Motes[1], Bart Rypma[1], Daniel Krawczyk[1]; [1]Center for BrainHealth, University of Texas at Dallas* – We studied the role of cortical regions in visuo-spatial reasoning by assessing the connectivity of cortical influences using multiple measures including connection density and directionality. Participants performed a visuo-spatial reasoning task that included three complexity levels during fMRI scanning. In each trial, multiple shapes with different changing patterns were shown simultaneously to subjects. Then they were asked to judge whether or not the changes occurred in accordance with predefined rules. The complexity level was manipulated by increasing or decreasing the number of shapes that changed together. Response time and accuracy were used as discriminators between subjects. The fMRI data analysis demonstrated strong activation peaks in right anterior prefrontal cortex, motor cortex, and left and right parietal cortices. Since the exact location of peaks differs across subjects, ROI analyses were performed for each individual subject. Using average response times, subjects were grouped into fast and slow performers. The time series associated with peaks of activations were extracted for further connectivity investigations. Granger causality analysis (Roebroeck et al., 2005 & Seth, 2005) was used to identify the connectivity pattern for the defined ROI sets. Results indicated that faster performers showed greater prefrontal connectivity to posterior cortical regions compared to slow performers. These findings will be contrasted to other studies (Rypma, 2006) that have found greater PFC connectivity to posterior cortical regions in slower performers.

D5

WHITE MATTER CONTRIBUTIONS TO BROAD COGNITIVE DYSFUNCTION IN SCHIZOPHRENIA *Rex Jung[1,2,3,4], Robert Chavez[1], Arvind Caprihan[1], Jeremy Bockholt[1]; [1]Mind Research Network, [2]University of New Mexico, Neurosurgery, [3]University of New Mexico, Psychology, [4]University of New Mexico, Neurology* – Schizophrenia (Sz) is a heterogeneous brain disorder characterized by broad cognitive decline. While numerous studies have established white matter abnormalities in Sz (Kubicki et al., 2005), none have specifically linked broad cognitive decline to specific white matter pathology. Based upon our previous work linking intellectual functioning to integrity of the parieto-frontal network (Jung & Haier, 2007), we hypothesized that white matter connections underlying this network would predict broad cognitive functioning in schizophrenia. The sample consisted of twenty-four first episode and chronic Sz patients scanned at 1.5 Tesla. Patients underwent a broad neuropsychological battery from which the first unrotated principal component g was obtained (Jensen, 1998). Diffusion Tensor Imaging data was processed using Tract-Based Spatial Statistics (Smith, et al. 2006) from which each subject's FA image was registered to a group skeletonized FA image. Major white matter tracts measured included bilateral uncinate, superior longitudinal, cingulum, inferior longitudinal, anterior thalamic radiation, forceps major/minor, corticospinal, and inferior fronto-occipital. Applying a white matter atlas to obtain regions of interest, FA values were average across each voxel within each subject's particular fiber tract to calculate the mean FA of that tract. When we regressed all tracts against g, we found that higher average FA in the right superior longitudinal fasciculus, linking the parietal and frontal lobes, was associated with higher g across patients diagnosed with schizophrenia [$F = 9.45$, $p = .006$; $r2 = .31$]. To our knowledge, this is the first report linking white matter integrity to broad cognitive functioning in schizophrenia.

Higher level cognition: Other

D6

SELF-CONTROL INVOLVES TOP-DOWN MODULATION OF THE BRAIN'S COMMON VALUE SYSTEM *Todd Hare[1], Colin Camerer[1], Antonio Rangel[1]; [1]California Institute of Technology* – Self-control problems in value-based decision-making are at the core of a large number of social and public policy problems, and play an important role in diseases and public health concerns such as addiction and obesity. Despite decades of research, we still lack answers to many basic questions regarding self-control and decision-making. To address these questions, we used fMRI to examine the neural correlates of self-control during a 'real life' decision-making task. We recruited individuals who were dieting to lose weight and non-dieting controls and had them decide whether or not to eat healthy and unhealthy food items. We show that ventral medial prefrontal cortex (vmPFC) activity correlated with value computations during decision-making. Furthermore, in dieting subjects who exercised self-control, vmPFC activity also correlated with the separate taste and health aspects of a food item consistent with the idea of a common valuation system in goal-directed choice. When subjects used self-control, activity in dorsolateral prefrontal cortex (DLPFC) increased and this increased activity correlated with changes in vmPFC activity. An analysis of psychophysiological interactions suggested that DLPFC might modulate activity in vmPFC and influence value computations during the exertion of self-control in decision-making.

D7

SEX DIFFERENCES IN REAL-LIFE SPATIAL COGNITION *Claudia Wolf[1,2], Sebastian Ocklenburg[1], Beyza Oeren[1], Andrea Hofstaetter[3], Christa Boes[3], Markus Popken[4], Truls Thorstensen[3], Onur Guentuerkuen[1]; [1]Institute of Cognitive Neuroscience, Biopsychology, Ruhr-University Bochum, Germany, [2]Faculty of Life Sciences, Neurobiology and Biology of Cognition, University of Vienna, Austria, [3]EFS Unternehmensberatung GmbH, Vienna, Austria, [4]Audi AG, Ingolstadt, Germany* – Sex differences in cognitive abilities have been investigated in numerous psychological studies. Whereas women outperform men in certain verbal tasks, men tend to be superior in some tests for spatial cognition. Most stable differences in favour of men are found in the Mental Rotations Test, a paper-and-pencil test requiring the comparison of highly abstract 3-dimensional figures. However, the ecological validity of results obtained in such artificial and controlled experimental procedures has been questioned. To obtain a more ecologically valid measure of spatial cognition, we investigated parking, a complex real-life situation. Participants parking speed and accuracy were recorded during three different parking manoeuvres: forward and backward bay as well as parallel parking. In addition, participants were tested in the Mental Rotations Test and asked to self-assess their parking skills. We found that men outperform women in parking accuracy by about 2.1%. Sex differences in parking speed were much more marked: On average, men parked about 35% faster than women. This difference, however, is not necessarily an indicator for women's inferior parking skills. It may also reflect greater cautiousness while parking. Performance is related to mental rotation skills in driving beginners and self-assessment in more experienced drivers. We assume that this shift in related variables is due to training and feedback effects. Taken together, our findings show that the Mental Rotations Test possesses some ecological validity. However, real-life spatial cognition is a much more complex process that is also influenced by other factors.

D8

DURATION MATTERS: DISSOCIATING NEURAL CORRELATES OF DETECTION AND EVALUATION OF SOCIAL GAZE *Bojana Kuzmanovic[1], Alexandra Georgescu[1], Simon Eickhoff[2,3], Nadim Shah[2,4], Gary Bente[5], Gereon Fink[2,4,6], Kai Vogeley[1,4]; [1]University Hospital Cologne, Psychiatry/Psychotherapy, [2]Institute of Neurosciences Medicine (INB3), Research Center Juelich, [3]University Hospital Aachen, Psychiatry, Psychotherapy, [4]Brain Imaging Center West, Research Center Juelich, [5]University of Cologne, Psychology, [6]University Hospital, Neurology, Cologne* – As a salient nonverbal signal for social interest and the intention to communicate, direct gaze indicate mental states of significant others. Despite of this assumed relation to higher-order cognitive processes, no consistent evidence as indexed by the recruitment of medial prefrontal neural regions is existent so far. The present functional magnetic resonance imaging (fMRI) study tries to clear up this discrepancy by considering additionally to the direction also the duration of gaze behavior. Direct gaze displayed by virtual characters was, firstly, compared with averted gaze and, secondly, systematically varied with respect to gaze duration (i.e., 1, 2.5 or 4 seconds). Consistent with prior findings, behavioural data showed that likeability was higher for direct than for averted gaze and correlated positively with gaze duration. On the neural level, distinct brain regions were associated with the processing of gaze direction and gaze duration: (i) the comparison between direct and averted gaze revealed activations in bilateral occipito-temporal regions including the posterior superior temporal sulcus (pSTS), (ii) whereas increasing direct gaze duration evoked differential neural responses in the medial prefrontal cortex (MPFC) including orbitofrontal and paracingulate regions. The results suggest two complementary cognitive processes related to different gaze parameters. On the one hand, the recruitment of multimodal sensory regions in the pSTS indicates detection of gaze direction via complex visual analysis. On the other hand, the involvement of the MPFC associated with outcome monitoring and mentalizing indicates higher-order social cognitive processes related to evaluation of the ongoing communicational input conveyed by direct gaze duration.

D9

EVENT-RELATED POTENTIALS OF EMOTIONAL PICTURES *Alana Campbell[1], Deana Davalos[1]; [1]Colorado State University* – The negativity bias is a robust response in which people value negative components of information more than positive. The negativity bias appears in

both behavioral and electrophysiological research and affects a number of cognitive processes including decision making and value judgments. The current study uses event-related potential (ERP) to investigate if this bias can be manipulated and diminished using framing in younger adults. Participants' brainwaves are recorded in response to positive, neutral and negative images. Participants are split into two conditions; the positive condition must respond if the image viewed is positive or not while the negative are asked if the image is negative are not. Comparisons between the groups are made based on changes in amplitude and latency of the late positive potential wave for the three types of images. Preliminary results suggest that framing may significantly alter the amplitude of ERPs.

D10

MODULATION OF MOTOR AREA ACTIVITY DURING OBSERVATION OF COMPETITIVE GAMES *Sotaro Shimada[1], Ryosuke Abe[1]; [1]Meiji University* – Observing competitive games, such as sports, is a pervasive entertainment for humans. It is reasonable to consider that this inclination to watch others play is based on our social cognitive ability to understand the internal states of others. The mirror neuron system, which is activated when a subject observes the actions of others, as well as when they perform the same action themselves, seems to play a crucial role in this process. However, how the mirror system responds during the observation of competitive games has not yet been fully investigated. In the present study, we measured the activity of motor areas using near-infrared spectroscopy (NIRS) when a subject watched short movie clips in which two models played a simple competitive game with physical gestures (rock-paper-scissors game). Motor areas were significantly activated when the subject observed the movie, as well as when they performed the same action. Interestingly, the activity in the motor areas was significantly greater when the player concordant with the subject's viewpoint won against the opponent, compared with when the player lost ($P<0.01$) or the game ended in a draw ($P<0.05$). This result indicates that mirror system activity is modulated by the outcome of the game, a higher-level evaluation of an action. We suggest that the observer is likely to share the winner's internal motor representation, but not that of the loser.

D11

THE ANTERIOR CINGULATE CORTEX CODES A NEGATIVE REWARD PREDICTION ERROR IN ACTIVE BUT NOT OBSERVATIONAL FEEDBACK-BASED LEARNING *Christian Bellebaum[1], Stefan Thiele[1], Irene Daum[1]; [1]Institute of Cognitive Neuroscience, Ruhr-University Bochum, Germany* – Performance feedback in learning tasks is accompanied by a negative event-related potentials component, the so-called feedback-related negativity (FRN), which is generated in the anterior cingulate cortex (ACC). According to a recent theory, the FRN codes a prediction error, providing a learning signal to guide action selection and optimize future behaviour. The present study aimed to determine, if the neural processing of monetary feedback stimuli for active learning differs from monetary feedback processing in observational learning. Two groups of 15 subjects matched for age and IQ participated in this study. Subjects of the first group performed an active feedback learning task in which a rule could be learned to maximize reward. Each participant of the second group observed the performance of one active subject. Observers were first required to learn the reward-determining rule based on the observed reactions and feedback stimuli to later implement it in blocks of test trials. As expected, FRN amplitude appeared to reflect a negative prediction error in active learners, being significantly enhanced in response to unexpected negative compared to positive feedback. In observers, no significant difference between the valence conditions was found. As revealed by their choice behaviour in active learning and test trials, respectively, the groups did not differ with respect to the level of insight into reward contingencies. These findings suggest that active and observational feedback learning are based on dissociable neural mechanisms, with the ACC receiving a feedback-locked learning signal from the basal ganglia for active choice behaviour only.

D12

THE ROLE OF THE NORADRENERGIC SYSTEM IN THE TRADE-OFF BETWEEN EXPLOITATION AND EXPLORATION: EVIDENCE FROM PUPILLOMETRY *Marieke Jepma[1,2], Sander Nieuwenhuis[1,2]; [1]Leiden University Institute for Psychological Research, [2]Leiden Institute for Brain and Cognition* – Recent studies have suggested an important role for the locus coeruleus-norepinephrine (LC-NE) system in regulating the trade-off between exploitative and exploratory behavioral strategies. The evidence for this theoretical progress is largely based on cell recordings in nonhuman primates. In order to further develop theories about LC-NE function, it is important to investigate the role of the LC-NE system in human cognition. It has recently been shown that pupil diameter is a reliable marker of LC activity in humans, reflecting both its tonic and phasic character. We measured participants' pupil diameter while they performed a gambling task with a gradually changing pay-off structure (Daw et al., 2006). Each choice in this task can be classified as exploitative or exploratory, by means of a computational model of reinforcement learning. Recent theories of the role of the noradrenergic system in the regulation of behavioral strategy would predict that exploratory choices are preceded by a larger baseline pupil diameter than exploitative choices. Our results are consistent with this prediction. Interestingly, part of the baseline pupil effect already developed during the preceding trial, which suggests that changes in the tendency to explore or exploit develop gradually. Together, our findings provide evidence for the idea that the LC-NE system mediates behavioral strategy (exploitation versus exploration), and reinforce the notion that pupillometry is a promising method for investigating the role of the noradrenergic system in human cognition.

D13

HUMAN BRAIN CODES THE PROBABILITY OF ACTIONS *Roger D. Newman-Norlund[1], Kim Bruggink[1], Raymond H. Cuijpers[2], Harold Bekkering[1]; [1]Donders Institute for Brain, Cognition and Behavior, [2]Eindhoven University of Technology* – The capacity to make informed decisions in ambiguous situations is critical to human survival. Computational neuroscientists often use probabilistic equations (Empirical Bayes) to model and predict human behavior in such situations. The questions of how, where, and even if such probabilities are represented in the human brain remain largely unexplored. Two possible candidates for the neural implementation of probability coding are the human mirror neuron system (MNS), hypothesized to play a key role in action understanding, and the theory of mind (ToM) network, which is believed to be involved in the understanding of intentions. Here, we manipulated the probability of a simple bottle pouring action along two dimensions, the relative fullness of two wine glasses (here we assumed that pouring into a relatively less full glass would be most probable) and the relative distance between the bottle and the glasses (here we assumed that the combination of spatially proximate objects would be more probable than the combination of spatially distant objects). Participants underwent whole-brain fMRI while viewing pouring actions of varying probability. Observation of improbable actions elicited relative increases in BOLD signal at core sites in the theory of mind (ToM) network including the mSTS and MFC. Observation of probable actions was associated with relative increases at sites in the left SMG, the precuneus and the visual cortex. These data are consistent with claims that the human brain distinguishes between high and low probability actions and provide novel support for computational models which assume this capability.

D14

NO EVIDENCE OF MIRRORING IN THE HUMAN 'MIRROR SYSTEM' *Eunji Huh[1], Susan Jones[1], Karin James[1]; [1]Indiana University, Psychological and Brain Sciences, Bloomington* – This study examines the response properties of the putative 'mirror system' in human adults in 2 conditions comparable to those in which mirror neurons were originally

identified in the cortex of the rhesus macaque. We hypothesized that if the human mirror system was actually the homologue of the mirror neurons found in the macaque, then one should observe similar activation patterns in the same 2 conditions: 1) performing specific actions; and 2) watching another individual performing the same actions. Previous studies have found activation of 5 brain regions both when subjects imitate and when they are imitated, but no previous studies have looked for mirroring properties in the absence of imitation. To this end, we compared neural activation, using fMRI, during performance and observation of the same actions. We also recorded activation while subjects were imitating and being imitated, to confirm that our task recruited the cortical areas previously identified as the mirror system. During both imitation conditions ,the classic human mirror system was active. However, during performance and observation of the same action, neural activation overlapped in only one (superior temporal sulcus) of the five brain regions of the 'mirror system'. These results demonstrate that the human mirror system does not display the same mirroring properties in the same tasks as monkey mirror neurons. The findings suggest that imitation, which does activate the human mirror system, is therefore not produced by a population of mirror neurons like those identified in the cortex of the rhesus macaque.

D15

A NEUROCOMPUTATIONAL MODEL OF AUTOMATICITY IN RULE-GUIDED BEHAVIOR *Sebastien Helie[1], F. Gregory Ashby[1]; [1]University of California, Laboratory for Computational Cognitive Neuroscience, Psychology, Santa Barbara* – Rule-guided behavior is essential in quickly adapting to one's ever-changing environment. In particular, learned rules can quickly be used in new contexts or applied to new stimuli (which confers an advantage over restricting behavior to associations). Here, we propose a new neurocomputational model of automaticity in rule-guided behavior. The proposed model assumes two parallel neural pathways corresponding to naïve and automatic rule use. In the longer pathway, stimuli activate object representations in the inferotemporal cortex, which in turn activates categorical object representations in the prefrontal cortex (PFC). PFC object representations then activate response units in the premotor cortex (PMC), while PFC rule units inhibit inappropriate PMC response units. In a second shorter pathway, visual areas of parietal cortex project directly to the PMC response units. Plasticity at parietal-PMC synapses is mediated by Hebbian learning. During training, the longer pathway through the PFC is used to strengthen the appropriate parietal-PMC synapses. The development of automaticity is characterized by a transfer of control of rule-guided behavior from the PFC mediated pathway to the direct parietal-PMC pathway. The model includes differential equations that describe voltage changes in the relevant brain areas and difference equations that describe the Hebbian learning. A variety of simulations are described, showing that the model accounts for some critical single-cell recording data from several key brain areas as well as some important behavioral results.

D16

DAMAGE TO THE HUMAN HOMOLOGUE OF V6A IMPAIRS POINTING IN PERIPERSONAL BUT NOT PERSONAL SPACE *Lana Goldberg[1], Carol Broderick[1], James Danckert; [1]University of Waterloo* – We examined pointing movement in near space in a patient with optic ataxia resulting from right superior parietal damage encompassing the human homologue of macaque area V6A. In an earlier study, the patient demonstrated deficits in pointing along the sagittal plane. More specifically, higher deceleration times and longer 'dwell times' (i.e., a period of time in which the hand rests on a target before commencing the next movement in a sequence) were found for movements made with either hand back toward the body. Here we examined movements made back toward the body to a variety of targets in either peripersonal space (near the patient's body midline) or personal space (three targets on the patient's body; chest, lips and nose). Participants first made a pointing movement to a target away from the body and then pointed to one of the four possible target locations (i.e., three proprioceptive and one visual target). Examination of dwell time for movements made to the first target (i.e., prior to initiating the movement back towards peripersonal or personal space) provided an index of movement difficulty. The patient demonstrated longer dwell times for the visually specified target when contrasted with the proprioceptively specified targets suggesting more time spent planning movements to be made in peripersonal space. In addition, dwell time decreased as the degree of specificity for the proprioceptive targets increased. These results suggest that damage to the human homologue of V6A impairs visually guided movements more so than movements made towards a proprioceptively specified target.

D17

CONSCIOUS OF CONFLICT BUT NOT OF THE ELICITING STIMULUS: IMPLICATIONS FOR THE NEUROSCIENCE OF COGNITIVE CONTROL *Taylor Rigby[1], Tim Gerrits[1], Travis Riddle[1], Christopher Berger[1], Ezequiel Morsella[1,2]; [1]San Francisco State University, Psychology, [2]University of California San Francisco, Neurology* – Recent developments in neuroscience (e.g., Pessiglione et al. 2008, Neuron, 2008) suggest that one can be aware of urges and other metacognitions while being unaware of the stimuli provoking these states (cf., Morsella 2005, Psychological Review). Yet, it has never been demonstrated that one can experience conscious conflict from a subliminal stimulus. To investigate this, we used a version of the subliminal Stroop color-naming task (Tzelgov et al. 1997, AJP) and found that, replicating previous studies, the Stroop response-time effect fails to occur for masked stimuli (17 msec word exposure, pre-mask). However, building on prior research on neural processing of subliminal stimuli, we found that when participants ($n = 33$) were faced with subliminal stimuli, they were still able to report conflict-related urges as a function of Stroop condition, $F(3, 96) = 3.538$, $p = .0176$: Stronger urges to err were reported for incongruent stimuli than for any other kind of stimuli (congruent, neutral, and control), $ps < .05$. In addition, for supraliminal Stroop stimuli, we examined whether the presence of intra-psychic conflict influences the sense of agency (e.g., when urges conflicting with the current goal of color-naming are perceived as foreign to the self), and whether the strength of the stimulus-evoked urge is inversely related to the overall number of action plans associated with that stimulusóa 'fan effect' of sorts. Together, these findings complement recent psychophysiological findings and constrain theories regarding the neuroscience of cognitive control, addiction, and the cognitive construction of the self.

D18

DOES POST-DECISION WAGERING REFLECT AN ONSET OF CONSCIOUS AWARENESS OR RISK AVERSION? *Shuo Wang[1], Naotsugu Tsuchiya[2], Ian Krajbich[2], Ralph Adolphs[2]; [1]Faculty of Science, National University of Singapore, Singapore, [2]Division of the Humanities and Social Sciences, Caltech* – In the Iowa Gambling Task, subjects start employing an optimal decision-making strategy before they can explicitly verbalize their strategy. To probe when subjects consciously notice their strategy, Persaud et al (2007) proposed a technique, called 'post-decision wagering', where subjects bet high or low depending on the confidence they have in their decision. Persaud et al showed that subjects start betting optimally many trials after they start to consistently select from the good decks, implying a period of unconscious optimal deck selection. To characterize the nature of post-decision wagering, we implemented it in several gambling tasks and compared the results with behaviorally derived measures of risk-aversion. Our goal was to determine whether subjects select cards optimally before they bet optimally 1) because they are unaware of the card-reward contingency or 2) because they are risk averse. First, we tried to replicate the Persaud et al finding. For our subject population, we could not replicate their findings. Second, we applied post-decision wagering to a different gambling task, where the card-reward contingency switches after subjects select the best card several times in a row. In this task, subjects did start betting optimally after several trials of optimal card selection. Interestingly, some subjects

continued to bet low even after they selected from the good decks 5-7 trials in a row. However, our behavioral results are unlikely to be explained by risk aversion; we found no correlation between the individual risk-aversion measures and differences in betting strategy.

D19

WHEN VISUAL KNOWLEDGE CAN MODULATE THE MOTOR CORTEX *Mirta Fiorio[1], Maria Carla Bresciani[1], Paola Cesari[1], Giampaolo Rodi[1], Mattia Gambarin[1], Antonio Fiaschi[1], Michele Tinazzi[1,2]; [1]Neurological and Vision Sciences, University of Verona, Italy, [2]Neurology Unit Borgo Trento Hospital Verona, Italy* – We aimed at unveiling any modulation of the motor system associated to the onlooker's visual, but not motor, expertise of observed actions. Two groups of subjects were recruited, with different visual expertise on a particular kind of action, i.e. a dystonic movement. Group 1 (Naïf): 8 subjects without expertise in neurological diseases and without previous exposure to the view of dystonic movements. Group 2 (Neurologists): 8 qualified neurologists working in the movement disorder divisions and dealing with dystonic patients. Single-pulse TMS was applied over the left M1 and motor evoked potentials (MEPs) were recorded from the FDI, AMD and FCR muscles, while subjects observed the following stimuli: 1) static hand; 2) healthy writing; 3) dystonic writing; 4) grasping, presented with a blocked design and with random order across subjects. Each condition consisted of 12 trials. Analysis (ANOVA) showed that naïf subjects had higher MEP amplitudes than neurologists only during observation of the dystonic writing ($p = 0.0007$). Higher activation in the FDI and FCR muscles were found in naïf subjects during observation of the dystonic compared to the healthy writing ($p < 0.0002$). Neurologists did not show different activation between the two writing conditions. Visual expertise can modulate motor cortex excitability during action observation. A future step of this study is to unveil the influence of action observation on the motor system of dystonic patients.

D20

NEURAL CORRELATES OF TAILORED MESSAGE PROCESSING: A SMOKE CESSATION CASE STUDY *Emre Demiralp[1], Hannah Faye Chua[2], Vic Strecher[2]; [1]University of Michigan, Psychology, [2]University of Michigan, School of Public Health* – Research has shown that individually tailored health programs are more successful than generic one-size-fits-all programs. That is, people are more likely to quit smoking or eat more vegetables when the message of the program is highly tailored to them. Moreover we have shown in the past that highly individually tailored messages engage rostral medial prefrontal cortex (rMPFC) and precuneus/posterior cingulate compared to low-tailored or generic smoking cessation statements. In the current study we investigate whether this differential activation for highly tailored smoking cessation messages can be operationalized in terms of self-related processing. Specifically the medial prefrontal cortex and precuneus/posterior cingulate has been implicated in processing information about the self, as well as performance of complex cognitive functions such as inferring other's mental and emotional states. In the current study, during one of the experiments smokers who are interested to quit smoking received messages with personalized feedback ('You are a 45 year old smoker'), targeted messages ('Looking better is a common reason for quitting.'), and neutral messages ('About 90 percent of people on Earth live north of the equator.'). Participants also completed a self-appraisal task. Participants judged whether an adjective describes them or not, or whether the adjective is of positive or negative valence. Our preliminary analysis of 20 subjects indicate significant overlap between tailored message processing and self related processing in rostral medial prefrontal cortex and precuneus. Further analysis will involve data from more subjects as well as connectivity, ROI, and further overlap analyses.

Higher level cognition: Numerical processing

D21

COUNT ME IN! ON THE AUTOMATICITY OF ENUMERATION PROCESSES *Sharon Naparstek[1], Avishai Henik[1]; [1]Psychology and the Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Beer-Sheva, Israel* – Enumeration processes are a basic component of mathematical abilities and are the subject of numerous studies. We have recently developed a task that gives rise to an enumeration congruity effect, enabling examination of both explicit and implicit processes of enumeration. Participants were presented with displays containing a variable number of digits and were asked to pay attention to the number of digits or to their identity in separate blocks. In two experiments we employed numerical comparison or parity judgment tasks. In the comparison task, participants were asked to report whether the number or the identity of the presented digits was larger or smaller than 5. In the parity judgment task, participants were asked to report whether the number or the identity of the presented digits was even or odd. When the number of items was relevant and identity irrelevant, there was a congruity effect regardless of task (comparison or parity judgment). In contrast, when identity was relevant and the number of items irrelevant, the congruity effect was present solely in the comparison task. These results provide further information on the representation and processing of numerosities, as well as expand our knowledge regarding the mental processes underlying enumeration.

D22

HEARING 9 ATTENDING RIGHT - INSIGHTS FROM NUMBER-FORM SYNESTHESIA *Limor Gertner[1], Avishai Henik[1]; [1]Ben-Gurion University of the Negev, Psychology and Zlotowski Center for Neuroscience, Israel* – In number-form synesthesia, numbers are experienced in spatially-defined configurations. A similar association between numbers and space appears also in the non-synesthete population in the form of a spatial mental number line. Recent researches have suggested that attending numbers may trigger shifts of spatial attention according to number magnitude. We examined this issue in 2 number-form synesthetes and a matched control group. In separate tasks, participants were presented with an auditory or a visual digit (cue) followed by an asterisk (target). Participants were asked to ignore the digit and press a key as soon as the target appeared. In both tasks, the synesthetes exhibited a validity effectóa shorter reaction time when the number-cue was valid (e.g., 8 followed by a right side asterisk) than when it was invalid (e.g., 2 followed by a right side asterisk). Validity was defined according to the synesthete's number-form (left-to-right or bottom-to-top). In contrast, no such effect was found for the controls. Our results reveal that: 1) number-form synesthesia can orient attention according to the specific spatial configuration without attending to the number-cue; 2) number-form synesthesia is a conscious yet involuntary condition that might restrain the flexibility of number representation; and 3) the presence of automaticity is contingent upon the existence of a strong relationship between stimulus featuresóin the current case, between numbers and space.

D23

AN MEG STUDY OF SYMBOLIC NUMBER COMPARISON *Silke M. Göbel[1], Johan D. Carlin[2], Isabella Paul[3]; [1]Psychology & York Neuroimaging Centre (YNIC), University of York, UK, [2]Medical Research Council Cognition and Brain Sciences Unit, Cambridge, UK, [3]Clinical Psychology and Neuropsychology, University of Konstanz, Germany* – Neuroimaging studies of number comparison (NC) have consistently found activation in the parietal lobes, often related to numerical distance. Numerical effects have been observed at frontal and parietal electrode sides within the first 200 ms post-stimulus. The current study investigated the time-course and location of parietal brain activity related to NC with Magnetoencephalography (MEG). During the NC condition, subjects (n = 18) had to indicate

whether visually presented digits (1, 4, 6, 9) were greater or smaller than a reference (5). In two control conditions they were asked to perform a perceptual task (vertical line present/absent) either on numerical or non-numerical stimuli. MEG signals were recorded using a 248-channel Magnes 3600 whole-head MEG device (4D Neuroimaging Inc., San Diego). Prior to recording, individual scalp landmarks were spatially co-registered using a Polhemus Fastrak system. These landmarks were matched with the subjects' anatomical magnetic resonance scans and spatially normalized into standard space. Time-locked event-related fields were derived by averaging over epochs for each condition after artifact rejection. MEG source analysis was performed using a minimum variance beamformer (Van Veen et al., 1997). Nonparametric Permutation Tests were employed for statistical comparisons. Significant differences in activation between NC and control conditions were found in right (from 135 ms onwards) and left (from 125 ms onwards) parieto-occipital cortex. Numerical distance had a significant effect on left parieto-occipital cortex from 172 ms onwards. Our results shed further light on the timing of parietal activity related to symbolic number processing.

D24

THE ODD EFFECT: REVIEW AND SUGGESTED MODEL *Terence Hines[1]; [1]Pace University, Pleasantville, NY* – The odd effect refers to the fact that under certain conditions it takes longer to make judgments about odd than even digits. The effect is found when subjects make explicit same/different judgments of digits or digit names based on parity and when explicit odd/even judgments are made. Children learn even / even addition and subtraction problems faster than they learn problems using two odd digits. This does not occur for multiplication problems. These latter are learned and performed using rote memory, not always the case for addition and subtraction problems. The internal code(s) responsible for the odd effect are not activated when retreiving solutions to multiplication problems. The odd effect is not due to a strategy in which subjects first test whether a stimulus is even and only then test for oddness. A model is presented in which the internal representations of the even digits are more closely linked than the representations of odd digits. Priming studies suport this model. An even digit prime speeds responses to even digits significantly more than an odd prime speeds responses to odd digits. The model makes predictions about observed hemispheric differences in the odd effect depending on the type of stimuli (digits, words or dot patterns) being judged.

D25

THE INFLUENCE OF NUMERICAL MAGNITUDE ON TIME PERCEPTION AND REPRODUCTION *Acer Y.-C. Chang[1,2], Ovid J.-L. Tzeng[1,2,3,4], Daisy L. Hung[1,2,3], Denise H. Wu[3]; [1]Laboratories for Cognitive Neuroscience, National Yang-Ming University, Taipei, Taiwan, [2]Institute of Neuroscience, National Yang-Ming University, Taipei, Taiwan, [3]Institute of Cognitive Neuroscience, National Central University, Jhongli, Taiwan, [4]Institute of Linguistics, Academia Sinica, Taipei, Taiwan* – Access to magnitude information in different quantity dimensions, such as numbers and time, has been assumed to rely on generalized magnitude representations underlying these dimensions. Recent research also demonstrated that task-irrelevant numerical information influenced temporal perception in a duration comparison task. However, empirical findings have suggested that the functions of time perception and reproduction have distinct characteristics and neural substrates. Therefore, whether numerical information modulates the abilities to perceive and reproduce time is still an open question. In the current study, perception and reproduction of the duration of different numbers were examined. In Experiment 1, we found that the duration of a large number was judged to be longer than the same duration of a small number. Similarly, in Experiment 2 we found that reproduction of the duration of a large number was longer than that of the same duration of a small number. In Experiment 3, numerical information only appeared as a result of the key-press action to reproduce a fixed duration. It was also found that magnitude of the number indicative of the reproduced duration modulated the reproduction of the same duration. These results clearly demonstrate the influence from magnitude information of numbers on time perception and reproduction, and are consistent with the proposal of generalized magnitude representations subserving numerical and time processing. Further neurophysiological experiments are carried out to examine the number-duration congruency effect and to determine whether ERP components related to temporal processing (e.g., frontal negative potential) is modulated by numerical magnitude.

D26

THE DEVELOPMENT OF AUTOMATED SYMBOLIC NUMEROSITY PROCESSING IN CHILDREN, AN ERP STUDY *Titia Gebuis[1], Leon Kenemans[1,2], Edward de Haan[3], Maarten van der Smagt[1]; [1]University of Utrecht, Experimental Psychology, [2]University of Utrecht, Psychopharmacology, [3]University of Amsterdam, Faculty of Social and Behavioural Sciences* – Infants can visually detect changes in numerosity, which suggests that a (non-symbolic) numerosity system is already present early in life. Children acquire knowledge about symbolic Arabic numerals around the age of five, and this knowledge gradually becomes automated. The resulting automatic link between the number symbols and their meaning is necessary for the acquisition of arithmetic skills. It is often suggested that before the Arabic numerals are fully automated, additional frontal processes are recruited when children process Arabic numerals. In the current study we investigated the development of automated symbolic number processing in children from second (age 5-6) and fourth grade (age 7-8) using a symbolic and non-symbolic size congruity task and event related potentials (ERP) as a measure. The comparison between symbolic and non-symbolic size congruity effects (SCE) allowed us to disentangle processes necessary to perform the task from processes specific to symbolic number processing. In contrast to previous studies, second grade children already revealed both a symbolic and non-symbolic SCE similar to that of adults. The concurrently measured ERP data revealed that the two magnitudes interfered at an early stimulus level in all age groups. In addition, we found no evidence for the additional recruitment of frontal processes in the early stages of symbolic number automatization. Apparently, already at the age of five automatic symbolic number processing mirrors that of adults.

D27

SPATIAL ORGANIZATION OF MAGNITUDE IN THE REPRESENTATION OF ABSTRACT DOMAINS *Kevin J. Holmes[1], Stella F. Lourenco[1]; [1]Emory University* – There is converging behavioral and neural evidence that numerical representations are spatially organized from left-to-right, the so-called mental number line. When judging parity (odd/even), for example, smaller and larger numbers produce faster left- and right-side responses, respectively ('SNARC' effect). Three experiments revealed that this left-to-right organization of magnitude extends to the representation of emotional valence. In Experiment 1, participants made parity judgments to numbers (0 to 9) and gender judgments (male/female) to human faces whose expressions ranged from neutral to happy. Results replicated the canonical SNARC effect for number. In the face task, there was a similar, albeit weaker, pattern of spatial organization, with right-side responses becoming increasingly faster as happiness increased. In Experiment 2, emotion ranged from angry to happy (and included neutral). Faster right-side responses were observed as the magnitude of either emotion, relative to neutral, increased (i.e., more happy or angry), suggesting that magnitude, even when instantiated as emotional expression, is spatially organized. In Experiment 3, participants made explicit emotion judgments (i.e., happy/not happy or angry/not angry). For happiness judgments, faster right-side responses were observed with increasing happiness, and for angriness judgments, faster right-side responses with increasing angriness, demonstrating that the left-to-right organization is flexible and depends on the magnitude-related representation of emotion. Together, our findings suggest that people automatically extract magnitude information in the mental organization of abstract domains, and that number is but one example of a

more general representational system linking space and other magnitude dimensions, perhaps with neural correlates in posterior parietal cortex.

D28

DIFFUSIVITY IN LEFT ANTERIOR SUPERIOR LONGITUDINAL FASCICULUS PREDICTS ARITHMETIC ABILITY IN CHILDREN *Jessica Tsang[1], Robert Dougherty[2], Gayle Deutsch[3], Brian Wandell[2], Michal Ben-Shachar[4,5]; [1]School of Education, Stanford University, [2]Stanford University, Psychology, [3]Stanford University Medical Center, Neurology and Neurological Sciences, [4]BAR-ILAN University, English,[5]BAR-ILAN University, Gonda Brain Research Center* – Studies of mental arithmetic consistently report fMRI activation in the inferior parietal, inferior frontal, and precentral cortex (Dehaene et al., 2004). To determine whether white matter pathways connecting these regions are related to mental arithmetic ability, we tested 28 children (10-15 years, 14 girls) on mental exact addition, approximate addition, and simple math facts. Using diffusion tensor imaging, we measured the anterior superior longitudinal fasciculus (antSLF), which connects inferior parietal with inferior frontal and precentral cortex. These regions are thought to support quantitative, linguistic, and working memory aspects of mental arithmetic. We used deterministic tractography and manual path labeling to identify the left and right antSLF in each child, and then extracted diffusion properties from a portion extending between two coronal planes defined by the central sulcus and a plane 7mm posterior. We found that approximation abilities positively correlate with fractional anisotropy in left antSLF (r=0.47, p=0.016). Right antSLF showed a similar, but non-significant, trend (r=0.31, p=0.11). Exact addition showed a similar, but non-significant, relationship with left antSLF (r=0.33, p=0.10), but no relationship with right antSLF (r=0.01). A diffusion simulation on the observed pattern of diffusion tensor eigenvalues suggests that children with higher arithmetic scores had fewer crossing fibers and higher fiber density in antSLF. Our findings indicate that connections between parietal and frontal areas are important in mental arithmetic ability. Funding: NIH EY015000; Stanford Interdisciplinary Graduate Fellowship to J.T.

D29

SITUATIONAL SOCIAL POWER AND THE NEUROCOGNITIVE MECHANISMS OF MATH PERFORMANCE *Donna J. Bridge[1,2], Joan Y. Chiao[1,2]; [1]Northwestern Interdepartmental Neuroscience Program, [2]Northwestern University, Psychology* – Heightening one's sense of social power has been shown to facilitate certain cognitive processes, including executive functions, cognitive flexibility, and abstract processing. Here we examined the influence of priming social power on the neurocognitive bases for two kinds of mathematical computations: exact and approximate calculation. Convergent evidence from electrophysiology and neuroimaging studies demonstrates that exact calculation (e.g. 3+4 = 7 or 6?) relies on language-dependent neural substrates, such as the left inferior frontal gyrus, whereas approximation (e.g. 3+4 = 6 or 9?) relies on language-independent neural circuitry within bilateral inferior parietal lobules. Based on prior evidence that priming high power enhances abstract processing, we hypothesized that priming high social power would enhance math performance, particularly for approximate calculations. Twenty-two participants were randomly primed with either high power (HP) or low power (LP) and then completed a series of small and large exact and approximate equations. Accuracy results revealed a marginally significant three-way interaction of power by type by size F(1,20) = 3.91, p =.06. HPs accurately computed more small approximate problems (M=.98, SE=.03) than LPs (M=.90, SE=.03), while LPs correctly answered more small exact problems (M=.98, SE=.03) relative to HPs (M=.93, SE=.03). For large equations there was a slight trend for HPs to have higher levels of accuracy for exact (M=.89, SE=.03) and approximate (M=.86, SE=.04) equations, relative to LPs (M=.85, SE= .03; and M=.85, SE=.04, exact and approximate respectively). Implications of these findings for the role of situational social power on neurocognitive routes to mathematical performance will be discussed.

D30

ANATOMICAL AND STRUCTURAL CONNECTIVITY DEFICITS IN YOUNG CHILDREN WITH MATH DISABILITY *Elena Rykhlevskaia[1,2], Lucina Uddin[1], Leeza Kondos[1], Vinod Menon[1]; [1]Stanford University, Psychiatry and Behavioral Sciences, [2]Stanford University, Psychology, CA* – Do math disabilities (MD) in young children have an anatomical correlate? Previous neuroimaging studies have indicated the involvement of a distributed network of parietal, prefrontal and inferior temporal cortices in numerical and mathematical information processing. We hypothesized that anatomical and brain connectivity impairments within this network may underlie MD. We acquired T1-weighted structural and diffusion-weighted images from well-characterized 7-9 year old children with MD (N = 23) and age-, IQ-, gender- and reading ability-matched typically developing (TD) children (N = 24). Optimized voxel-based morphometry (VBM) analyses revealed reduced grey and white matter volume in MD compared to TD. Children with MD group showed reduced gray matter volumes in the right occipito-temporal cortex, fusiform, parahippocampal and lingual gyri, and bilaterally in the cerebellum. They also showed reduced white matter volumes in the splenium of corpus callosum, and within a continuous cluster in the right hemisphere including portions of the retroventicular part of internal capsule, saggital stratum, posterior corona radiata and superior longitudinal fasciculus. Analysis of diffusion tensor imaging data revealed significantly reduced fractional anisotropy in children with MD in a right hemisphere region of interest obtained from the VBM analysis of white matter. No such differences were observed in a homologous region of the left hemisphere. These results, together with visualization of fiber tracts, suggest significant deficits in inferior-temporal and parietal connectivity in children with MD and provide compelling evidence that structural deficits in anatomy and brain connectivity may contribute to math disability in young children.

D31

FUNCTIONAL OPTICAL SIGNAL ANALYSIS OF CALCULATION AND LANGUAGE LATERALITY *Teresa Iuculano[1], Peck Hui Koh[2], Clare Elizabeth Elwell[2], Brian Butterworth[1]; [1]Institute of Cognitive Neuroscience, UCL, London, UK, [2]Medical Physics and Bioengineering, UCL, London, UK* – Neuropsychological studies have shown selective number processing deficits following unilateral cerebral lesions suggesting that calculation may be a lateralized process similar to language. Cerebral dominance is often related to handedness, however, how this lateralization is genetically determined and its link to language and calculation is currently unknown. We aimed to investigate the influence of genes and handedness on the lateralization of calculation and language in Monozygotic and Dizygotic twins who were either concordant or discordant for handedness. During functional Near Infrared Spectroscopy recordings we tested twin pairs on addition, semantic word classification and letter classification tasks. Second level analyses comparing task effects in relation to zigosity and handedness revealed that monozygotic twins with discordant handedness showed the same pattern of lateralization for both the addition and the word tasks, while opposite patterns of lateralization where found in Dizygotic twins regardless of handedness. Our results suggest that calculation abilities may share the same pattern of lateralization as language processes and that zigosity has a more profound effect on the neural organization of these networks than handedness.

D32

THE ARITHMETIC INCONGRUENCY EFFECT: SAME PROCESSING FOR DIFFERENT SYMBOLIC REPRESENTATIONS *Kristie Fisher[1], Miriam Bassok[1], Lee Osterhout[1]; [1]University of Washington, Psychology* – The incongruency effect is well-established by language research using the event-related potential (ERP) methodology (N400 component; e.g., Kutas & Hillyard, 1998). The N400 effect occurs when a word is incongruent with the words that precede it, and it is assumed to indicate the degree of integration of a word with its semantic context. Investigations of this effect have been extended to

measure conceptual integration in arithmetic. It has been found that incorrect answers to arithmetic problems elicit a similar incongruency effect, and that the patterns of latency and amplitude reflect the organization of arithmetic facts in memory (e.g., Niedeggen & Rosler, 1999; Szucs & Csepe, 2005; Zhou et al., 2006). Most studies have shown that this effect occurs slightly earlier in arithmetic (N300). This difference raises the question of whether the incongruency effect in arithmetic is truly analogous to that in language. We examined whether this difference is due to the format of the respective symbols in these two domains - digits vs. words. Participants in this study verified the correctness of arithmetic problems presented as digits (e.g., 12 + 3 = 15) and as words (e.g., Twelve plus three equals fifteen). In both conditions, we compared ERP responses to correct answers (e.g., 15) with numerically close and far incorrect answers (e.g., 14 and 4). We found that the processing of mathematical information presented in two different symbolic formats is remarkably similar, indicating that conceptual integration does not depend on the symbolic form used to represent the relevant concepts.

D33

THE IMPORTANCE OF LOLA: BRAIN AND BEHAVIOR INDICES OF THE ORGANIZATION OF ARITHMETIC FACTS IN BILINGUALS *Elena Salillas[1], Nicole Wicha[1,2]; [1]University of Texas at San Antonio, [2]University of Texas Health Science Center at San Antonio* – How arithmetic is related to language is a question of intense debate. According to Campbell and Epp (2004) arithmetic facts are represented in the bilingual brain as three modular codes (L1, L2 and Digits). Our findings indicate that the proposed memory networks supporting arithmetic are more strongly and accurately represented in both the Digits format and the Language of Learning Arithmetic - LoLA, which may or may not coincide with L1, than in the other language (toL). In a series of 8 behavioral and ERP experiments using the error-priming method (Niedeggen, et al 1999) we explored the organization of the three arithmetic codes in balanced bilinguals and, through code switching, the connections between the representations. Specifically, judging the correctness of a solution lead to a congruency effect with faster times for correct (3x2=6) than incorrect (3x2=7) solutions, but only for the Digit and LoLA formats. Convergent ERP data showed larger N400 congruency effects for Digit and LoLA formats. Moreover, a relatedness effect modulated the N400 only in the LoLA and Digit formats, with a larger N400 congruency effect for related (3x2=8, where 8 is a factor of 2) than unrelated (3x2=7) incorrect solutions. Switching across codes (3x2=six) elicited a late positive component, as did using the toL, indicating that translation across codes may be necessary when processing in a language other than LoLA. Based on these findings, we propose modifications to the Encoding Complex Model for bilinguals and address the general format dependencies for arithmetic (e.g., Dehaene, 1997).

Linguistic processes: Lexicon

D34

DE COLORES: AN ERP STUDY OF CROSS-LANGUAGE INTERFERENCE USING A BILINGUAL COLOR-STROOP TASK *Nicole Wicha[1,2], Lavelda Bradley[1]; [1]University of Texas at San Antonio, [2]University of Texas Health Science Center at San Antonio* – Bilinguals can experience cross-language interference from an inhibited language, and exhibit changes in brain activity related to this inhibitory process. We tested the timing of lexical interference in the first and second languages of fluent bilinguals using a modified Stroop task - an event-related potentials (ERP) extension of previous behavioral findings (Stanley, Kothmann and Wicha, 2007, JCN Supplement). Spanish-English balanced bilinguals named the ink color of color words that either matched in color or not. The color words were presented in English or Spanish, and naming was performed either in the same language as the text or not, across alternating blocks. In keeping with the bilingual Stroop literature, both between- and within-language interference was found. Additionally, ERPs showed that both color incongruent and language incongruent trials elicited an increased negativity between 250 to 450 ms, with language interference effects occurring earlier than Stroop interference effects. The negativity was largest in amplitude when naming incongruent ink colors in one language while reading in the other language, reflecting dual interference from both color and language. However, the negativity was more frontally localized for color interference and more broadly distributed for language interference. These findings suggest partially overlapping neural substrates for cross-language inhibition and Stroop-related inhibition for balanced bilinguals, with joint inhibitory effects at frontal sites. Additionally, a late positive component reflected differences across conditions. Results will be discussed in light of models of bilingual lexical activation and inhibitory control.

Linguistic processes: Other

D35

THE TALE OF THE PERRO AND THE BONE: READING CODE-SWITCHED NOUNS AND VERBS IN DISCOURSE *Christian Gonzalez[1], Nicole Wicha[1, 2]; [1]University of Texas at San Antonio, [2]University of Texas Health Science Center at San Antonio* – Switching between two languages while comprehending a single sentence elicits a Late Positive Component (LPC), with larger amplitude for the switched than the non-switched word (Moreno, et. al, 2002). However, the majority of code switching studies have used target nouns, even though the literature indicates that nouns and verbs are processed differently (Federmeier,2000; Pulvermuller, 1999). The goal of the current study is to look at code-switching in a discourse context, and to compare the brain's response to code-switched nouns and verbs. Spanish-English bilinguals read short Aesop's tales in English with occasional switches into Spanish. The target words were both nouns and verbs and were presented either early or late in the story. Preliminary data from six participants show a LPC effect for both nouns and verbs, possibly reflecting a processing cost when interpreting a switch. The LPC code-switch effect was larger for nouns than verbs over central and parietal recording sites; verbs also elicited increased N400 amplitude. An effect of discourse was also observed, with a larger LPC code-switching effect for words that were switched later in context than earlier. In contrast, only earlier code-switches elicited increased N400 amplitude. These data support the hypothesis that the brain treats nouns and verbs differently even when code-switching. In addition, whereas the N400 effect shows that more context helps process the meaning of the switched word, the increase in the LPC effect with additional context potentially reflects a difference in activation between the story language and the language of the code-switched word.

Linguistic processes: Semantics

D36

BOOSTING THE N400: SYNTACTIC GENDER MODULATION AS A FUNCTION OF CONTEXTUAL CONSTRAINT *Lourdes Guajardo[1], Nicole Wicha[1, 2]; [1]University of Texas at San Antonio, [2]University of Texas Health Science Center at San Antonio* – A central issue in psycholinguistics is how we process semantic and grammatical information and how these processes interact during online comprehension. Previous studies have yielded inconclusive results on how and when this interaction occurs; it is unclear whether these processes are continuously interacting or if they only interact at a later stage. The purpose of this study was to examine this interaction using the N400 and P600 as indices of semantic and grammatical processing, respectively. Native speakers of Spanish were presented with Spanish sentences containing a target adjective that was either semantically and grammatically correct or disagreed in meaning, grammatical gender, or both with the preceding noun. The

advantage of using gender-marked adjectives in Spanish is that they allow us to compare both types of processes at a single word. The adjectives were embedded in a range of weakly to strongly constraining sentences in order to compare the interaction effect as a function of contextual constraint. Semantic violations elicited a robust N400 effect followed by a late positivity, while grammatical gender violations elicited a P600 effect. Combined violations elicited a larger N400 and a reduced P600 compared to the individual violations. Crucially, this boosting effect on the N400 was significant for high, but not low cloze sentences. The findings support fully interactive models whereby semantic and grammatical processes are continuously interacting as they unfold in time. However, the interaction may be modulated by the amount of contextual information available, as both processors are combining efforts to predict upcoming words.

Linguistic processes: Lexicon

D37

NEURAL CORRELATES OF MEANING IN THE ACQUISITION OF NOVEL WORDS *M. Gareth Gaskell[1], Shane Lindsay[1], Jakke Tamminen[1], Yuanyuan Chen[1,2], Ruowen Li[1], Jennifer Wolfson[1], Matthew H. Davis[2]; [1]University of York, Psychology, UK, [2]Medical Research Council Cognition and Brain Sciences Unit, Cambridge, UK* – Recent behavioral and neuroimaging data suggest that acquiring novel words (without meanings) involves two components of learning: immediate acquisition of phonological representations, followed by sleep-associated integration of novel words with lexical neighbors (Dumay & Gaskell, 2007; Davis, Di Betta, Macdonald & Gaskell, in press). The current study examined the meaning side of vocabulary acquisition using event-related fMRI. Adult participants learned different sets of visually presented novel words and associated meanings on two consecutive days. On the second day, BOLD responses to both sets of stimuli, plus untrained novel and existing words, were measured during a one-back meaning comparison task. Retrieval of the meanings of novel words learned that day engaged a broad brain network including bilateral inferior temporal regions, and left inferior and middle frontal gyrus. The pattern for novel words learned the previous day was similar, suggesting that sleep had not led to major restructuring of the representations. Behavioral post-test data supported this conclusion. However, both sets of novel words also exhibited substantially different patterns of activity from the pre-existing words in bilateral occipital and superior temporal regions. The results suggest that learning novel word meanings, like learning their forms, involves fast and slow aspects of learning. However, unlike learning of form, the representation of novel meanings does not change substantially after a single night's sleep, with further consolidation presumably taking place over subsequent weeks or months. We interpret the similarities and differences between form and meaning acquisition with respect to the systematicity of the mappings to be learned.

D38

THE NEURAL CORRELATES OF MORPHOLOGICAL PRIMING DURING OVERT LANGUAGE PRODUCTION *Dirk Koester[1,2], Niels O. Schiller[1]; [1]Leiden Institute for Brain and Cognition, Leiden, The Netherlands, [2]Donders Institute for Brain, Cognition and Behaviour, Nijmegen, The Netherlands* – Findings about the neuroanatomical correlates of morphological processing in language are sparse and partially inconsistent (e.g. Devlin et al., 2004; Joanisse et al., 2005; Bozic et al., 2007) and the contributions of production processes have not been strictly dissociated from comprehension processes. Moreover, it has been suggested that morphological effects emerge from an interaction of semantic and phonological factors (e.g. Gonnerman et al., 2007). To investigate the neural correlates of morphological priming during overt production of Dutch, we used a long-lag word-picture priming paradigm. With this paradigm it has been shown that the production of morphologically complex words (primes) facilitates the subsequent production of picture names (targets) that were part of the complex word prime (e.g. Koester & Schiller, 2008). A morphological priming effect is expected in the left middle temporal gyrus if morphological priming relies on lexically stored information. However, if such priming involves combinatorial lexical operations, a priming effect is expected in the left inferior frontal gyrus (IFG). Native speakers of Dutch named line drawings that were primed by semantically transparent or opaque compounds, or by monomorphemic nouns that fully contained the target picture name. Significantly increased brain activity was observed in the left IFG (BA 47) for the transparent and opaque priming conditions, but not for pure form overlap. These results suggest that morphological priming involves combinatorial operations that are supported by the left IFG. On the basis of the present data, we therefore propose that morphological information about words has a neurocognitive correlate.

D39

A COMPUTATIONAL CASE-SERIES APPROACH TO FREQUENCY EFFECTS IN APHASIC WORD PRODUCTION *Nazbanou Nozari[1], Audrey Kittredge[1], Gary Dell[1]; [1]Beckman Institute, University of Illinois at Urbana-Champaign* – How do we retrieve words when speaking? Comparing retrieval during picture naming and auditory word repetition can answer this question. In the 2-step model of lexical access, both the word retrieval and phonological retrieval steps are involved in naming, but the former has no role in repetition. We computationally implemented four accounts of word repetition, using the interactive 2-step model of Foygel and Dell (2000). Assuming accurate recognition of the to-be-repeated word, repetition could consist of retrieving the word's output phonemes from the lexicon (pure lexical route model), or words could be repeated via a direct route from input phonology to output phonology (pure non-lexical route model). Alternatively, both routes might be used, either by summing their activation (summation dual route model) or choosing one route on any given repetition trial (independent dual route model). We empirically tested these four models by comparing the size of the word frequency effect (an index of lexical retrieval) in aphasic naming and repetition. Using multinomial hierarchical logistic multiple regression, we analyzed the naming and repetition errors from 59 patients, and from simulations of the four repetition models. A comparison of the patient and simulation data supported the pure lexical and summation dual route models: the effect of frequency in repetition was at least as strong as in naming, demonstrating that the lexical-to-phonological mapping, required for naming, is equally influential in repetition. We further claim that cognitive neuropsychological questions can be addressed by doing comparable analyses on patient data and output of computational models.

D40

NEURAL MECHANISM UNDERLYING ORTHOGRAPHIC INFLUENCE ON SPEECH PROCESSING: A COMBINED TRANSCRANIAL MAGNETIC STIMULATION AND BEHAVIORAL STUDY *Chotiga Pattamadilok[1,2,3], Iris, N. Knierim[1,4], Keith, J. Duncan[1], Joseph, T. Devlin[1]; [1]University College London, UK, [2]Université Libre de Bruxelles, Belgium, [3]Fonds de la Recherche Scientifique-FNRS, Belgium, [4]Université Pierre et Marie Curie, and Ecole Normale Supérieure, Paris, France* – Several behavioral studies have demonstrated that learning to read and write affects the way spoken language is processed. The present study investigates the neural mechanism underlying the emergence of such orthographic effects during speech processing. rTMS was used to tease apart two competing hypotheses considering the orthographic influence either as a consequence of online co-activation of the phonological and orthographic representations during speech processing or as a consequence of a profound modification of the very nature of the phonological representations during literacy acquisition. Precisely, rTMS was applied to disrupt the function of the brain regions involved either in phonological (left supramarginal gyrus-SMG) or orthographic processing (left ventral occipito-temporal cortex-vOTC) during the auditory lexical decision task in which the orthographic consistency of spoken words was

manipulated. If the orthographic effect results from the co-activation of the auditory and visual systems during speech processing, interrupting the function of left vOTC would reduce the orthographic consistency effect. On the contrary, if the orthographic effect reflects a modification of the very nature of the phonological representations via the contact with written code, interrupting the function of left SMG would reduce the effect. By demonstrating a disruptive effect of rTMS on the magnitude of the orthographic influence only when the stimulation was delivered over SMG, we provided first direct evidence for a profound modification of the nature of the phonological representations as a consequence of literacy acquisition and argues against the widely accepted idea that written code simply co-exists with spoken code of language.

D41

AN ERP STUDY OF CASE AND LOCATION INVARIANCE IN ORTHOGRAPHIC PROCESSING *Janelle LaMarche[1], Phillip J. Holcomb[1], Jonathan Grainger[2]; [1]Tufts University, Medford, MA, [2]LPC-CNRS, University of Provence, Marseilles, FR* – In an experiment combining masked repetition priming and the recording of event-related potentials, the visual similarity of prime target pairs as well as prime location were manipulated. Single-word items were composed of letters that were either similar (c-C) or dissimilar (a-A) in lower- and uppercase formats (i.e. cook-COOK, area-AREA). The location of prime stimuli relative to centrally located target words was also manipulated so that prime words could appear at the same target location, or shifted to the right or left by 20 pixels. Repetition priming effects were found in a series of early visual ERP components - the N/P150, the N250, and the N400. Critically, results indicate an interaction between repetition and similarity, where items with similar features show priming patterns in all three windows similar to previous findings, while items with dissimilar features show repetition priming effects that emerge later. Results provide further evidence for shape and location invariant orthographic representations, and elucidate the nature of the processes that underlie the mapping of retinotopic visual features onto higher-level location invariant representations during visual word recognition.

D42

THE INTERPLAY OF FREQUENCY, PREDICTABILITY, AND SOA IN WORD RECOGNITION: EVIDENCE FROM EVENT-RELATED POTENTIALS AND EYE MOVEMENTS *Michael Dambacher[1,2], Mario Braun[2], Sarah Risse[1], Olaf Dimigen[1,3], Kristin Göllner, Arthur Jacobs[2], Reinhold Kliegl[1]; [1]Universität Potsdam, Psychology, Germany, [2]Freie Universität Berlin, Germany, Experimental and Neurocognitive Psychology, [3]Humboldt Universität zu Berlin, Biological Psychology, Germany* – In linguistic research, word frequency is commonly regarded as major bottom-up determinant for the speed of lexical access. However, the temporal role of top-down processes is debated: There is uncertainty whether context-based predictions about incoming words affect lexical or solely post-lexical phases. Here, we used event-related potentials (ERPs) to delineate the interplay of bottom-up and top-down processes during sentence reading. In 144 sentences, frequency (low/high) and predictability (low/high) were experimentally manipulated on target words; sentence frames were kept constant. Compatible with most ERP reading studies, sentences were displayed word-by-word with an SOA of 700 ms. However, normal reading speed with a faster rate of four to five words per second challenges the generalizability of such data. The influence of input rate was examined with the same stimuli in a second experiment approximating normal reading speed with an SOA of 280 ms. ERPs revealed interactions of frequency and predictability within 200 ms post-stimulus in both experiments. Furthermore, presentation rate affected the timeline: At SOA700, frequency effects emerged with a shorter latency for high (90-140 ms) than for low predictability words (240-290 ms). SOA280 yielded frequency effects for both predictability conditions in an intermediate epoch (140-190 ms). The results indicate that early lexical processes are directed by bottom-up as well as top-down information. This interplay is modulated by the time available for word processing and prediction. We present an approach that reconciles the findings and discuss their link to eye movement data from left-to-right reading.

D43

TIME AND MONEY VERSUS MONEY AND TIME: AN ERP STUDY OF BINOMIAL EXPRESSIONS IN ENGLISH *Anna Siyanova[1], Kathy Conklin[1], Walter J. B. van Heuven[2]; [1]School of English Studies, University of Nottingham, [2]School of Psychology, University of Nottingham* – It is generally accepted that we store representations of words in our mental lexicon. However, what exactly is stored remains an open question. Previous research has looked at whether multi-word units (e.g., idioms, phrasal verbs, and compounds) are stored holistically or computed on-line. In previous behavioural and eye-tracking studies, we have investigated the processing of binomials, which are recurrent expressions formed by two words from the same lexical class connected by a conjunction (e.g., time and money). In such expressions, a particular word order is more frequent and considered more acceptable (e.g., time and money vs. money and time). Results showed a processing advantage for binomials over their reversed forms. The current investigation looks at the processing of binomials in sentence context using ERP. Of greatest interest is the N400 component, which has been shown to be sensitive to the processing of lexical-semantic information and frequency, as well as real-world knowledge (e.g., Hagoort et al., 2004). Our results revealed larger N400 amplitudes for reversed binomials (e.g., money and time) and binomials with semantic violations (e.g., time and party) relative to high frequency binomials (e.g., time and money). These findings support a view in which lexical storage is maximised, while on-line computation is minimised. However, a more computational view of the mental lexicon cannot be ruled out, where the processing advantage for time and money is the result of a very quick, almost simultaneous activation of money upon reading time. On this account, binomials are strongly linked but computed on-line.

D44

AN ELECTROPHYSIOLOGICAL STUDY ON WORD AND PICTURE PROCESSING IN MANDARIN CHINESE SPEAKERS *Yen Na Yum[1], Katherine Midgley[1,2], Jonathan Grainger[2], Phillip Holcomb[1]; [1]Tufts University, Medford, MA, [2]LPC-CNRS University of Provence, Marsailles, France* – A number of previous studies have looked at similarities and differences between word and picture processing, but not many of them have made direct comparisons between the two. These differences are particularly interesting in languages with non-alphabetic scripts like Chinese because of the arguably more pictographic nature of the words. This study investigated how pictures and Chinese characters are processed by native Mandarin Chinese speakers and native English speakers using the Event-Related Potential (ERP) technique. Both groups of participants performed a semantic categorization task with the same set of stimuli, which consisted of pictures of objects and concrete one and two character Chinese words, pseudo-randomly mixed to minimize priming and expectation effects. Pictures and words were presented for 400 ms, and participants were instructed to respond whenever the stimulus was a human body part (~15% of trials). Results on the non-body part critical words showed large ERP effects in the 300-600 ms time range. For native Chinese speakers, large N400-like negativities were found for both words and pictures, with the effects greater for words than for pictures especially late in the N400 epoch. For monolingual English speakers there were clear negativities for pictures, but as expected, there was no evidence of N400 activity for Chinese words. This pattern of effects is consistent with the possibility that Chinese speakers have a system for word processing that is similar to that of picture processing. The results will be discussed with respect to their implications for models of visual word and picture processing.

D45

CORPUS CALLOSUM MORPHOLOGY AND LATERALIZATION IN WILLIAMS SYNDROME *Tiffany Nash[1], Katherine Roe[1], Shane Kippenhan[1], Christopher Coutlee[1], Carolyn Mervis[2], Colleen Morris[3], Philip*

Kohn[1], Andreas Meyer-Lindenberg[1, 4], Karen Berman[1]; [1]Section on Integrative Neuroimaging, CBDB, NIMH IRP, NIH, DHHS, Bethesda, MD, [2]Neurodevelopmental Sciences Laboratory, Psychological and Brain Sciences, University of Louisville, Louisville, KY, [3]University of Nevada School of Medicine, Pediatrics, Las Vegas, NV, [4]Central Institute of Mental Health, Mannheim, Germany – Williams syndrome (WS) is a rare genetic condition caused by a micro deletion of ~1.6 megabases on chromosome 7q11.23. Although language is relatively preserved in WS, language acquisition is delayed, and previous research suggests reduced hemispheric specialization and interhemispheric cooperativity during lexical processing. The corpus callosum (CC), critical for mediating cross-talk between the two hemispheres, is known to be atypical in volume and shape in WS. The current study investigated the relation between CC volume and hemispheric specialization during a lexical processing task in WS. We used oxygen-15 water PET to measure regional cerebral blood flow (rCBF) in 14 normal-IQ participants with WS (mean age 27.7, seven female) performing a verbal fluency task. For each participant, six high-resolution, 1.5T structural images were averaged, and corpus callosum volumes (as segmented by FreeSurfer) were divided into five equal-length segments along the rostral-caudal axis. These sub-volumes, adjusted for total intracranial volume, were entered into a correlation analysis with laterality indices and functional connectivity maps derived from the verbal fluency rCBF data. Reduced functional lateralization of rCBF in the left frontal and parietal lobes was associated with decreased anterior CC (genu) volume ($p<.001$, uncorrected). Moreover, functional connectivity between Broca's area and right inferior parietal regions, previously found to be reduced in this population, was correlated with the volume of anterior corpus callosum ($p<.001$, uncorrected). These findings suggest a strong relation between compromised white matter tract integrity in the CC and aberrant functional lateralization during language processing in WS.

D46

SHEDDING NEW LIGHT ON READING IN BILINGUAL AND MONOLINGUAL CHILDREN *Melody S. Berens[1], Ioulia Kovelman[2], Matthew Dubins[1], Mark Shalinsky[1], Laura-Ann Petitto[1]; [1]University of Toronto, [2]Massachusetts Institute of Technology* – Little is known about the neural basis of reading and language development in typical bilingual and monolingual children. We ask whether and how early systematic exposure to two languages modifies brain tissue underlying reading and language capacities, and across important time periods of neural reading and language development. English-Spanish bilingual children in the Second and Third grades (ages 7-9; n=7) and English monolingual children (n=11) read aloud words during English and Spanish reading tasks while undergoing functional Near Infrared Spectroscopy (fNIRS, Hitachi ETG-4000) brain-imaging. All children read aloud Regular words (high sound to letter correspondence), Irregular words (low sound to letter correspondence), and Non-words in English. Bilinguals read aloud Spanish Regular and Non-words. fNIRS measures changes in the brain's oxygen level density (BOLD), and also its building blocks, deoxygenated and oxygenated hemoglobin, with 10-Hz temporal resolution. fNIRS' spatial resolution is excellent for cortical studies of language (~3-4 cm depth), child-friendly, quiet, portable, and tolerates movement. Results Behavioral. Bilingual and monolingual children performed similarly on the English reading tasks ($p > .05$). Imaging. Consistent with our published discoveries comparing bilingual and monolingual adult brains, we predict differences between bilingual and monolingual children's recruitment of left inferior frontal tissue and bilateral posterior superior temporal gyrus. Significance. Using innovative fNIRS allows first-time examination of the neural underpinnings of reading in bilingual and monolingual children providing important information both for neuroscientists about the extent and variability of reading/language in the developing bilingual brain and for educators. Funding Petitto (P.I.): NIHR01HD04582203, NIHR21HD05055802.

D47

THE SPATIOTEMPORAL DYNAMICS OF BILINGUAL LEXICO-SEMANTIC REPRESENTATIONS *Matthew Leonard[1,4], Tim Brown[3,4], Katie Travis[3,4], Lusineh Gharapetian[4], Matt Erhart[4], Eric Halgren[2,4], Jeff Elman[1]; [1]University of California, San Diego, Cognitive Science, [2]University of California, San Diego, Radiology, [3]University of California, San Diego, Neurosciences, [4]University of California, San Diego, Multimodal Imaging Laboratory* – More than two-thirds of the global population is proficient in more than one language, yet we do not understand how the brain organizes and processes multiple lexicons. It has been shown behaviorally that the first (L1) and second (L2) languages can both facilitate and interfere with each other, however the existing neuroimaging literature on bilingual lexico-semantic representations is inconclusive and contradictory with regard to shared versus separate neural substrates (Simos et al., 2005; Indefrey, 2006). We used a multimodal imaging method that combines the millisecond temporal resolution of magnetoencephalography (MEG) with the spatial resolution of structural magnetic resonance imaging (MRI) to examine these cortical representations in a group of Spanish-English bilingual adults. Participants viewed single concrete nouns presented visually in both languages, and made size judgments to the words. Using a distributed source anatomically-constrained MEG analysis (Dale et al., 2000), we found that while the L1 and the L2 share neural representations in classical left hemisphere frontal regions, the L2 additionally recruits right hemisphere and posterior areas. These results suggest that there are both separate and shared representations for lexico-semantic information between the two languages in relatively high proficiency adult bilinguals. The nature of the additional bilateral posterior activity for the L2 relative to the native language also suggests that the second language, prior to achieving native-like proficiency, may be represented in a manner similar to a school-age child's developing L1 (Brown et al., 2005). These findings pose potentially important questions concerning L2 instruction, acquisition, and bilingual language disorders.

D48

EVIDENCE OF MOTOR ENCODING DURING SIGN LANGUAGE PERCEPTION *Nicole Spotswood[1], David Corina[1]; [1]Center for Mind and Brain, University of California, Davis* – Of fundamental concern in the cognitive neuroscience of language is how speakers understand words. There has been a renewed interest in theories which ground language understanding in biological substrates of bodily senses. According to one such theory, the motor theory of speech perception, words are encoded, in part, in reference to one's internal motor representations utilized in speech production. Our interests were to examine whether this link between perception and production could be found in sign language processing. We collected data from 20 fluent signers as they performed a lexical decision task. Right- and left-handed signers were asked to perform lexical decisions to right- and left-handed tokens of well formed American Sign Language (ASL) words and non-lexical, yet phonologically possible 'non-signs.' To the extent that there is a mapping between one's internal production of sign forms and the perception of another's signing, we asked whether handedness would affect this task. Each subject saw video clips showing either an ASL sign or non-sign - half of the videos displayed a left-handed signer signing, the other half showed a right-handed signer. Reaction times (RTs) were recorded while subjects made lexical decisions to these stimuli. RTs for signs were significantly faster than for non-signs. RTs for left- versus right-handed signs did not differ significantly; however, we did find highly significant differences between RTs for right-handed and left-handed non-signs. These results suggest that motoric properties of language form may be brought to bear as discriminations become more difficult, as in the case of non-signs.

D49

FROM NUMBERS TO LETTERS: FEEDBACK REGULARIZATION IN VISUAL WORD RECOGNITION *Nicola Molinaro[1], Jon Andoni Duñabeitia[1], Alejandro Marìn-Gutièrrez[1], Manuel Carreiras[1,2]; [1]Instituto de Tecnologías Biomédicas, Universidad de La Laguna, Spain, [2]BCBL - Basque Research Center on Cognition, Brain and Language, Spain* – Alphabetic word reading involves letter identification based on elementary visual features, independently of the format of the written letters. This process is sensitive to the word context, leading to the regularization of the input even when numbers that resemble letters are inserted among letters (e.g., A=4, E=3, S=5, I=1; Perea et al., 2008). Here we investigate the electrophysiological correlates of number-to-letter regularization by means of the masked priming paradigm: target words were preceded by alphabetic primes (e.g., MATERIAL-MATERIAL), primes with letter-like numbers (e.g., M4T3R14L-MATERIAL), or primes with unrelated numbers (e.g., M7T6R28L-MATERIAL). The ERP patterns (N=26) were different in three consecutive time windows. The P150 component was more positive for the unrelated numbers condition compared to the two other conditions in occipital areas. Then, target words preceded by primes with numbers elicited a more negative N200 compared to the fully alphabetic condition, showing that the ERP effects are not due to visual overlap between prime and target. Finally, a positive component peaking around 260 ms was more positive for targets preceded by alphabetic primes and primes with letter-like numbers, compared to the condition with unrelated numbers. We explain these results as reflecting top-down feedback activation from word units, which strongly influences the activation of the letter units at a format-independent abstract level. Moreover, we propose an extension of the Local Combination Detectors model (Dehaene et al., 2005).

D50

THE PROCESSING OF CONSONANTS AND VOWELS DURING LETTER IDENTITY AND LETTER POSITION ASSIGNMENT IN VISUAL-WORD RECOGNITION *Manuel Carreiras[1,2], Marta Vergara[3], Alejandro Marín[2], Manuel Perea[4]; [1]Basque Research Center on Cognition, Brain and Language, Spain, [2]Instituto de Tecnologías Biomédicas, Universidad de La Laguna. Spain, [3]Center for Brain and Mind, UC Davis, [4]University of Valencia, Spain* – Recent research suggests that there is a processing distinction between consonants and vowels in visual-word recognition. To further investigate the neural bases of consonant and vowel processing, Event Related Potentials (ERPs) were recorded while participants read words and pseudowords in a lexical decision task. To assess the time course of vowels and consonants in letter identity/position assignment, the stimuli were displayed in six different conditions in a masked priming paradigm with a 50-ms SOA: i) identity condition; ii) vowels-delayed condition (e.g., choc?l?te-CHOCOLATE), iii) consonants-delayed condition (cho?o?ate-CHOCOLATE); iv) transposed-consonant condition (cholocate-CHOCOLATE); v) transposed-vowel condition (chocalote-CHOCOLATE), and vi) unrelated (baseline) condition. Results showed that the consonant- and vowel-delayed conditions differed in early ERPs windows (over frontal areas), while consonant- and vowel-transposed conditions differed in a later window (over right frontal areas). Furthermore, the comparison between delayed and transposition conditions showed a larger negativity for transpositions starting at around 300 ms over central areas. In addition, the identity and unrelated conditions differed from the consonant and vowel manipulation conditions in the N250 and the N400 components, respectively. The time course and scalp distribution of these effects seem to reflect different stages on the process of letter coding during lexical access. Finally, RTs were longer in the conditions involving consonants than vowels and in the delayed-letter conditions than the transposed-letter conditions. The RTs in these four delayed/transposed-letter conditions differed from the identity and the unrelated conditions. We examine the implications of these findings for computational models of visual-word recognition and reading.

D51

LANGUAGE USE AFFECTS LONG-TERM SEMANTIC PRIMING IN CHILD BILINGUALS: EVIDENCE FROM EVENT-RELATED POTENTIAL *Arturo Hernandez[1], Manfred Gugler[2], Isabell Wartenburger[2,3]; [1]University of Houston, Psychology, [2]Berlin NeuroImaging Center, Charite Berlin, [3]University of Potsdam, Linguistics* – The present study investigated and examined the effects of language use on neurophysiological activity during auditory word recognition. Participants were early German-English bilingual children, ages 6 to 7, who learned both languages from birth and were currently living in Germany. Participants were asked to listen passively to auditorily presented words in English and German while EEG activity was being monitored. Each word was presented twice with varying lags between repetitions. Results revealed an N400 for all words presented. However, a reduction in the N400 was only observed upon the second instance of a repeated German word when it had been preceded earlier in the experiment by its English translation. No other modulation of the N400 was observed for repetition in any of the other conditions. Hence, repetition priming was observed in only one direction and only when items were repeated first in English and then in German. These results suggest that immersion in a language may modulate the magnitude of semantic processing. The findings are consistent with the view that lexical-semantic processing in bilingual children, even those who exhibit high proficiency in two simultaneously learned languages, are sensitive to factors such as language use.

D52

EFFECTS OF MORPHOLOGICAL COMPLEXITY ON LEXICAL PROCESSING: EVIDENCE FROM MEG *Caroline M. Whiting[1], Yury Shtyrov[1], William D. Marslen-Wilson[1]; [1]MRC Cognition and Brain Sciences Unit, Cambridge UK* – The role of morphological structure and semantic transparency during visual word processing was investigated in a magnetoencephalography (MEG) study. Recent evidence has suggested that morpho-orthographic cues - the presence of a potential stem and affix - can be sufficient to trigger morphological segmentation, regardless of the semantic relationship between the stem and whole form (Longtin et al, 2003). In this study we aimed to examine the spatiotemporal pattern of lexical processing, in particular the point at which stems and affixes can cue the presence of morphological complexity. Furthermore, we investigated how the semantic transparency of complex forms could influence attempts at segmentation. Stimuli co-varied on the presence and absence of a potential stem and affix in English. Source analysis using L2 minimum norm estimates (MNE) revealed a left-lateralised fronto-temporal network activated during word recognition. Using a region-of-interest analysis, we found activity at the M170 associated with visual string processing within left fusiform gyrus, but no difference between complex and non-complex forms. At approximately 250ms, anterior temporal regions showed differential processing for forms containing both a stem and affix (e.g. farmer) from those that could not be morphologically complex (e.g. scandal). A late transparency effect appeared in the 400ms time-window, associated with the semantic relatedness between the stem and whole form. Our results support recent behavioural and neuroimaging results pointing to early processing based on the presence of orthographic cues to morphological structure.

D53

NATIVE LANGUAGE SEMANTIC ACTIVATION IN NON-NATIVE SPEECH COMPREHENSION: EVIDENCE FROM EVENT-RELATED POTENTIALS *Ian FitzPatrick[1,2], Peter Indefrey[1,2]; [1]Max Planck Institute for Psycholinguistics, [2]Radboud Unversity Nijmegen, Donders Institute for Brain Cognition and Behaviour* – Converging evidence suggests that there is language non-selective access to the bilingual lexicon in the domain of written word comprehension. For auditory comprehension the situation is less clear-cut. The current study further investigated the availability of first language (L1) semantic features in second language (L2) speech processing. We recorded EEG from 30 Dutch-English bilinguals who listened

to spoken sentences in their L2 (English). Experiment 1 used sentences in which the critical word was a: (a) semantially congruent L2 word, (b) semantically incongruent L2 word, (c) congruent L1 word, or (d) an incongruent L1 word . Incongruent L1 and L2 words elicited a canonical N400 effect. Furthermore, the N400 to congruent L1 words had a substantially earlier offset than the N400 to inconruent L1and L2 words. Experiment 2 the critical word in the sentence was an L1-L2 interlingual homophone. In separate conditions: (a) the L2 meaning, (b) the L1 meaning, or (c) neither meaning was congruent with the sentence context. Whenever the L1 meaning was congruent with the sentence context we observed an N400 with an earlier offest than the N400 to incongruent homophones. When the L2 meaning of the homophone was congruent a negativity emerged, but substantially later than the N400 to incongruent homophones. Taken together these results firstly show that interlingual homophones activate semantic features from L1 and L2, however L1 semantic features become available later. Secondly, while L1 words are not initially available for semantic integration, congruent L1 words are nevertheless eventually successfully integrated.

D54

FRACTIONATING THE N400 EFFECT WITH SIMULTANEOUS MEG AND EEG *Ellen Lau[1], Diogo Almeida[1], Nuria Abdulsabur[2,1], Allen Braun[2], David Poeppel[1,3]; [1]University of Maryland, College Park, [2]National Institutes of Health, NIDCD, [3]NYU* – Contextual modulation of the N400 evoked response to words has been demonstrated in sentential contexts and word priming manipulations. Conditions lacking in contextual support (incongruent sentence completions and unrelated word pairs) elicit higher N400 amplitudes than contextually supportive conditions (congruous sentence completions and related word pairs). The difference in amplitude appears in the ERP as a single broad peak lasting 200-300 ms. However, different localization techniques (intracranial recording, fMRI, MEG) have implicated different sources in generating the N400. We hypothesized that the N400 MEG response fractionates multiple processes that are temporally and spatially smeared in the ERP response. To explore this, we simultaneously recorded participants' brain activity from 275 MEG channels and 34 EEG electrodes in response to (i) congruous or incongruous sentence endings and (ii) semantically related or unrelated word pairs. Participants performed a probe detection task (single words in the sentence block, single letters in the word pair block). The EEG data (n=12) replicate the typical N400 effect, a centro-parietal, slightly rightward monophasic amplitude difference from 250-600ms. The MEG data replicate previous work (Lau et al 2008) and reveal a biphasic, left-lateralized response, involving two distinct stages: The first (250-350ms) is left lateralized, whereas the second (350-550ms) has right anterior hemispheric activity in addition to the left hemisphere pattern observed in the first stage. These results suggest that the spatial dimension of MEG may be used to derive more detailed information about the time course of contextual processing within the N400 effect observed in ERP.

D55

BILINGUAL LEXICAL ACCESS: INDIVIDUAL DIFFERENCES IN WORKING MEMORY CAPACITY AND LEVEL OF PROFICIENCY *Gicele Vieira Prebianca[1], Mailce Borges Mota[2], Thomas Redick[3]; [1]Universidade Federal de Santa Catarina, [2]Universidade Federal de Santa Catarina; Georgetown University, [3]Georgia Institute of Technology* – In order to produce speech, bilinguals need to manage two linguistic systems so as to verbalize thoughts in just one intended language at a time. Although the ability to avoid interference from the unintended language seems to be crucial to this endeavor, it is not the only one a bilingual speaker must develop. Bilinguals also need to deal with within-language competition since a concept may be lexicalized in different ways in the intended language (De Bot & Schreuder, 1993). The set of experiments reported in this study explores the role of working memory capacity (WMC) and second language (L2) proficiency level in bilingual lexical competition. One-hundred L2 speakers of American English were submitted to three WM span tests, two L2 proficiency tests and one L2 picture-naming task carried out under the semantic competitor paradigm in a control and an experimental condition. WMC and L2 proficiency both significantly predicted bilingual lexical access. Higher spans retrieved lexical items faster than lowers spans. In addition, more proficient bilinguals presented faster reaction times during the retrieval of L2 lexical items than less proficient ones, regardless of doing the control or the experimental condition first. These data are compatible with the proposal that bilingual lexical access is affected by the ability to control attention and by level of proficiency. Findings are discussed in the context of the controlled-attention view of working memory capacity (Kane, Bleckley, Conway & Engle, 2001) and the Inhibitory Control Model (Green, 1998).

D56

THE NEUROBIOLOGY OF ADAPTIVE LEARNING IN READING LOW-FREQUENCY CHINESE PHONOGRAMS: A CONTRAST BETWEEN PHONOLOGICAL AND SEMANTIC TRAINING CONDITIONS *Jingjing Zhao[1], Jay Rueckl[1], Stephen Frost[2], Xiaoyi Wang[3], Wan Sun[3], Hua Shu[3], Shin-Yi Fang[1], W. Einar Mencl[2], Kenneth Pugh[2]; [1]University of Connecticut & Haskins Laboratories, Psychology, [2]Haskins Laboratories, [3]State Key Laboratory for Cognitive Neuroscience and Learning, Beijing Normal University* – fMRI used to investigate the influence of phonological and semantic training on the cortical circuitry of Chinese skilled readers recruited to read low-frequency Chinese regular phonograms. The experiment provide direct evidence of the neural basis of reading in Chinese, and present indirect evidence about the similarities and differences of division labor of phonological and semantic processing between readers of different writing system (Chinese vs. English). The experiment happened in two stages. During the training phase, subjects made phonological or semantic judgments about 84 Chinese phonograms (42 in each task, each phonogram 8 exposures). Subsequently, subjects were scanned while naming the trained 84 phonograms and 84 additional untrained phonograms (42 regular and 42 irregular). Behaviorally, subjects' reaction time decreased and accuracy increased along 8 exposures during both training conditions; phonological and semantic training both resulted in transfer facilitation in naming. In addition, we found regularity effect for untrained phonograms: regular phonograms named faster and better than irregular phonograms. Brain imaging data mirrored the behavioral regularity effect: irregular phonograms showed higher activation in inferior frontal gyrus and occipitotemporal junction than regular phonograms. Phonological training and semantic training of Chinese phonograms yielded different functional activation patterns comparing to English study (Sandak, et al., 2004). The findings indicate that even though in some sense the neural circuits of reading Chinese may show the same pattern to English (regularity effect), the division labor of the neural circuits in reading Chinese still differ from reading English.

D57

ERP EFFECTS OF SUBLEXICAL PROCESSING IN VISUAL WORD RECOGNITION: ARE SYLLABIC EFFECTS MODULATED BY SYLLABIC STRUCTURE? *Marta Vergara-Martínez[1], Alejandro Marín[2], Manuel Carreiras[2,3]; [1]University of California, Davis, [2]Instituto de Tecnologías Biomédicas, University of La Laguna, Spain, [3]Basque Research Center on Cognition, Brain and Language, Spain* – The aim of this study was to investigate electrophysiological correlates of sublexical processing in visual word recognition in Spanish. Previous work using event-related potentials (ERPs) to examine syllabic processing has shown very early effects; however, only consonant-vowel (CV) syllabic structure was considered. We recorded ERPs while participants made lexical decisions to words and pseudowords in two priming experiments. Target word pairs were selected that shared the first 3 graphemes but differed in their syllabic structures (CV; ca.mi.no; or CVC: cam.po). They were preceded either by unrelated syllabic primes (po/ren-ca.mi.no; ren/po-cam.po) or by related primes. When primes were related, they were either syllabically congruent primes (ca-ca.mi.no; cam-cam.po) or syllabically incongruent primes (cam-ca.mi.no; ca-cam.po). This allowed us to disentangle

syllabic from orthographic overlap priming effects. If syllables play a role during lexical access, early ERP differences would be expected for our syllabic manipulation. Experiment 1 had a 200 ms SOA, and replicated P350 effects for prime-target relatedness (P350: lexical access; Friedrich et al., 2004). No effect of the syllabic manipulation emerged. Early effects (P200) were observed for the type of prime (CV vs CVC). Experiment 2 tried to overcome the problem of conscious priming by masking the prime with a shorter SOA of 55 ms. Early effects of relatedness and prime type were present; however, syllabic congruency effects were not observed. These results are discussed in terms of the primary role that the consonant-vowel syllabic structure plays in the Spanish language.

D58

DIRECT ELECTROPHYSIOLOGICAL EVIDENCE OF A NEURAL SUBSTRATE FOR MORPHOLOGICAL RULE APPLICATION *Riadh Lebib[1], Andrea Krott[1]; [1]School of Psychology, University of Birmingham - United Kingdom* – A critical issue for understanding language processing in the brain is whether linguistic rule application is subserved by a distinct neural substrate. One of the evidence supporting this hypothesis comes from studies employing electroencephalographic measurements during the processing of rule misapplication. This evidence is inconclusive because it might reflect processes caused by the violation such as error handling rather than application of rules per se. Here we provide first evidence that correct regular formations, i.e. German past participles, are associated with left frontal negative-going activity, i.e. a LAN, providing direct encephalographic evidence for rule application in the brain. Moreover, a LAN response is present regardless of the participles' frequency, suggesting that independently from the mode of lexical access (i.e. decomposition or full-form activation), the cerebral structures associated with rule-based mechanisms are activated. We will discuss how our results shed further light on the functional cerebral mechanisms associated with the LAN response during the information processing stream.

Linguistic processes: Syntax

D59

ATTENTION MAKES THE DIFFERENCE - A SYNTAX ERP-STUDY WITH 3-4-YEAR-OLD CHILDREN *Franziska Suess[1], Angela D. Friederici[1]; [1]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany* – In a recent event-related potential (ERP) study we showed that the syntactic sentence processing in 3-4-year-old children is influenced by varying the proportions of syntactically incorrect sentences (20% vs. 80%). In this passive listening task we found an early negativity for the 20% condition but no effect for the 80% condition. In a prior study with adults Hahne and Friederici (1999) had used the same manipulation and found an ELAN for both conditions and a P600 only for the 20% condition. They interpreted this result to indicate automaticity of the first pass parsing process reflected by the ELAN, and more controlled syntactic revision processes reflected by the P600. In their study, Hahne and Friederici had used a grammaticality judgement task. In order to be able to compare children with adults we tested 30 children at the age of 3-4 years in an ERP study with the same sentence material, now using a grammaticality judgment task. Under this task children showed an ERP pattern similar to that reported by Hahne and Friederici for adults. In a nutshell these findings indicate that children at the age of 3-4 years similar to adults show an automatic first pass parsing process and a more controlled syntactic revision process, depending on the amount of attention induced.

D60

AN INVESTIGATION OF THE NEURAL GENERATORS OF ERP INDICES OF SYNTACTIC PROCESSING USING PROFICIENCY-RELATED ERP MODULATIONS IN AN ERP-FMRI PARADIGM *Eric Pakulak[1], Mark Dow[1], Helen Neville[1]; [1]University of Oregon* – Event-related potential (ERP) studies of syntactic violations typically report a biphasic response in which an earlier negativity, often maximal over left anterior sites (LAN), is followed by a later positivity usually maximal over posterior sites (P600). Evidence bearing on the neural generators of these components is limited: evidence from functional magnetic resonance imaging (fMRI), magnetoencephalography dipole modeling, and ERP studies of patients with focalized brain lesions (e.g., Friederici et al., 2000; Friederici et al., 2003; Friederici & Kotz, 2003; Kotz et al., 2003) has implicated inferior frontal and anterior temporal regions as possible neural generators of the LAN and the basal ganglia and posterior temporal regions as possible neural generators of the P600. Here we take a novel approach to this question. Using an auditory syntactic violation paradigm, we gathered ERP and fMRI data from monolinguals who varied on measures of English proficiency and used individual proficiency-related modulations of the LAN and P600 as covariates in the analysis of fMRI data from the same participants. Results suggest that multiple neural generators may contribute to both effects. Implicated in the generation of the anterior negativity were left inferior frontal gyrus and left temporal pole, while several posterior temporal and temporoparietal areas were implicated in the generation of the P600. These results illustrate the potential for the use of individual modulations in ERP components in conjunction with fMRI to provide valuable insight into the interplay between ERP and fMRI data and the neural generators of ERP indices of syntactic processing.

D61

TENSOR PRODUCT MODELS FOR LANGUAGE-RELATED BRAIN POTENTIALS *Sabrina Gerth[1], Peter beim Graben[2], Shravan Vasishth[1]; [1]Institute for Linguistics, University of Potsdam, Germany, [2]School of Psychology and Clinical Language Sciences, University of Reading, UK* – An important online measure of language processing is event-related brain potentials (ERPs) that are currently interpreted purely phenomenologically. We use tensor product representations (TPR) of symbolic structures to model syntactic parsing as nonlinear dynamics in neural activation space. In an ERP experiment on the processing of German subject-object ambiguities, we observed a P600 ERP for object first sentences reflecting an initial garden path interpretation. Starting with a Government and Binding formulation of the sentences, we construct a locally ambiguous context-free grammar from the phrase structure trees. This grammar is decomposed into its unambiguous parts representing the two alternative processing strategies, namely subject preference against object preference in order to construct two appropriate deterministic pushdown recognizers. Using the TPR, the syntactic categories of the disambiguated grammars are mapped onto filler vectors, while positions in a labeled binary tree are represented by three role vectors. In order to build a parallel processor the two parses for the subject-object sentence (regular vs. garden path) and the other two for the object-subject sentence respectively were linearly superimposed in activation space. Then, model ERPs are obtained as the first principal component. Our model is able to describe, at least qualitatively, the obtained ERP results by trajectories that explore functionally and causally different regions in activation space while pursuing different language processing strategies. During its transient evolution, the trajectories of the model diverged exactly when the garden path was encountered which shows remarkable resemblance with the P600 effect in the ERP.

D62

BIMODAL ASPECTS OF THE FUNCTIONAL ORGANISATION OF LANGUAGES AS REVEALED BY GERMAN/GERMAN SIGN LANGUAGE BILINGUALS: AN EVENT-RELATED POTENTIAL STUDY *Monique Kügow[1,2], Nils Skotara[1,2], Uta Salden[1,2], Barbara Hänel-Faulhaber[2,3], Brigitte Röder[1,2]; [1]Biological Psychology and Neuropsychology, University of Hamburg, [2]Research Centre 538: Multilingualism, University of Hamburg, [3]Educational Sciences, Section II: Perception & Communication, University of Hamburg* – Brainimaging studies in early bilinguals have provided evidence that two oral languages learned simultaneously from birth activate overlapping brain systems. Thus, studying people who grew up with an oral and a signed language provide the unique opportunity to investigate modality-specific aspects of the neural systems mediating language comprehension. German and German Sign Language (DGS) sentences were presented to hearing adults, who were born to deaf parents (CODAs) and who, thus, were exposed to both German Sign Language (DGS) and German from birth. The electroencephalogram was recorded throughout the experiment. Task of the participants was to decide whether or not the just seen sentence had been correct. Half of the sentences were correct while either a semantic violation or a syntactic violation was embedded in the other half of the sentences. The German and the DGS ERP data of the CODAs were compared to those of hearing native German speakers and a group of deaf native signers of DGS. At the behavioural level the CODAs did not differ in either language. For German, the typical ERP correlates of semantic and syntactic processing were observed in both groups. For DGS both, the CODAs and the native signers showed a P600 while only for the native signers a bilateral central negativity prior to a P600 was observed after syntax. Thus, these results suggest that language processing in CODAs and native signers recruits partially similar (P600), and partially distinct brain systems. We discuss in how far hearing status might contribute to the ERP differences.

D63

PHONOLOGY PLAYS A ROLE IN MORPHOSYNTACTIC PROCESSING: EVIDENCE FROM ERPS *Cheryl Frenck-Mestre[1,2], Haydee Carrasco[2]; [1]Centre National de Recherche Scientifique, [2]Université de Provence* – Herein we show that when morphosyntactic agreement is phonologically realized, native French readers process agreement more systematically than when it is silent. We manipulated the presence versus absence of phonological cues to morphosyntactic agreement in written French for gender concord between a noun and immediately following adjective in short sentential contexts. Both our behavioural and ERP results show a clear role of phonological cues, which, furthermore, interacted with grammatical gender. Gender concord errors produced a graded ERP response, with a larger P600 response elicited by phonologically realized errors (stylo(masc) verte*(fem)) than by silent errors (stylo(masc) bleue*(fem)); however, the difference between silent and orally realized gender concord errors was more marked for masculine than feminine nouns (stylo(masc) verte*(fem) vs. table(fem) vert*(masc), stylo(masc) bleue*(fem) vs. table(fem) bleu*(masc)), in line with the hypothesis that default gender in French is masculine (Nelson, 2005). These results further the finding of a role of phonological cues in processing verbal person agreement in written French (Frenck-Mestre et al., 2008), and add to the existing evidence of the importance of phonological cues in reading.

D64

WHY THE METRIC NEGATIVITY IS NOT AN N400: AN ERP STUDY ON METRIC AND SYNTACTIC PROCESSING USING JABBERWOCKY SENTENCES *Kathrin Rothermich[1], Maren Schmidt-Kassow[1], Sonja A. Kotz[1]; [1]MPI CBS, Leipzig, Germany* – Meter and syntax are assumed to be principles governing the arrangement of discrete structural elements in sequences (Patel, 2003). Recent ERP data support these principles and show that processes underlying these principles interact during language processing (Schmidt-Kassow and Kotz, in press). Listening to metrically violated sentences leads to a biphasic pattern consisting of an early negativity and a late positivity (Schmidt-Kassow and Kotz, in press; Magne et al, 2007; Knaus et al., 2007). In particular, the function of the early negativity is a matter of debate as it is unclear whether the negativity reflects an N400 as a result of misplaced stress in lexical access or mirrors deviance detection of a rule-based principle comparable to the LAN elicited by syntactic violations. The current experiment addressed this conflict by using German jabberwocky sentences, thus omitting lexical information. These sentences were metrically, syntactically, or syntactically and metrically violated. If the initially reported metrical negativity is an electrophysiological index of effortful lexical access (N400), no negativity should be elicited by metric violations in jabberwocky sentences. Our results show that both metric and syntactic violations elicited an anteriorly distributed negativity. This implies that the metric negativity is not an N400 but rather a response to metric deviation comparable to the LAN elicited by syntactic violations.

D65

ERP EVIDENCES IN WORD ORDER PROCESSING BY BASQUE-SPANISH BILINGUALS *Kepa Erdozia[1], Itziar Laka[1]; [1]University of the Basque Country* – We present results from a series of behavioral and ERP experiments investigating processing preferences in bilinguals of two languages with opposite word orders (Basque-ObjectVerb/Spanish-VerbObject). We compare very fluent and proficient groups of bilinguals. In one group, the first language (L1) of bilinguals is Basque, in the other group L1 is Spanish. The L1Spanish population learnt Basque starting at 3 years. We compare processing of canonical (SOV) versus non-canonical (OSV) sentences in Basque, a language never explored with this methodology. Experimental materials consist of (a) a set of transitive sentences in Basque containing a Subject, an Object and a Verb: OSV sentences are syntactically derived from canonical SOV. (b) Syntactically fully ambiguous sentences which can be disambiguated as OSV order resorting to world-knowledge. Comparison of canonical (SOV) and derived (OSV) sentences in L1Basque bilinguals shows a modulation of anterior negativities and P600 components in derived word order (OSV) suggesting the load of increased syntactic complexity with respect to canonical (SOV) word order. Results on ambiguity resolution show that ambiguous stimuli were processed as canonical SOV sentences; frontal negativity distinguished simple SOV and complex ambiguous OSV sequences. These results show a sharp processing contrast between basic SOV and derived OSV word order in L1Basque speakers. Results from the group of L2Basque bilinguals who are native of Spanish will determine whether their SVO native preferences modulate their word order processing in Basque, and hence will shed light on how early language processing mechanisms impact on nonnative language processing.

D66

PARAMETERS OF GRAMMAR AND MATURATIONAL EFFECTS: AN ERP STUDY ON ERGATIVITY AND OBJECT VERB AGREEMENT PROCESSING BY NATIVE VERSUS NONNATIVE SPEAKERS OF BASQUE *Adam Zawiszewski[1,2], Itziar Laka[2]; [1]MPI for Human Cognitive and Brain Sciences, Leipzig, Germany, [2]University of the Basque Country, Bilbao / Vitoria-Gasteiz, Spain* – The extent to which specific aspects of human grammars show maturational effects is still not well known: some studies report Age of Acquisition (AoA) effects (Weber-Fox and Neville, 1996; Hahne, 2001) whereas others do not find them for very proficient nonnatives (Rossi et al., 2006; Kotz et al., 2008). We study specific grammatical parameters (Chomsky 1981) absent in the native language of very proficient nonnatives (ergativity and object-verb agreement). We find a difference in processing between natives and nonnatives in one parameter (ergative case) but not in the other (OV agreement). This suggests that different parameters of grammar may have different acquisition windows, and that AoA versus proficiency studies must carefully control for language distance. We conducted an Event-Related Brain potentials (ERP) study on ergative case and OV agreement processing in Basque, an isolate typologically very distant from Spanish, to determine how natives and very proficient nonnatives (AoA = 3 years)

process these grammatical parameters (Baker 2001). Spanish, native language of the nonnative group, has no ergative case or OV agreement, so our study controls not only for AoA and proficiency but also for language distance. ERP data revealed no differences in processing of OV agreement violations across groups. However, nonnatives did not show a P600 component elicited by the native group for ergative case violations. We thus report maturational effects for one parameter of the grammar but not the other, which suggests that AoA can have an asymmetrical impact, depending on the grammatical parameter at play, independent of proficiency.

D67

GRAMMATICAL GENDER PROCESSING IN FRENCH AS A FIRST AND SECOND LANGUAGE: AN ERP STUDY OF THE EFFECT OF PHONOLOGICAL REALIZATION *Haydee Carrasco[1], Cheryl Frenck-Mestre[1]; [1]Université de Provence* – The present study further examined how phonological cues may impact grammatical gender processing in French as a first and second language. Recent ERP studies have shown that native and non-native readers benefit from the presence of phonological cues during grammatical processing (Osterhout et al., 2006; Frenck-Mestre et al., 2008). Herein, ERPs were recorded while French natives (N=14) and Spanish-French learners (N=14) read sentences that varied according to the presence versus absence of phonological cues to gender agreement in the determiner phrase (e.g. la musique française/français* vs. la musique espagnole/espagnol*). Grammatical gender was held constant across languages. Results for both natives and learners showed a P600 effect for gender concord errors, which was larger for errors that involved phonological cues. However, differences between groups were observed. Spanish-French learners showed a greater reponse to orally realized than silent errors independent of noun gender. For French native speakers phonology and grammatical gender interacted; the P600 effect was larger for phonologically realized errors that violated masculine than feminine gender concord, whereas for silent errors the P600 effect was of equal magnitude for both genders. These results suggest that native readers are more sensitive to the statistical probability of errors than are learners; gender concord errors on the adjective are indeed least likely for masculine in the presence of phonological cues. Together, our results show that native and non-native readers alike benefit from the phonological realization of morphosyntax and provide further evidence of the role of phonology in processing written language (Harm & Seidenberg, 2005).

D68

SYNTACTIC PROCESSING IN PROGRESSIVE NON-FLUENT APHASIA: THE FUNCTIONAL STATUS OF THE LEFT INFERIOR FRONTAL GYRUS *Stephen M. Wilson[1], Jennifer M. Ogar[1], Federica Agosta[1], Bruce L. Miller[1], Nina F. Dronkers[2], Maria Luisa Gorno-Tempini[1]; [1]Memory and Aging Center, Neurology, University of California, San Francisco, CA, [2]Center for Aphasia and Related Disorders, Veterans Administration Northern California Health Care Service, Martinez, CA* – Progressive non-fluent aphasia (PNFA) is a clinical syndrome characterized by motor speech impairments along with expressive and receptive agrammatism. Patients show left-lateralized atrophy of inferior frontal, motor and insula regions, typically resulting from taopathies. A recent voxel-based morphometric study of syntactic comprehension in a mixed neurodegenerative cohort suggested that the left inferior frontal gyrus (IFG), pars triangularis, is crucial for comprehension of syntactically complex sentences (Amici et al., 2007, J. Neurosci). We used fMRI to investigate functional activity in this region in agrammatic PNFA patients during a syntactic comprehension task. Six patients and eleven healthy age-matched controls were scanned as they performed a sentence-picture matching task with seven conditions varying in degree of syntactic complexity. Controls performed well on all but the hardest sentences; imaging results showed that they differentially recruited several perisylvian regions as sentences became more difficult, including the left IFG. PNFA patients failed on the harder conditions, but performed well on the easier ones. Our central finding was that even while processing these easier sentences, patients exhibited much more extensive activity than controls in the left IFG. This increased activity was likely not due to difficulty alone, since it was observed even when contrasting (different) syntactic conditions on which patients and controls performed comparably. These data suggest that in the earlier stages of PNFA, when tissue is atrophied but not entirely lost, the left IFG is still involved in sentence processing and actually demonstrates excessive BOLD activity, possibly as a consequence of its structurally compromised state.

D69

ADAPTING TO COMPLEXITY: FMRI ADAPTATION DISTINGUISHES SYNTACTIC SPECIFICITY IN SUBREGIONS OF BROCA'S AREA *Andrea Santi[1], Yosef Grodzinsky[1]; [1]McGill University* – We know Broca's area demonstrates greater activation for noncanonical ('The boy [who the tall girl is smiling at _] is Derek') than canonical ('The boy [who _ is smiling at the tall girl] is Derek') sentences, but is this due to a general complexity contrast or a more specific one? The current fMRI adaptation study sought to distinguish between general and selective syntactic accounts of Broca's area by comparing two complexity factors: canonicity (ie, subject vs object extraction) and relative clause position (ie, right-branching vs center-embedding). According to global syntactic accounts, Broca's area is responsible for computing all syntactic representations, but is recruited more the greater the syntactic complexity (Caplan et al., 2000; Just et al., 1996; Stromswold et al., 1996; Friederici, 2006). General syntactic accounts of Broca's area contrast with ones that stipulate it is sensitive to a selective dimension of syntactic complexity represented by the canonicity contrast (Bornkessel et al., 2005; Grewe et al., 2005, 2006; Grodzinsky, 2000; Santi & Grodzinsky, 2007b). In this experiment we investigated adaptation to the two complexity factors - canonicity and relative clause position - in a fast-event related design. A deconvolution analysis demonstrated that posterior Broca's area (BA 44) adapted to both canonicity and relative clause position, whereas anterior Broca's area (BA 45) adapted to canonicity only. Therefore, the results suggest a parcellation of Broca's area with it being general syntactically posteriorly and selective syntactically anteriorly.

D70

OPTIONAL INFINITIVE: EVIDENCE OF HOW THE ADULT BRAIN PROCESSES GRAMMATICAL ERRORS THAT ARE TYPICAL AND ATYPICAL OF CHILDHOOD LANGUAGE ACQUISITION *Ioulia Kovelman[1], Satrajit S. Ghosh[2], Patricia K. OLoughlin[1], Irina Ostrovskaya[1], Tyler K. Perrachione[1], John Lymberis[1], Elizabeth S. Norton[1], Sonia Cosman[1], Kenneth Wexler[1], John D. E. Gabrieli[1]; [1]Brain & Cognitive Sciences, Massachusetts Institute of Technology, [2]Research Laboratory of Electronics, Massachusetts Institute of Technology* – Child language acquisition in many languages is marked by an Optional Infinitive (OI) stage (ages 2-4) during which children use nonfinite (infinitival) verb-forms and finite verb-forms interchangeably in grammatical contexts that require finite forms. In English, children's errors include omissions of past-tense /-ed/ and 3rd singular /-s/. The OI stage phenomenon is well established, but little is known about its neural basis or the impact it may have on adult language use. We compared behavior and fMRI brain activation of grammaticality judgments for sentences with OI-developmental errors (He tall) versus Non-developmental errors (He am tall), that do not occur in typical child language acquisition. Previous imaging studies found that left inferior frontal (LIFG) regions participate in grammaticality judgment, and we hypothesized that LIFG would participate in OI-error judgments. METHODS: In fMRI, fifteen adult English speakers completed a grammaticality judgment task with OI-developmental errors, Non-developmental errors, and Correct sentences. RESULTS: Participants were significantly slower and less accurate on OI-developmental errors relative to other sentences. Consistent with our predictions, OI-developmental errors yielded greater activation in LIFG relative to Correct and Non-developmental error sentences. Sentences with Non-developmental errors yielded greater activation in left inferior parietal cortex relative to

Correct sentences. CONCLUSIONS: This study shows for the first time that processing OI grammatical errors in adulthood results in increased response time and LIFG activation relative to other grammatical errors that are not made in childhood. These findings suggest that the OI stage of child development influences grammatical mental and neural function in adulthood.

D71

AN EVENT-RELATED POTENTIAL STUDY OF VERBAL MEMORY SPAN EFFECTS ON GAP FILLING *Arild Hestvik[1], Evan Bradley[1], Catherine Bradley[1], Tyler Prescott[1], Lauren Sparacino[1], Megan Kaufmann[1]; [1]University of Delaware* – The goal of this study was to examine the relationship between verbal memory span and antecedent reactivation in syntactic gap-filling. Whereas a working memory cost is known to be incurred during the storage stage of this process, less is known about the completion stage of the dependency resolution. (Roberts et al., 2007) reported that only subjects with high verbal memory span exhibited antecedent priming at gap-positions in a cross-modal lexical decision task. This suggests that low-span subjects require more time to integrate the filler, and reactivate the antecedent later. We aimed to measure the time course of gap-filling in different working memory groups by using a continuous event-related potentials measure of the completion stage process. 27 college aged subjects were divided into a low vs. high verbal memory span group based on the Listening Span Test (Daneman & Carpenter, 1980). EEG was recorded from 128 channels while subjects heard sentences like (i) and (ii): (i) *The zebra that the hippo kissed the camel on the nose... (ii) The weekend that the hippo kissed the camel on the nose... We predicted that 'the camel' in (i) should elicit an Early Left Anterior Negativity (ELAN), followed by a P600 (Friederici, 2002), when compared to the grammatical 'the camel' in (ii), and that low-span subjects should show a latency delay. However, both groups exhibited a P600 to the ungrammatical noun phrase, with no group interaction. This suggests that differences in verbal memory span do not affect the completion stage of gap-filling.

D72

TIME-FREQUENCY ANALYSIS OF LATE POSITIVE COMPONENTS DURING LANGUAGE COMPREHENSION *José Corral[1], Horacio Barber[2,1], Maartje van der Meij[2,3], Manuel Carreiras[4,1]; [1]Instituto de Tecnologías Biomédicas, Universidad de La Laguna, Spain, [2]Psicología Cognitiva, Universidad de La Laguna, Spain, [3]Neuropsicología, Universidad de Oviedo, Spain, [4]Basque Research Center for Cognition, Brain and Language, Spain* – Event-Related Potential (ERP) analysis is a robust technique for investigating the temporal brain dynamics related to cognitive processes. In this study we combine this approach with time-frequency analyses of two similar language-related late positivities. Subjects read sentences that involved code switching from L2 (English) to L1 (Spanish), which resulted in a Late Positive Component (LPC). They also read L1 sentences that included a morphosyntactic violation, which again produced a late positivity (P600 effect). Both effects occurred in the same time window and had a similar topographical scalp distribution. We extracted the power and phase of the frequency components active during the ERP effects, for possible differences that could be hidden when comparing the averaged wave amplitudes. Event-Related Synchronization (ERS) in the delta frequency band and Event-Related Desynchronization (ERD) in the alpha frequency band reflect both positivities. Phase information allowed us to compare the topography and strength of synchronization between electrodes in the two experimental tasks. Similarities and differences between both types of effects are discussed in relation with the different interpretations of the late positivities associated to language comprehension.

D73

THE NEUROCOGNITION OF MORPHO-SYNTACTIC PROCESSING IN SECOND LANGUAGE: AN ARTIFICIAL LANGUAGE STUDY *Kara Morgan-Short[1], Karsten Steinhauer[2], Cristina Sanz[3], Mandy Faretta[1], Michael Ullman[3]; [1]University of Illinois at Chicago, [2]McGill University, [3]Georgetown University* – Recent research has shown that artificial language learning can provide a useful model of second language acquisition (e.g., Friederici, Steinhauer and Pfeifer, 2002). Here we use an artificial language to examine the acquisition of morpho-syntax, which is particularly problematic in second language learning (White, 2003). Adult native English speakers learned to speak and comprehend to advanced levels of proficiency an artificial language with both noun-adjective and noun-article gender agreement. Half the subjects learned the artificial language under explicit (classroom-like) training conditions and half learned under implicit (immersion-like) training conditions. Event-Related Potentials (ERPs) were measured in response to auditorily-presented sentences with correct or incorrect agreement twice within each subject, once at low proficiency and once at high proficiency. At low proficiency both types of agreement violation (adjective, article) yielded N400s, but only for the group with implicit training. At high proficiency noun-adjective agreement violations elicited N400s for both the explicit and implicit groups, whereas noun-article agreement violations elicited P600s for both groups. The results suggest that various factors can influence the neurocognition of morpho-syntactic processing in second language acquisition, including training condition (classroom-like vs. immersion-like), proficiency level (low vs. high), and type of morpho-syntactic structure (e.g., article vs. adjective gender agreement). Implications for second language acquisition will be discussed.

D74

READING FLUENCY IN PHONOLOGICAL ALEXIA: FROM SINGLE WORDS TO PHRASES *Kathleen Baynes[1], Eunike Jonathan[2], Christine H. Davis[3]; [1]Center for Mind and Brain, University of California at Davis, [2]University of California at Davis, Psychology, [3]University of California, Speech Pathology and Audiology, Davis* – Phonological alexia is an acquired reading disorder that results in an inability to read out loud function words, verbs and grammatical morphemes whereas concrete nouns and other words with greater semantic content are relatively spared. In the second of a series of interventions, a 46-year-old male with phonological alexia was trained for two weeks for about 1 hour per day. The use of semantic cues at the single word level and intensive implicit practice on sound recognition of function words, verbs, and grammatical morphemes in short sentences were combined in this intervention. Data from reading out loud 20 probe sentences demonstrated a trend toward an increased number of correctly read sentences and a decrease in the number of errors overall, However, some targeted items remained impossible for our participant to read accurately in a sentence context. Generalization of changes in fluency, comprehension and error types were also tracked using the Gray Oral Reading Test pre and post training, Reasons for the difficulty in making a useful improvement in reading specific aspects of text will be discussed in terms of the psycholinguistic source of the deficit and the intended target of the intervention.

D75

THE DYNAMIC ACTIVATION AND RESOLUTION OF SYNTACTIC AND SEMANTIC AMBIGUITY IN SPOKEN LANGUAGE COMPREHENSION: A MEG STUDY *Guosheng Ding[2,1], Billi Randall[1], Barry Devereux[1], Anna Shestokova[1], Lorraine K. Tyler[1]; [1]Experimental Psychology, University of Cambridge, [2]State Key Laboratory of Cognitive Neuroscience and Learning, Bejing Normal University* – Ambiguity is an ubiquitous property of language. Here we investigate when and how ambiguity is resolved during language processing using magnetoencephalography (MEG) to probe the moment-by-moment processing of sentences containing semantic (greasy locks) or syntactic (playing cards) ambiguities. Ambiguous phrases vary in the strength of preference for one reading or another, therefore all sentences were presented twice

with each ambiguous phrase being immediately followed by a disambiguating verb which was consistent with the subordinate (least preferred) reading and therefore inconsistent with the dominant (most preferred) reading. Participants passively listened to the sentences while we recorded activity using MEG (306-channel Vectorview system). Event-related magnetic fields (ERF) were analyzed after MEG epochs were aligned to key points in the speech stream. Neural generator sources were localized using the MNE software. We analysed data from 2 VOIs (LIFG, LpMTG) based on our previous fMRI study (Rodd et al, 2004). Semantic and syntactic ambiguity showed different effects of dominance and disambiguation. Semantic ambiguity produced increased activity for the dominant meaning starting during the ambiguous phrase, which persisted even when the disambiguating word (consistent with the subordinate meaning) was heard. The subordinate meaning became more strongly activated only 900 msec after the disambiguating word. Both LMTG and to a lesser extent LIFG showed this pattern. In contrast, syntactic ambiguity produced minimal effects of preference strength in LMTG, but LIFG showed early and stronger activity for the dominant reading, with a rapid switch to the subordinate reading as soon as the disambiguating word was heard.

D76

ELECTROPHYSIOLOGICAL RESPONSES INDEX GRAMMATICAL ACQUISITION IN SECOND LANGUAGE LEARNERS *Darren Tanner[1], Lee Osterhout[2], Julia Herschensohn[1]; [1]University of Washington, Linguistics, [2]University of Washington, Psychology* – Previous findings on language processing using event-related potentials (ERPs) have shown a neurocognitive dissociation between processing of lexical/semantic violations and morphosyntactic violations, which elicit N400 and P600 ERP components, respectively (Osterhout & Nicol 1999). The current study investigates processing of morphosyntactic (subject-verb agreement) violations in German native speakers (n=13) and low- and intermediate-proficiency second language (L2) learners of German (n=33). Findings show that while morphosyntactic violations elicited the expected P600 component in natives and intermediate L2 learners, the lowest proficiency group showed only an N400 effect. We interpret these results as indicating that L2 learners initially memorize morphologically complex, inflected words as unanalyzed wholes and later decompose these forms into stem+affix sequences, having induced a productive syntactic rule. The low-proficiency learners showed sensitivity to the unexpected forms in the agreement violation condition both behaviorally and electrophysiologically; however, the N400 response indicates difficulty integrating a whole word form into a preceding context. The P600 response in intermediate learners is indicative of more native-like morphosyntactic processing and application morphological decomposition mechanisms in parsing agreement. Moreover, learners', but not native speakers', individual P600 amplitudes showed a significant linear correlation with performance on a grammaticality judgment task. This contrasts with previous ERP findings on L2 learning, which showed no relationship between behavioral and electrophysiological responses (McLaughlin, Osterhout & Kim 2004).

D77

WHAT DOES IT MEAN TO BE PROMINENT? AN ERP INVESTIGATION OF FOCUS *Clinton L. Johns[1,2], Peter C. Gordon[3], Debra L. Long[1,2,4], Tamara Y. Swaab[1,2]; [1]University of California, Davis, [2]Center for Mind and Brain, [3]University of North Carolina, Chapel Hill, [4]University of Central Lancashire, Preston, England* – Repeated name anaphors refer to previously mentioned discourse entities (antecedents). When antecedents are in discourse focus (Debra taught the class because Debra...), processing difficulty results (repeated name penalty, RNP). Discourse focus, which in this case results from syntactic prominence, is a linguistic property that is encoded relatively automatically during sentence comprehension. Non-linguistic devices may also be employed to focus a comprehender's attention on elements of a discourse. However, little is known about the extent to which non-linguistic focus influences the encoding of antecedent representations, or subsequent processing of anaphoric references to them. To study this, we manipulated linguistic and non-linguistic prominence in a series of ERP studies. Linguistic prominence was a function of antecedents' embedding in sentences' syntactic trees (Debra vs Debra and Clint). Non-linguistic prominence was established by transposing the first two letters of the antecedent (eDbra) and asking subjects to generate the name. For the linguistic prominence conditions an RNP effect was found; a reduced N400 effect to coreferential repeated names preceded by non-prominent, normal antecedents. In contrast, when prominent antecedents were generated, increased priming for repeated names was found. Interestingly, memory performance was enhanced for both linguistic and non-linguistic focus conditions. In our last experiment we investigated whether previous results reflect the match of encoding and retrieval processes. Critical names either were read following normal antecedents, or were letter-reversed following generated antecedents. Results reveal differences between the match conditions (normal vs. generation) and strongly suggest that language processing does not simply follow the principles of recognition memory.

Memory: Memory systems

D78

DLPFC DISRUPTION FACILITATES PROCEDURAL MEMORY CONSOLIDATION AND IMPAIRS DECLARATIVE KNOWLEDGE *Neil B. Albert[1,2], Joseph M. Galea[1,3], R. Chris Miall[1]; [1]University of Birmingham, Psychology, UK, [2]University of Chicago, Psychology, [3]Johns Hopkins Medical Institution, Physical Medicine and Rehabilitation* – In procedural learning tasks, an improvement in skill is typically seen after sleep - leading to the recent literature on sleep-dependent motor consolidation. Procedural consolidation can also occur during wakefulness if the declarative memory system's competitive encoding of the sequence is reduced through a secondary cognitive task. Here we used continuous theta-burst transcranial magnetic stimulation (cTBS) to disrupt the dorsolateral prefrontal cortex (DLPFC) immediately after learning a 12-item sequence. We hypothesize that disruption of the DLPFC immediately after sequence learning would degrade declarative memory systems and thus facilitate wakeful skill improvement. Inhibitory cTBS was applied to the left DLPFC (n=10), right DLPFC (n=10), or to an occipital cortical control site (n=10) immediately after sequential reaction time task (SRTT) training. All three groups were retested after 8 daytime hours without sleep. cTBS to the DLPFC degraded recall of the sequence but led to a significant increase in skill. No within day improvement was observed in the control group. These results confirm that processes that interfere with declarative knowledge of recent events allow procedural consolidation during wakefulness. Moreover, we show that the DLPFC is directly involved. Accordingly, sleep-independent procedural consolidation may be driven by processes which thrive in the absence of declarative memory systems.

D79

DELINEATING PERCEPTUAL AND CONCEPTUAL CONTRIBUTIONS TO REPETITION SUPPRESSION WITHIN OCCIPITAL AND TEMPORAL CORTICES *Aidan Horner[1], Rik Henson[1]; [1]MRC Cognition and Brain Science Unit* – Prior exposure to a stimulus can facilitate its subsequent identification and classification. This behavioural facilitation is usually accompanied by a reduction in neural response within distinct cortical regions (Repetition Suppression - RS) (Grill-Spector, Henson, & Martin, 2006). Despite previous research suggesting RS within Occipital/Temporal regions reflects repetition of perceptual and/or conceptual processes (Henson et al., 2003; Horner & Henson, 2008; Race, Shanker, & Wagner, in press) delineating these two possible contributions has not yet been possible. Previous research has suggested RS within left, as opposed to right, Fusiform cortex is less sensitive to changes in view-point (Vuilleumier, Henson, Driver, & Dolan,

2002) and exemplar (Koutstaal et al., 2001). Although these data suggest RS within the left Fusiform may reflect repetition of conceptual processes to a greater degree than right Fusiform it is also possible that such effects are attributable to the repetition of more high-level perceptual processes (e.g., the extraction of three-dimensional object properties). To control for such a possibility we visually presented the names of concrete objects at Study whereas we presented object pictures at Test. Results from two fMRI experiments demonstrate significant RS within left Fusiform and left Lateral Occipital cortex. Furthermore, RS within the equivalent right hemisphere regions do not demonstrate significant RS (indeed, a significant Region-by-RS interaction is present). These results suggest that RS within left Fusiform and Lateral Occipital cortex can result from the repetition of conceptual processes, whereas RS within the equivalent right hemisphere regions is primarily driven by the repetition of perceptual processes.

D80

RESOLVING RETRIEVAL CONFLICT THROUGH INHIBITION *Justin Hulbert[1], Michael Anderson[1]; [1]University of St. Andrews, Scotland* – The very act of retrieving a particular memory can reduce the accessibility of related items, a finding termed Retrieval-Induced Forgetting (RIF). According to the inhibition account of RIF, a retrieval cue (e.g., FRUIT-O__) activates the target memory (ORANGE), as well as its competitors (BANANA), creating conflict, which is detected by the ACC, and resolved by inhibiting the interfering competitor through the intervention of the prefrontal cortex (Kuhl et al., 2007). Non-inhibitory accounts of RIF have largely struggled to account for the finding that RIF generalizes to novel test cues, such as MONKEY-B__. Recently, however, it has been suggested that the cue-independent impairment reflects associative interference arising from the covert retrieval of study cues (FRUIT) while trying to access the competitor from the independent probe. If true, strengthened competitors (ORANGE) might then impede retrieval. In the current series of experiments, we demonstrate that strengthening a target in the absence of retrieval fails to generate the predicted impairment, indicating that associative blocking is insufficient as an account of cue-independent impairment. Moreover, the results support an inhibitory account, in that RIF is found to be cue-independent, retrieval-specific, and interference-dependent. Methods for further specifying the neural underpinnings of cue-independent forgetting are discussed.

D81

BRAIN ELECTROPHYSIOLOGICAL CORRELATES OF RECOGNITION WITHOUT IDENTIFICATION *Anne Cleary[1], Anthony Ryals[1], Carly Yadon[1], Jason Nomi[1], Faith Williams[2], Madeline Krawzoff[1], Chris Boreson[1], Joshua Rooney[1]; [1]Colorado State University, [2]Capital University* – Old-new recognition memory is typically characterized by two ERP signatures, an earlier FN400 old-new effect that is thought to be related to familiarity, and a later parietal old-new effect that is thought to be related to recollection. The present study demonstrates a very early ERP old-new effect related to the recognition without identification (RWI) effect. RWI is the finding that people can discriminate between old and new items on a recognition test when the items themselves cannot be identified. For example, when participants study a list of words and are tested with word fragments, they can discriminate between unidentified fragments of studied and of unstudied words. The present study searched for ERP correlates to this effect. ERPs were recorded at test using a 128-channel Hydrocel Geodesic sensor net. Our primary interest was in ERPs for word fragments that went unidentified. ERP old-new differentiation among unidentified items began to emerge as early as 100-150 ms post-stimulus. This ERP old-new differentiation was characterized by a polarity reversal across hemispheres such that unidentified old items led to greater positivity than unidentified new items in the left hemisphere and new items led to greater positivity than old items in the right hemisphere. This old-new polarity reversal across hemispheres was significantly greater over inferior sites than over superior sites and persisted across the entire 1000 ms recording window once it emerged. These findings suggest that, among items that are not identified, the brain can differentiate old and new items very early on in processing.

D82

IMPAIRED CATEGORY FLUENCY IN MEDIAL TEMPORAL LOBE AMNESIA: THE ROLE OF EPISODIC MEMORY *Daniel Greenberg[1], Margaret Keane[1,2], Lee Ryan[3], Mieke Verfaellie[1]; [1]VA Boston Healthcare System, Boston University, Boston, MA, [2]Wellesley College, Wellesley, MA, [3]University of Arizona, Tuscon, AZ* – Memory tasks are often classified as semantic or episodic, but recent research shows that semantic and episodic memory are highly interactive. Category fluency, for example, is generally considered to reflect retrieval from semantic memory, but behavioral evidence suggests that episodic memory is also involved: Participants frequently draw on their autobiographical experiences while generating exemplars for certain categories. Neuroimaging studies accordingly have reported increased medial temporal lobe (MTL) activation during exemplar generation. Studies of MTL amnesics have yielded mixed results, but these studies were not designed to examine potential contributions of episodic memory. We addressed this issue by asking MTL amnesics and controls to generate exemplars for three types of categories. One type tended to elicit autobiographical and spatial strategies (AS). Another type elicited strategies that were autobiographical but nonspatial (AN). The third type elicited neither autobiographical nor spatial strategies (N). 9 patients and 10 controls generated exemplars for 8 categories of each type. Patients were impaired on all three category types but showed greater impairment on AS and AN categories. After covarying for verbal fluency (total FAS score), the N category impairment was not significant, but the impairment on AS and AN categories remained. The same results were seen when patients with damage extending into lateral temporal regions were excluded. We conclude that patients' episodic memory impairment hindered their performance on this putatively semantic task. This interaction between episodic and semantic memory might partially account for the fluency deficits seen in aging, depression, mild cognitive impairment, and Alzheimer's.

D83

AGE EFFECTS ON NEURAL CORRELATES OF CUED RECALL: AN EVENT-RELATED POTENTIAL STUDY *Séverine Fay[1], Lucie Angel[1], Badiâa Bouazzaoui[1], Laurence Taconnat[1], Lionel Granjon[1], Michel Isingrini[1]; [1]UMR CNRS, Université François-Rabelais de Tours* – A hallmark of cognitive aging is a deficit in episodic memory, which reflects structural and functional cerebral changes. The purpose of the present study was to investigate age differences in electrophysiological correlates of retrieval success in a word-stem cued recall task. To do so, event-related potentials (ERPs) were recorded while young (M ± SD: 21.4 years ± 1.9) and older (M ± SD: 65.1 years ± 3.3) adults tried to complete stems with a previously studied item or with any other suitable word if a studied item cannot be recalled. Behavioural data indicated that correct recall rate was significantly lower for older than for young participants. Robust event-related brain potential (ERP) old/new effects were identified in both age groups: event-related potentials evoked by stems completed with studied words were more positive than those evoked by stems completed with unstudied items. The main age differences were observed in latency and lateralization of old/new effects. Young adults exhibited a parietal effect that became focused over left parietal electrodes, whereas no asymmetry was observed in older adults. These results are congruent with the hemispheric asymmetry reduction in older adults model. Moreover, ERP effects were delayed in the older group relative to the young group. Overall, these findings provide some evidence of the reduction of processing speed during aging and suggest that young and older adults may recruit distinct cerebral patterns during episodic cued recall.

D84

PROTECTIVE ROLE OF EDUCATIONAL LEVEL ON MEMORY AGING: AN EVENT-RELATED POTENTIAL STUDY *Lucie Angel[1], Michel Isingrini[1], Séverine Fay[1], Badiâa Bouazzaoui[1], Laurence Taconnat[1]; [1]UMR-CNRS University François-Rabelais of Tours, France* – The present experiment aimed at investigating whether educational level could modulate age effects on episodic memory and on the electrophysiological correlates of retrieval success (old/new effects). Participants were dissociated into four groups of 14 adults according to age (young vs. old) and educational level (high vs. low). Event-related brain potentials (ERPs) were recorded while participants were performing a word-stem cued recall task. A significant interaction between education and age indicated that age-related memory deficits were greater for the less educated individuals. Old/new effects differed according to age and education. The young groups exhibited effects on both frontal and parietal areas. For the young-high group, the parietal effect was predominant over the left hemisphere whereas for the young-low participants, it was entirely left-sided. In addition, the parietal effect was earlier, longer and greater for the more educated young adults. Long-lasting old/new effects that were symmetrically distributed on both hemispheres were also reported in the old-high group on frontal and parietal electrodes. No age effect was observed on frontal areas whereas the magnitude of the parietal effect was reduced in old-high relative to young-high participants. Old-low adults showed a late and short ERP effect on the right parietal site, smaller than for young-low participants. This study demonstrated that age effects on episodic memory and ERP correlates of retrieval success were reduced in high-educated relative to less-educated individuals. These findings provide support for the brain reserve hypothesis and raise the need for considering individuals differences when studying cognitive and cerebral changes in aging.

D85

FORGETTING OF EMOTIONAL VERSUS NEUTRAL IMAGES IN THE AGING BRAIN *Håkan Fischer[1], Stuart MacDonald[2], Anna Rieckmann[1], Joachim Gavazzeni[1], Lars Bäckman[1]; [1]Karolinska Institute, Sweden, [2]University of Victoria, Canada* – Forgetting is a memory-related process that begins immediately following the initial encoding of information and proceeds across time. Our objective was to investigate the neurobiological basis of the forgetting process by means of event-related functional magnetic resonance imaging (fMRI). Of chief interest was the extent to which aging and the emotional valence of images affect patterns of functional brain activation over time. Twenty younger (20-30 years) and 20 older (65-75 years) adults were scanned during encoding. Episodic memory performance was assessed on three separate occasions, and forgetting slopes were regressed on BOLD activations at encoding. Initial results indicate that both aging and emotionality influence the neural correlates of forgetting. Countering previous claims, the present results indicate that (a) rate of forgetting is not uniform across individuals, and (b) the neurobiological basis of forgetting varies as a function of both age and the emotional content of images.

D86

THE UN-RESTED RESTING BRAIN: SLEEP-DEPRIVATION AS A STATE OF ABERRANT DEFAULT-MODE ACTIVITY *Ninad Gujar[1], Seung-Schik Yoo[2], Peter Hu[1], Matthew Walker[1]; [1]Sleep and Neuroimaging Laboratory, Psychology and Helen Wills Neuroscience Institute, University of California, Berkeley, California, [2]Brigham and Women's Hospital, Radiology, Harvard Medical School, Boston, MA* – The sleep-deprived brain has principally been characterized by examining dysfunction during cognitive-task performance. However, far less attention has been afforded the possibility that sleep deprivation may be as, if not more, accurately characterized on the basis of abnormal resting-state brain activity. Here we report that one night of sleep deprivation significantly disrupts the canonical signature of task-induced deactivation, resulting in a double dissociation within the dorsal medial frontal cortex and precuneus of the default network. Indeed, deactivation within these regions alone discriminated sleep-deprived from sleep-control subjects with a 93% degree of sensitivity and 92% specificity. In addition, the relative balance of deactivation within these default nodes significantly correlated with the amount of prior sleep in the control group (and not extended time awake in the deprivation group). Therefore, the stability and balance of task-induced brain deactivation in key default-mode regions may be dependent on prior sleep, such that a lack thereof disrupts the intrinsic mode of resting brain activity; findings that may offer explanatory insights into conditions associated with sleep loss at both a clinical as well as societal level.

D87

RELATIONAL AND NON-RELATIONAL MEMORY: ELECTROPHYSIOLOGICAL CORRELATES OF NOVELTY DETECTION, REPETITION DETECTION, AND SUBSEQUENT MEMORY *Eleonore Xian-Chay Soei[1,2], Christian Bellebaum[1], Irene Daum[1,2]; [1]Institute of Cognitive Neuroscience, Neuropsychology, Ruhr-University Bochum, Universitaetsstrasse, Bochum, [2]International Graduate School of Neuroscience, Ruhr-University Bochum* – The dissociability of novelty detection in relational and non-relational memory is currently under debate. To further address the time courses and underlying brain correlates of novelty detection, event-related potentials were analysed for encoding and retrieval on three memory tasks in healthy subjects. Spatial and non-spatial relational as well as non-relational memory were assessed separately. The event-related potentials related to relational and non-relational memory were dissociable for hits and correct rejections in an early and late time window. An early old/new effect was observed for non-relational memory. A late old/new effect replicated the frequently reported recollection-associated old/new effect in terms of direction and amplitudes. Four different novelty types (spatial relational, non-spatial relational, horizontal non-relational and inverted non-relational) were examined. The P3a related to novelty detection differed in horizontal vs. inverted distractors in non-relational memory but not in spatial vs. non-spatial relational memory. Event-related potentials for repetition detection (hits during retrieval) and also for subsequent hits (encoding phase) differed between relational and non-relational memory. These findings are discussed in relation to potential brain correlates in relational and non-relational memory during encoding and retrieval.

D88

NEURAL CORRELATES OF IMPLICIT LEARNING - EFFECTS OF PERFORMANCE AND AGE *Anna Rieckmann[1], Håkan Fischer[1], Lars Bäckman[1]; [1]Aging Research Center, Karolinska Institute, Sweden* – There is evidence that increases in striatal activation are accompanied by decreases in hippocampal activation over time during implicit learning (IL) in young adults. This study investigates this interaction in relation to (a) performance and (b) to striatal integrity as a function of aging. Twenty-seven adults (14 young and 13 old) performed a Serial Reaction Time task (SRTT) during fMRI acquisition. Both groups showed comparable IL, but age differences appeared on the neural level. For young adults, better IL performance was related to a larger increase in striatal activation and a larger decrease in hippocampal activation over time. For older adults, better IL performance was linked to a parallel increase in both striatal and hippocampal activation. This interaction is interpreted in terms of competing memory systems that may become more cooperative in advanced age for compensatory purposes. We also present preliminary data on the effects of a hippocampal-dependent dual task on performance in the SRTT for both younger and older adults.

D89

THE OPAQUE RECOLLECTION: AN ERP STUDY OF THE ROLE OF SEMANTIC TRANSPARENCY IN THE RECOGNITION MEMORY OF CHINESE TWO-CHARACTERS COMPOUND WORDS *Shih-kuen Cheng[1], Shuo-Chieh Huang[1], Daisy L. Hung[1], Ovid J.-L. Tzeng[1,2]; [1]Institute of Cognitive Neuroscience, National Centra University, Taiwan, [2]Institute of Linguistics, Academia Sinica, Taiwan* – The Remember/Know judgments and ERP old/new effects were used in two experiments to investigate how the recognition memory for Chinese compound words is modulated by the words' semantic transparency. At study, participants made lexical decisions to 46 semantic transparent words [e.g., ? (/cha/, tea) ? (/bei/, cup): teacup], 46 semantic opaque words [e.g., ? (/yang/, sun) ? (/chun/, spring): plain], and 92 two-characters nonwords. At test, they made old/new judgments to the 92 studied real words and 92 non-studied new words, among which half were transparent and the other half were opaque. The frequency, neighborhood size, and concreteness were matched for the transparent and opaque words. The behavioral results showed that opaque words gave rise to a higher hit rate than transparent words. In addition, the proportion of Remember response was higher for opaque words than transparent ones. The ERP results showed that the mid-frontal old/new effect, thought to index familiarity-based recognition, was of similar magnitudes for both types of words. Opaque words, when compared with transparent words, yielded a larger parietal old/new effect, which has been thought to index recollection-based recognition. These results demonstrated that opaque words are better remembered than transparent ones, and the advantage for opaque words is related to the contribution of recollection processes. The greater recollection for opaque words than semantic ones may result from the different morphological structures between the two types of words.

D90

CORTICAL-MTL CIRCUITRY DURING LONG-TERM MEMORY FORMATION *Katherine V. Roe[1], Karen F. Berman[1]; [1]Section on Integrative Neuroimaging, Clinical Brain Disorders Branch, National Institute of Mental Health, National Institutes of Health* – The hippocampus and adjacent medial temporal structures are critical to the formation of contextually rich, multi-featured long-term memory (LTM) representations. The current study used event-related fMRI to investigate hippocampal-cortical interactions necessary for binding different information types together in LTM. Functional T2*-weighted gradient echo, echo planar images were acquired at 3T while 24 participants performed a delayed match to sample task. Test items were drawn from a small, fixed set of distinct object-classes (letters, shapes, and line-orientations), allowing for repeated exposure to each item. Color and location of each item remained constant across each presentation, and participants' recollection of this contextual information was assessed at the end of the session. Random effects analyses ($p<.01$, corrected) were used to identify regions differentially active during short-term maintenance of different stimulus types and regions crucial for encoding and recall of different contextual information (color, location). Hippocampal-cortical interactions during successful multi-feature learning were also assessed. Results suggest regions involved in learning item-context associations are similar to those needed for short-term maintenance, with greater hippocampal involvement during successful multi-feature binding, independent of specific feature or context type. Context recall varied across stimulus types, including greater IFG recruitment during recall of letter-context information but greater parahippocampal (PHG) and parietal recruitment during recall of shape-context associations. Functional connectivity analyses demonstrated greater coherence between hippocampus-PHG-parietal regions during shape-context association formation, but greater hippocampal-fusiform coherence learning letter-context association learning. These data suggest the MTL-cortical networks crucial for creating multi-faceted LTM representations depend on the specific associations being learned.

D91

PROCESSING OF LIVING AND NONLIVING OBJECTS DIVERGES IN OCCIPITO-TEMPORAL CORTEX: EVIDENCE FROM MEG *Jessica Gilbert[1], Laura Shapiro[1], Gareth Barnes[1]; [1]Clinical and Cognitive Neurosciences Research Group, Aston University, Birmingham, UK* – We explored the time-course of category-specific effects using magnetoencephalography (MEG) in order to assess when processing living and nonliving objects diverges in the visual object-processing system. We used a superordinate categorization task in which participants (N=10) were shown a category label followed by a target object and were instructed to decide whether the object and category label matched. A total of 78 target objects were displayed, drawn from 3 living and 3 nonliving categories. Each object was displayed twice, once as a congruent trial and once as an incongruent trial. The behavioral data revealed no difference in performance between living and nonliving objects. Utilizing a 400 ms window beginning at target object onset, we directly contrasted living and nonliving objects using a wide-band (1-80Hz) source analysis. This group analysis identified a region in left occipito-temporal cortex showing greater power for living compared to nonliving objects We then constructed virtual electrodes at the peak location in this region for each subject to assess the time at which these category differences occurred. Time-frequency findings from this region identified a peak difference at roughly 180-200 ms after a target object, driven by low-frequency (~1-20 Hz) differences in processing living and nonliving objects. These findings suggest an early, perceptually-driven difference in processing living versus nonliving objects, which should be considered in current theories of category-specificity. The influence of this early difference on later, semantic processing will be discussed.

D92

COMPARISON OF THE NEURAL CORRELATES OF RETRIEVAL SUCCESS IN TESTS OF CUED RECALL AND RECOGNITION MEMORY *Kaia Vilberg[1], Kayoko Okada[1], Michael Rugg[1]; [1]Center for the Neurobiology of Learning and Memory, University of California, Irvine* – While numerous event-related fMRI studies have characterized the neural correlates of successful recognition memory, almost none have studied cued recall, and none have directly contrasted the correlates of successful recall and recognition. The present study addressed this issue by identifying commonalities and differences between retrieval success effects in these two tasks. Participants (N = 19) underwent two study-test blocks. The two study phases were identical, but one test phase involved word-stem cued recall, whereas the other involved a yes/no recognition test. Retrieval success (Hit > Correct Rejection (CR)) effects common to the two tasks were found in bilateral medial (BA 7) and lateral parietal cortex (BA39/40), and the right entorhinal cortex. The reverse contrast revealed common CR > Hit effects in anterior cingulate/medial BA6, left inferior prefrontal cortex (PFC), and left anterior intraparietal sulcus. Interaction contrasts revealed greater Hit > CR effects for cued recall in a left inferior lateral parietal region abutting the region showing the common effect. More striking, the contrasts also revealed a cross-over interaction in right dorsolateral and lateral anterior PFC, these regions demonstrating CR > Hit effects for recall, and Hit > CR effects for recognition. These findings suggest that medial and lateral parietal regions support processes engaged by successful episodic retrieval regardless of how retrieved information is accessed. The findings for the right PFC are consistent with a role for this region in evaluating the outcome of a retrieval attempt.

D93

TWO PATHS TO ATTRIBUTING TRUSTWORTHINESS: NEURAL SIGNALS OF PERCEPTUAL- AND MEMORY-DRIVEN INFLUENCES *John Rudoy[1,2], Ken Paller[1,2]; [1]Northwestern University Interdepartmental Neuroscience Program, [2]Northwestern University, Psychology* – When people rate the trustworthiness of a novel face, their judgments tend to resemble the consensus ratings made by others. Therefore, something about the appearance of a person's face can bias one's

estimate of another's trustworthiness. Fortunately, one can also use memory for past events when deciding who should be trusted. When participants in fMRI experiments view faces, amygdala activation correlates more closely with consensus ratings more than with idiosyncratic trustworthiness ratings made by the participant (Engell, Haxby, & Todorov, 2007, J Cog Neurosci). Two processes may thus compete for control of trustworthiness judgments: 1) a fast, amygdala-associated process of perceptual analysis, corresponding to consensus judgments, and 2) a slow process of conscious retrieval, corresponding to idiosyncratic judgments. We recorded EEG responses to faces to determine the relative timing of these two hypothesized processes. First, faces were paired with positive or negative attributes, such that attribute valence varied orthogonally with consensus ratings of face trustworthiness. Subsequently, trustworthiness ratings for these faces were found to vary as a function of both consensus trustworthiness and the previous attribute pairings. During this rating phase, frontal brain potentials at about 400-600 ms were associated with consensus trustworthiness, independent of ratings, and posterior brain potentials at 800-1000 ms were associated with the valence of the word paired with the face earlier. These findings thus provide evidence of both an early path to trustworthiness judgments based on perceptual analysis and a later path to trustworthiness judgments based on memory retrieval.

D94

EFFECTS OF AGE AND MEMORY FUNCTION ON THE NEURAL CORRELATES OF SUCCESSFUL ASSOCIATIVE MEMORY ENCODING *Marianne de Chastelaine[1], Tracy H. Wang[1], Brian Minton[1], Heekyeong Park[1], Michael Rugg[1]; [1]University of California, Irvine* – Studies of age-related differences in the neural correlates of successful memory encoding often report encoding-related activity that is more bilaterally distributed in older adults compared to young individuals. This tendency towards bilateral distribution of encoding-related activity has recently been associated specifically with relatively low levels of memory function rather than with the effects of age per se. These findings are inconsistent with proposals that the relative preservation of memory performance with increasing age depends upon right prefrontal 'over-recruitment'. Here, we used an associative memory task to further investigate the relationship between the lateral distribution of encoding-related activity and memory function in older adults. Eighteen young, and 36 older, adults were scanned while they made relational semantic decisions on a series of visually presented word pairs. Participants later made associative recognition judgments on studied, rearranged and new pairs. Older adults were segregated according to a median split of their performance on a standard neuropsychological test of memory function, the California Verbal Learning Test (CVLT). Analyses of subsequent memory effects in left prefrontal and homotopic right prefrontal voxels revealed that the effects were more bilaterally distributed in the older adults. As was found previously, this age-related laterality difference was confined to low-performing older adults. Additionally, CVLT performance was positively correlated with the level of asymmetry of prefrontal subsequent memory effects, and was negatively correlated with the magnitude of the right prefrontal effect. These findings are consistent with proposals that right prefrontal over-recruitment reflects age-related degradation of cortical function.

D95

HUMANS DISPLAY CONDITIONED PLACE PREFERENCES FOR VIRTUAL ROOMS PAIRED WITH NICOTINE *Robert Astur[1,2], Seth Shipman[1], Heather Breslawski[1], Albert Rizzo[3], Shepard Seigel[4]; [1]Olin Neuropsychiatry Research Center, Institute of Living, Hartford, CT, [2]Yale University School of Medicine, Psychiatry, New Haven, CT, [3]Institute for Creative Technologies, School of Gerontology, University of Southern California, Los Angeles, CA, [4]McMaster University, Psychology, Neuroscience and Behavior, Hamilton, Ontario, Canada* – Within human research, there has been a lack of research aimed at elucidating how environmental or contextual factors provoke drug cravings. Within rodent research, these factors are studied using a conditioned place preference (CPP) paradigm, whereby a specific environment is paired with a positive reinforcer such as cocaine, alcohol, sex, or food, and via classical conditioning, a preference exists for the reinforcer-paired environment in the absence of the reinforcer. To study this in humans, we have created a virtual analogue of the CPP to examine whether such a preference can be established in a virtual reality environment. In this study, 34 social or heavy nicotine smokers were given repeated pairings of nicotine via cigarettes in one specific virtual environment, and a placebo in a different virtual environment. We also collected data on how much the participants enjoyed their laboratory drug use and also how negative they felt about their overall drug use. Accounting for the relative reinforcement strength of the nicotine strongly predicts the extent to which participants display a CPP. Specifically, the more that the participants preferred the nicotine cigarettes, the stronger their place preference for the nicotine-paired room, $r = 0.83$, $p < 0.001$. Interestingly, this effect is different for the social vs. the heavy smokers. We discuss how reinforcement and design factors account for these differences. Nonetheless, we can establish a CPP in humans using nicotine, and we are now poised to attempt to block CPPs in humans.

D96

MEDIAL TEMPORAL LOBE CONTRIBUTIONS TO RAPID ACQUISITION AND FLEXIBLE TRANSFER OF EPISODIC MEMORIES *Dagmar Zeithamova[1,2], Nicolaus Schmandt[1,2], Alison Preston[1,2]; [1]University of Texas at Austin, Psychology, [2]University of Texas at Austin, Center for Learning and Memory* – The medial temporal lobe (MTL) is thought to support rapid acquisition of episodic experience and to create memories that are flexible in nature, allowing for generalization from previous experiences to novel events and stimuli. One theory suggests that such generalization stems from inference based processes at the time of retrieval, while a competing hypothesis proposes that generalization results from integrative processes at the time of encoding of overlapping events. The goal of the present study was to test these competing hypotheses by using an associative inference paradigm (AIP) where participants rapidly learned overlapping associations in a single trial and were subsequently probed with novel stimulus combinations that required flexible transfer of learned information. Functional MRI revealed MTL regions, including hippocampus and surrounding MTL cortices, that were preferentially active during encoding of the overlapping associations. Subsequent memory analyses further revealed that encoding activation in MTL regions predicted later transfer performance both within and across participants, consistent with the integrative encoding hypotheses. During flexible transfer, we identified MTL regions distinct from those at encoding whose activation differed based on correct transfer performance, consistent with the hypothesis of inferential processes during retrieval. Additional high-resolution fMRI data further localized these encoding and retrieval effects to specific MTL subregions. These findings suggest that flexible generalization of rapidly acquired episodic experience depends on integrative processes during encoding as well as inferential processes during retrieval.

D97

DEEP BRAIN STIMULATION OF THE SUBTHALAMIC NUCLEUS IMPROVES IMPLICIT SEQUENCE LEARNING AND LEARNING-RELATED CORTICO-STRIATAL ACTIVATION IN PARKINSON'S DISEASE. EVIDENCE FROM A [15O]H2O-PET STUDY *Leonora Wilkinson[1], Gary Hotton[2], Yen Tai[2], Nicola Pavese[2], David Brooks[2], Marjan Jahanshahi[1]; [1]Sobell Motor Neuroscience, Institute of Neurology, UCL, [2]MRC Cyclotron Building, Faculty of Medicine, Imperial College, London* – Implicit sequence learning during the serial reaction time task (SRTT) has been shown to be mediated by the cortico-striatal circuits. Patients with Parkinson's disease (PD) show attenuated learning on the SRTT, which is completely abolished following surgical lesioning of the internal segment of the globus pallidus The present study examined the effect of deep brain stimulation (DBS) of the subthalamic nucleus (STN) on SRTT learning in PD and on associated patterns of brain activation. 7 PD patients

with DBS of the STN assessed after overnight withdrawal of dopaminergic medication and 9 matched controls were studied with a [15O]H2O-PET. PD patients completed the SRTT (5 scans) or a control random sequence (1 scan) with DBS on and off, with order counterbalanced and using parallel sequences. Controls also performed the SRTT (5 scans) and random sequences (2 scans) twice during PET scanning. Controls showed significant SRTT learning-related activation in the -striatal circuits. In contrast, with DBS off, PD patients, showed no learning and no learning-related activation in the striatum. However, with DBS on, PD patients showed significantly more learning and more learning-related activation in the cortico-striatal circuits. The results provide evidence for the modulation of the cortico-striatal circuits involved in implicit sequence learning by DBS of the STN in PD. The differing effects of DBS of the STN and pallidotomy on SRTT in PD suggest that their mechanisms of action are different.

D98

NEURAL CORRELATES OF SEMANTIC AND EPISODIC MEMORY IN HEALTHY ELDERLY SUBJECTS: A MAGNETOENCEPHALOGRAPHIC (MEG) STUDY *Valentina La Corte[1,2,3,4], Nathalie George[2,3,4], Bruno Dubois[1,3], Line Garnero[2,3,4], Gianfranco Dalla Barba[1,3,5]; [1]INSERM Unité 610, Hôpital de La Salpêtrière, Paris, France, [2]CNRS, UPR 640, Laboratoire de Neurosciences Cognitives et Imagerie Cérébrale, Hôpital de La Salpêtrière, Paris, France, [3]Université Pierre et Marie Curie-Paris 6, France, [4]Centre MEG/EEG, Hôpital de La Salpêtrière, Paris, France, [5]AP-HP, Hôpital Henri Mondor, Service de Neurologie, Créteil, France* – The hierarchical hypothesis assumes that episodic memory is a specific subsystem of semantic memory and that the neural networks implicated in the two systems largely overlap. In this study, we used MEG in 17 healthy elderly subjects who performed a semantic and an episodic memory task. The aim of this work was to determine the neural correlates and the temporal dynamic underlying the semantic and episodic components of face recognition in cognitive aging. In the semantic task, 56 faces (28 famous and 28 unknowns) were presented and subjects had to decide for each face whether it was famous or unknown. In the episodic task, subjects were asked to recognize among distracters the faces they had seen in the semantic task. Behavioral results show that the level of semantic awareness of an item affects the recognition of that same item in the episodic memory task. At physiological level, in the semantic task, evoked fields associated to famous faces were stronger than those associated to unknown faces, in the right temporal region between 400 and 600 ms and in the left fronto-temporal region between 600 and 800 ms. During episodic task, evoked fields associated to the recognition of the studied faces were stronger than those associated to new faces, between 400 and 600 ms, and between 600 and 800 ms in temporo-parietal sensors (old/new effect). Consistently with the hierarchical hypothesis, our results show that episodic memory strongly relies on semantic memory and that the neural correlates of the two systems largely overlap.

D99

DIFFERENTIAL PATTERNS OF HIPPOCAMPAL ACTIVITY DURING CONTINUOUS RECOGNITION: A HIGH-RESOLUTION FMRI STUDY *Maki Suzuki[1], Jeffrey D. Johnson[1], Michael D. Rugg[1]; [1]Center for the Neurobiology of Learning and Memory & Neurobiology and Behavior, University of California, Irvine* – In a previous study (Johnson and Rugg, 2008, Hippocampus), it was reported that different hippocampal regions responded to multiple repetitions of items in a continuous recognition task in two distinct ways. Some regions demonstrated repetition-related response reductions that were 'graded' (gradually diminishing responses across repetitions), whereas other regions demonstrated a 'categorical' repetition effect (asymptotic response reduction on the first repetition). Here, we used high-resolution functional magnetic resonance imaging (fMRI) to investigate whether medial temporal lobe (MTL) activity varies across successive item presentations when the requirement was to track the number of presentations of each item. While being scanned, 16 subjects were presented with a series of pictures and were required to respond with one finger to items presented for the first or the third time, and with another finger to items appearing for the second or the fourth time. Repetitions were separated by a mean of 23 trials. Consistent with previous findings, new items elicited larger fMRI responses than repeated items in both bilateral hippocampus and parahippocampal cortex. There were no MTL regions where activity was greater for old items. Both graded and categorical response profiles were evident within adjacent hippocampal regions. Other regions, however, demonstrated profiles that varied between these two extremes. These findings highlight the ubiquity of hippocampal 'recognition suppression effects' during continuous recognition, and add to the evidence that different hippocampal regions respond to the relative novelty/familiarity of stimulus events in very different ways.

D100

WHAT DOES THE POSTERIOR PARIETAL CORTEX (PPC) TELL US ABOUT EPISODIC ENCODING? A META-ANALYSIS OF PPC SUBSEQUENT MEMORY EFFECTS *Melina Uncapher[1], Anthony Wagner[1,2]; [1]Stanford University, Psychology, Stanford CA, [2]Stanford University, Neurosciences Program, Stanford CA* – The formation of episodic memories -- memories for life events -- is affected by attention during event processing. A leading neurobiological model of attention posits two separate yet interacting systems that depend on distinct regions in lateral posterior parietal cortex (PPC). From this dual-attention perspective, dorsal PPC is thought to support the goal-directed allocation of attention, whereas ventral PPC is thought to support reflexive orienting to information that automatically captures attention. To advance understanding of how parietal mechanisms may impact event encoding, we present a meta-analysis of functional MRI studies that document the relationship between lateral PPC activation during encoding and subsequent memory performance (e.g., later remembering or forgetting). This meta-analysis reveals that (a) encoding-related activity is frequently observed in human lateral PPC, (b) increased activation in dorsal PPC is associated with later memory success, and (c) increased activation in ventral PPC predominantly correlates with later memory failure. From a dual-attention perspective, these findings suggest that allocating goal-directed attention during event processing increases the probability that the event will be remembered later, whereas the capture of reflexive attention during event processing may have negative consequences for event encoding. The prevalence of encoding-related activation in parietal cortex suggests that neurobiological models of episodic memory should consider how parietal-mediated attentional mechanisms regulate encoding.

D101

MODULATION OF THE EMOTIONAL MEMORY NETWORK DURING FREE VIEWING OF A BASKETBALL GAME *Anne Botzung[1], Kevin S LaBar[1], Amanda Miles[1], Philip Kragel[1], David C Rubin[1]; [1]Duke University, Psychology & Neuroscience* – Our aim was to investigate brain activity associated with the encoding of realistic, highly emotional and self-relevant stimuli. A 30-minute portion of a basketball game involving a traditional college basketball rivalry, Duke vs. UNC, was presented in the fMRI scanner to dedicated fans from the two opposing schools. During a subsequent recognition memory task outside the scanner, the participants were shown eighty 15-s video clips depicting plays from the most exciting periods of the game, stemming either from the portion viewed before (targets), or from non viewed portions of the same game (foils). Half the clips were emotionally positive and half emotionally negative for fans of each team. After an old-new judgment, participants provided memory confidence, and emotional valence and intensity ratings for each clip. fMRI signal acquired during the entire free-viewing session was decomposed into spatially independent networks using independent component analysis. A correlation analysis was performed between neural activity associated with each component during the previously selected 15-s portions of the game and corresponding post-viewing ratings. Interestingly, the component showing the highest level of correlation with intensity included key regions of both memory and emo-

tional circuitries: respectively, the hippocampus bilaterally, visual cortex, medial posterior cingulate and precuneus, medial and orbital prefrontal cortex, as well as the amygdala. These findings contribute to our understanding of the effects of emotion on the encoding process of real-life emotional stimuli.

D102

EFFECT OF SUBCHRONIC NOISE STRESS ON SPATIAL MEMORY AND LEARNING IN WISTAR RATS *Leonardo Hernandez[1], Jassica Soria-Fregoso[1], Alma Cisneros-Esparza[1], Gabriela Camargo[1]; [1]Neurociencias, CUCS, Universidad de Guadalajara* – Background: Central Nervous System is (CNS) strongly involved in response to chronic and acute stress. If a stressful event is intense and long, the limbic, hypothalamus-pituitary-adrenal system undergoes changes which depend on intensity and duration of stimulus. However, in case of non extreme conditions of stress is not clear. In this sense, we explore implications on spatial memory and learning in rats undergoing subchronic noise stress. Methods: We used 16 young male Wistar rats were distributed as following: a) Control , 8 animal in standard conditions of vivarium and b) Test, 8 rats in noise condition. Noise exposition consisted in expose animals to high frequency tones (22KHz, at 80-90 dB) 8 hours at day during 10 days. Spatial memory and learning were evaluated in both groups using Morris water maze (MWM), in its classic and reverse learning variant. The quantified parameters were Latency, Spatial specificity, navigation velocity, and locomotion. Results: Noise exposed rats show a better performing in relation of control in both variants of MWM in both variants, classical and reverse learning. Conclusion: Apparently, subchronic noise stress conditions improve the construction of cognitive maps in Hippocampus, (which able to spacial navigation in rats), and optimize the synaptic plasticity mechanisms at hippocampus. These results are different from those reported for chronic or acute stress, where the cognitive impairment and hippocampus plasticity constriction were found.

D103

AUTOBIOGRAPHICAL, EPISODIC, AND SEMANTIC MEMORY: MODELING OF A COMMON FUNCTIONAL NETWORK *Hana Burianova[1,2], Cheryl L. Grady[1,2]; [1]The Rotman Research Institute, [2]University of Toronto* – The objective of this study was to delineate a functional network common to autobiographical, episodic, and semantic types of retrieval. Autobiographical retrieval was defined as the recollection of personally relevant events, episodic retrieval as the recollection of stimuli presented in the laboratory, and semantic retrieval as the recollection of factual information and general knowledge about the world. Young adults participated in an event-related functional magnetic resonance imaging (fMRI) study in which pictorial stimuli were presented as cues for retrieval. By manipulating retrieval demands, autobiographical, episodic, or semantic memories were extracted in response to the same stimulus. We conducted a three-seed partial least squares (PLS) analysis to determine whole-brain functional connections with the left hippocampus, left lingual gyrus, and right caudate nucleus. We delineated a large-scale functional network common to the three memory conditions that comprised 21 functionally connected neural areas (i.e., their activity covaried during any type of declarative retrieval), including the inferior and medial frontal gyri, as well as a number of temporal and parietal areas. These findings lend support to the notion of a common network, which is hypothesized to give rise to declarative memory retrieval, regardless of the type of information processed, along a contextual continuum (i.e., highly contextualized or highly decontextualized).

D104

EVENT-RELATED POTENTIAL CORRELATES OF MEMORY STRENGTH FOR SOURCE JUDGMENTS *Brion Woroch[1], Brian Gonsalves[1]; [1]Beckman Institute, Univ. of Illinois Urbana-Champaign* – Event-related potential (ERP) studies of recognition memory have shown dissociations between item recognition and source memory, wherein item recognition is associated with the mid-frontal FN400 component, which varies continuously with item memory strength, while source memory is associated with the late parietal effect (LPC). There is current debate about whether source memory can vary along a continuum of memory strength or is a threshold process. The LPC has been shown to be generally sensitive to correct versus incorrect source judgments, but varying levels of 'source strength' have not been tested. The current experiment had participants encode novel visual objects in one of two different task contexts by performing either a conceptual or perceptual judgment about the object. On a subsequent memory test, participants made an old/new decision on a 4-point confidence scale followed by a source memory confidence judgment, in which they indicated their confidence about which task they had performed with the object at encoding. ERPs from the memory test were examined for electrophysiological correlates of both item and source memory strength. Item memory was associated with differences in the 300-500ms time window, consistent with the timing of the FN400. Differences in the amplitude of the LPC were observed between correct and incorrect source decisions, consistent with previous findings. Comparing low and high confidence source decisions also revealed differences, suggesting that the LPC is also sensitive to variations in the strength of source memory.

D105

BEHAVIOURAL AND ERP MEASURES OF FAMILIARITY AND RECOLLECTION: EVIDENCE AGAINST THE DOMAIN DICHOTOMY VIEW OF ASSOCIATIVE RECOGNITION *Iain M. Harlow[1], Graham MacKenzie[2], David I. Donaldson[3]; [1]University of Edinburgh, Neuroinformatics DTC, [2]University of Glasgow, Psychology, [3]University of Stirling, Psychology* – Episodic recognition memory is mediated by familiarity and recollection, whose relative engagement depends on both the nature of the stimuli being retrieved and the manner in which memory is tested. For associative retrieval tests, it is unclear exactly what stimulus parameters determine the engagement of familiarity and recollection. One recent proposal, the Domain Dichotomy view (Mayes et al., 2007), states that familiarity should contribute more to associative recognition when pairs of stimuli are similar (i.e., within-domain) than when they are distinct (i.e., between-domain). We tested this prediction using neuroimaging and behavioural measures of familiarity (Event-Related Potentials or ERPs; the Modified Remember Know procedure; and Receiver Operator Characteristics). Participants studied stimulus pairs, and at test discriminated intact from rearranged pairs. Stimuli were either within-domain (word-word or image-image pairs) or between-domain (word-image pairs), allowing familiarity to be estimated for each condition. Contrary to the Domain Dichotomy view, behavioural measures revealed that the contribution of familiarity (and consequently recognition performance overall) was at least as high for the between-domain condition as either within-domain condition. Moreover, ERPs measured at retrieval did not reliably differ between conditions; each revealed a central positivity between 500-1000ms for hits to intact pairs compared to correct rejections of rearranged pairs. When pairs of new items were included as a baseline (in an otherwise identical follow-up study) standard early mid-frontal and left parietal old/new effects were observed in each condition. The results provide convergent evidence that familiarity and recollection support associative retrieval, but not in the way Domain Dichotomy predicts.

D106

BEHAVIOURAL AND EVENT-RELATED POTENTIAL EVIDENCE FOR A DOUBLE DISSOCIATION BETWEEN WORKING AND LONG-TERM MEMORY *Chia-Yun Wu[1], David E. J. Linden[1], Christoph Klein[1], Stephan G. Boehm[1]; [1]School of Psychology, Bangor University, United Kingdom* – Working and long-term memory have long been considered distinct memory types. Based on recent neuroimaging studies and a critical re-evaluation of earlier lesion studies, a high degree of overlap between the areas subserving both types of memory has been highlighted, raising doubts on a double dissociation of working and long-term memory. Furthermore, it is widely accepted that working memory is the pathway to long-term memory. Here, we investigated whether

working memory encoding is indeed a pre-requisite for successful formation of long-term memory. Additionally, we used event-related potentials to investigate whether similar neural processes support both types of memory. Participants were engaged in a working memory task for famous faces, which was followed by a long-term memory test for faces presented during the working memory task. Behavioural results showed a considerable degree of independence between performance in working memory and long-term memory. Clear neural signatures of successful encoding into working and long-term memory were present between 550-1100 ms; the spatial distributions of these potentials indicate different encoding between working and long-term memory. Positive old/new effects were present for both working (300-500 ms, 500-700 ms) and long-term memory (500-800 ms). The topographies of all these old/new effects were significantly different from each other. Both our behavioural and event-related potential results support at least partially distinct memory systems for working and long-term memory. Our results raise questions on the idea of working memory as the pathway into long-term memory and support a high degree of dissociation between working and long-term memory.

D107

IMPLICIT SEQUENCE LEARNING: BEHAVIORAL AND FMRI EVIDENCE FOR DISTINCT UNDERLYING REPRESENTATIONS AND NEURAL STRUCTURES *Freja Gheysen[1], Filip Van Opstal[1], Chantal Roggeman[1], Hilde Van Waelvelde[1], Wim Fias[1]; [1]Ghent University, Belgium* – Sensitivity for serial order has been the topic of cognitive psychology research for many years. The cognitive ability to encode serial information from the environment allows us to predict and prepare for upcoming events, even without the need of having full conscious knowledge of this information. In this study, the question concerning which representation (stimulus or response) contributes to the implicit learning process and which brain structures play a significant role in the acquisition and storage of these representations is addressed. In the original Serial Reaction Time task (Nissen & Bullemer, 1987), many types of sequential information are intermixed. To distinguish perceptual from motor sequencing, we developed a new serial reaction task and controlled for confounds occurring in previous studies. First, behavioral results from this serial color matching task demonstrated that both stimulus and response contingencies contribute to sequence acquisition. However, perceptual sequence learning seems less robust than the learning process of motor sequences. Next, this behavioral work was related to brain function. The distinct areas engaged in the early and advanced stages of sequence acquisition were investigated using a blocked fMRI design with the same paradigm. Subjects were scanned over two sessions with additional sequence training in between. Moreover, the study aimed at exploring specifically the role of the cerebellum in learning different types of sequential information.

Poster Session E

Memory: False memory

E1

NEURAL ACTIVITY PREDICTS TRUE AND FALSE MEMORIES IN THE MISINFORMATION PARADIGM *Carol Baym[1], Brian Gonsalves[1,2]; [1]University of Illinois at Urbana-Champaign, Psychology, [2]Beckman Institute, University of Illinois at Urbana-Champaign* – False memories occur when people report having encountered something they have not actually experienced. Of interest here are the neural mechanisms that underlie this type of memory failure. In the current study, 18 healthy young adults viewed vignettes of common activities such as preparing dinner while we monitored their brain activity using functional magnetic resonance imaging. In the Original Event Phase (OE) participants viewed photographs of actors portraying the scenarios. Later, in the Misinformation Phase (MP), participants viewed sentences describing the previously seen photographs and were instructed to visualize the corresponding photograph. Critically, some of the verbal presentations contained information conflicting with that depicted in the photographs. Twenty-four hours later, participants returned for a memory test for what they had seen in the photographs. Our manipulation showed reliable creation of false memories, defined as instances where the participant reported information that was not in the photographs, but was presented in the verbal information. Consistent with previous findings (Gonsalves, 2004), participants who were most susceptible to false memory formation showed activity in medial prefrontal cortex, right parietal cortex, and visual areas during the MP when they would later report a false memory compared to a true memory. Region-of-interest analyses showed that activity in several regions during the OE predicted later accurate memory and resistance to misinformation. These findings suggest that different patterns of neural activity at encoding predict subsequent accurate and false memory.

E2

THE FUNCTIONAL LOCUS OF MEMORY DISTORSIONS: ENCODING OR RETRIEVAL? *Eve Attali[1,2], Victoria Cristancho[1,2], Gianfranco Dalla Barba[1,3]; [1]INSERM U 610 Paris, [2]UPMC Univeristé Paris VI, [3]Hopital Henri Mondor Créteil* – Many current accounts of the origin of intrusions and other confabulatory-like phenomena emphasize the role of a retrieval or postretrieval deficit in these disorders. Our previous experiments showed that the probability of false memories production was associated with the quality of the memory trace. However, this memory trace is elaborated during encoding processes. One might then ask the question whether the origin of memory distorsions is located at encoding or at retrieval. We propose to disturb differentially these two stages of processing by the addition of a divided attention (DA) task at encoding and at retrieval. Methods Forty young and 40 older adults participated in two studies. The first task consists in a free recall of three different types of stories, and the second one is a words recognition test based on High and Low frequency words. These two tasks were administrated under three conditions: -1: full attention at encoding/ full attention at retrieval -2: DA at encoding/ full attention at retrieval -3: full attention at encoding/ DA at retrieval Results In both tasks, DA at encoding was associated with both a decrease of memory performance and an increase of false memories whereas DA at retrieval had little effect on both the accuracy of the retrieval and the probability in creating memory distorsions. Conclusion The greater number of confabulations and false recognitions when divided attention was provided at encoding than at retrieval suggests that encoding processes might be strongly involved in the generation of memory distorsions.

E3

TRUE MEMORY, FALSE MEMORY, AND THE EFFECT OF REPEATED ITEMS ON EVENT-RELATED POTENTIALS REGARDLESS OF MEMORY *Matthew Burden[1], Alissa Westerlund[2], Gina Muckle[3], Pierre Ayotte[3], Eric Dewailly[3], Charles Nelson[2], Sandra Jacobson[1], Joseph Jacobson; [1]Wayne State University School of Medicine, [2]Children's Hospital Boston, Harvard Medical School, [3]Laval University* – Event-related potential (ERP) studies often show a larger late positive component (LPC) associated with repeated, successfully remembered items. Little is known, however, about how the LPC and preceding components are influenced by repetition in true vs. false memory. We recorded ERPs during a continuous recognition memory task in which children (N = 103; mean age = 11.3 yr) determined if each visually presented object was "new" (seen once) or "old" (repeated). ERPs were analyzed with respect to hits (old/correct), misses (old/incorrect), false alarms (new/incorrect), and correct rejections (new/correct). Bonferroni-adjusted comparisons showed that, as expected, LPC peak amplitude (500-650 ms) at Pz was larger for mean (?V) hits (18.3) vs. correct rejections (14.1), false alarms (14.5), and misses (15.6; ps < .01); planned comparisons showed that the peak for misses was also larger than correct rejections ($p < .05$), which did not differ from false alarms ($p = .63$). By contrast, the P2 peak (250-400 ms) at Pz was virtually identical for mean (?V) hits and misses (14.2 vs. 14.1, respectively, $p = .99$), and both were larger than the corresponding P2 for correct rejections (11.5; ps < .001), which did not differ from false alarms (12.6; $p = .74$). These findings suggest that the early P2 component is sensitive to repetition effects ("old" vs. "new") regardless of memory, perhaps reflecting equally successful visual encoding of repeated items, and the LPC, which is partially enhanced by repetition alone (misses) but unaffected by false memory (false alarms), reflects true memory retrieval.

Memory: Memory disorders

E4

TEMPORAL REPRODUCTION AS AN EARLY MARKER OF ALZHEIMER'S DISEASE *Ashley Bangert[1], Jeremy Missuk[1], David Balota[1]; [1]Washington University in St. Louis, Psychology* – Early stages of dementia of the Alzheimer's type (DAT) are marked by deficits in attentional control (Balota & Faust, 2001). Changes in attention and executive control influence the temporal perception of supra-second durations (Lewis & Miall, 2003). In the current study, young adults (YA), healthy older adults (OA), and individuals classified as very mildly demented (CDR .5) on the Clinical Dementia Rating Scale (Berg, 1988) performed a continuous tapping task with 500, 1000, and 1500 ms intervals. We hypothesized that CDR .5 would show poorer performance than YA and OA especially on longer durations as a consequence of higher attentional demands. Despite equivalent performance to YA during paced tapping, both OA and CDR .5 individuals produced significantly less accurate reproductions compared to YA during 1000 ms and 1500 ms unpaced tapping. Additionally, CDR .5 were less accurate than OA for the 1500 ms condition. Performance in this condition also discriminated carriers from non-carriers of the APOE e4 allele in a subset of OA. These results suggest that CDR .5 and OA who are at risk for developing DAT due to e4 status have difficulty continuously monitoring and updating the passage of time in order to maintain the appropriate temporal task set. Moreover, finding that a simple repetitive timing task is sensitive to differences between OA and CDR .5 individuals as well as e4 status has implications for the development of simple diagnostic tools for early detection of DAT. This work was supported by NIA PO1 AGO3991 and T32 AG000030-32.

E5

RELATIONS BETWEEN STM DEFICITS AND EXECUTIVE FUNCTION *Corinne Allen[1], Randi Martin[1]; [1]Rice University, Psychology* – Hoffman and colleagues (2008) claimed that executive function (EF) deficits cause semantic and semantic short-term memory (STM) impairments in aphasic patients. Consistent with this claim, Hamilton and Martin (2007) demonstrated a verbal inhibition deficit in a patient with a semantic STM deficit. The present study investigated whether EF deficits are related to semantic but not phonological STM deficits. We used complex EF tasks and tasks tapping basic EF components (inhibition, updating, and shifting). Seventeen aphasic patients with varying degrees of semantic or phonological STM deficits were tested on semantic, STM, and EF tasks. Wisconsin Card Sorting Task (WCST) performance correlated with phonological retention and semantic ability whereas Tower of Hanoi (TOH) performance did not, suggesting a greater verbal component to the WCST than the TOH. For basic EF components, inhibition correlated with semantic retention, but also correlated with phonological retention. Interestingly, verbal and nonverbal updating tasks correlated with several span tasks tapping phonological retention, despite the fact that the updating tasks only required retaining one item. Finally, shifting was unrelated to semantic or phonological retention. These results provide little support for the notion that global EF deficits cause STM deficits, given that TOH performance was unrelated to STM. Instead, causation may go in the other direction-deficits in phonological retention may cause deficits on complex and simple EF tasks that have verbal components. The claim that verbal inhibition deficits are the source of semantic STM deficits remains viable; however inhibition deficits also appear to be related to phonological STM.

E6

GENERALIZATION GRADIENTS IN HUMAN CATEGORY LEARNING: AMNESIC PATIENTS CAN OUTPERFORM CONTROLS ON HIGH-DISTORTION EXEMPLARS *Catherine Myers[1], Ramona Hopkins[2,3], A. J. Wills[4], Mark Gluck[5]; [1]Rutgers University, Psychology, Newark, NJ, [2]Brigham Young University, Psychology, UT, [3]Medicine, LDS Hospital and Intermountain Medical Center, Salt Lake City, UT, [4]University of Exeter, Psychology, Exeter, UK, [5]Center for Neuroscience, Rutgers University, Newark, NJ* – Prior work has suggested that the hippocampal region is important for contextual and configural processing, but is not required for simple stimulus-response learning. We tested 9 amnesic patients with bilateral hippocampal damage and 9 healthy controls on a categorization task (Wills & McLaren, 1997) in which subjects learn by trial and error to categorize prototype-structured patterns of 12 symbols; symbols are selected from two sets, A and B, and each pattern belongs to the category from which a majority of its symbols are taken. This task can be solved by configural learning about groups of symbols that reliably co-occur and signal category membership, or by forming individual symbol-category associations and then using a majority rule to deduce category membership. If the hippocampal region mediates contextual/configural learning, the configural strategy should be hippocampal-dependent but the associational strategy should not. Training was followed by a test phase in which subjects categorized new patterns including prototypes (all 12 symbols from one class) as well as high- and low-distortion exemplars. On the test phase, controls showed high accuracy for prototypes, with a generalization gradient that declined smoothly for progressively more distorted exemplars. Consistent with prior findings, amnesic patients performed as well as controls on classifying prototypes and low-distortion exemplars; but on high-distortion exemplars, amnesics actually outperformed controls. This is consistent with the idea that the amnesic patients are biased to form individual cue-category associations, leading to good performance on high-distortion exemplars, since categorization is made by majority vote based on the symbols present.

E7

EFFECTS OF COGNITIVE REHABILITATION ON MEMORY-RELATED FUNCTIONAL BRAIN ACTIVATION IN PEOPLE WITH EARLY STAGE ALZHEIMER'S DISEASE *Jorien van Paasschen[1], Linda Clare[1], Robert T. Woods[1], David E.J. Linden[1]; [1]School of Psychology, Bangor University* – Recent studies show that using learning strategies in combination with teaching personally relevant information can be effective in improving memory for that information in people with Alzheimer's disease (AD). Six people participating in an eight-week cognitive rehabilitation intervention programme were taught a mnemonic strategy to (re)learn the names of familiar people. Using functional magnetic resonance imaging (fMRI), possible changes in brain activation during face-name learning were examined pre and post treatment while participants learned and recognised unfamiliar face-name pairs, and engaged in a control task (making decisions about the gender of a face). Behaviourally, we observed small improvements on immediate recognition of the face-name associations as well as on the control task. On a neural level, brain activity was generally higher prior to than following the treatment during memory-related processing. During encoding, activation decreases following treatment occurred mainly in visual areas. The most prominent alterations occurred during recognition, where activation was lower following the intervention period in mainly parietal, occipital and temporal regions. Changes in brain activity during the control task were minimal. Although preliminary, the results were suggestive of more effective inhibition of regions comprising a default mode network. The approach adopted here to study the neural bases of cognitive rehabilitation has not been reported before, and the present findings indicate that this method can feasibly be employed with people with AD.

E8

EFFECTS OF INTIMATE PARTNER VIOLENCE ON MEMORY *Carolyn Edwards[1], Robert Astur[2], Sarah Raskin[1]; [1]Neuroscience Program, Trinity College, Hartford CT, [2]Olin Neuropsychiatry Research Center, Institute of Living, Hartford CT* – This study examined prospective, spatial and verbal memory deficits in female victims of intimate partner violence (IPV). Eighteen women who had experienced IPV were given tests of memory, posttraumatic stress disorder, daily stress inventory, a brain injury screening measure, Beck Anxiety Inventory, Beck Depression Inventory, the Cognitive Difficulties Scale and a quality of life measure. Memory tests included the Memory for Intentions Screening Test (MIST), the virtual radial arm maze, and the Hopkins Verbal Learning Test (HVLT). The aim of the study was to determine how various health outcomes such as brain injury, post-traumatic stress disorder, and depression affect memory in these women. Results indicated that women with increased stress performed better on the memory tasks than women reporting less stress. Other results verified previous findings that women who had suffered more severe IPV were more likely to be experiencing PTSD, depression, anxiety, and a lower quality of life. Women who had undergone more severe IPV were more likely to report having cognitive difficulties, however, there was no correlation between increased IPV severity and performance on standardized memory tests.

E9

REDUCED ERP WORD REPETITION EFFECTS IN PATIENTS WITH FRAGILE X-ASSOCIATED TREMOR/ATAXIA SYNDROME *John Olichney[1,2], Shiao-hui Chan[1,2], Andrea Schneider[3], Adam Niese[1,2,4], Kelsey Laird[5], Rawi Nanakul[1,2], Flora Tassone[3], Randi Hagerman[3]; [1]UC Davis, Neurology, [2]Center for Mind and Brain, UC Davis, [3]MIND Institute, UC Davis, [4]University of Iowa, Psychology, [5]UC Davis, Neuroscience* – Fragile X-associated tremor/ataxia syndrome (FXTAS), a neurodegenerative disorder associated with premutations of the FMR1 gene, affects many carriers in late-life. Patients with FXTAS typically have cerebellar ataxia, neuronal intranuclear inclusions (especially in hippocampus), and cognitive impairment. Neuropsychological tests have shown similar deficits in FXTAS dementia and AD. Thus, we sought to characterize the P600 and N400 word repetition effects in patients with FXTAS. We hypothesized

that FXTAS patients with poor declarative verbal memory will have pronounced abnormalities in the P600 repetition effect. Methods: Auditory category statements were each followed by an associated visual target word (50% "congruous" category exemplars, 50% "incongruous" nouns) while 32 channel ERPs were recorded during a category decision task. Two-thirds of the stimuli were repeated, either at short-lag (~10-40 seconds) or long-lag (~100-140 seconds later). Results: Preliminary group ANOVAs showed a highly significant reduction of the N400 repetition effect (F=12.7; p=0.001), but not of the P600 repetition effect, in FXTAS (n=16, mean age=68.7, MMSE=26.4). However, the FXTAS patients with abnormal verbal memory also had reduced P600 word repetition effects, with significant within-group correlations (r's > 0.55 with free and cued recall measures). The relationship between P600 and N400 effects, CGG repeat length, FMR1 mRNA expression levels, and memory performance will be discussed. In conclusion, ERP word repetition effects appear sensitive to the memory dysfunction present in patients with FXTAS. Their more severe reduction in N400, than P600, repetition effect is in contrast to the reverse pattern found in amnestic MCI (Olichney et al 2002 JNNP).

E10

DIFFERENTIAL IMPAIRMENT OF RELATIONAL VERSUS ITEM-SPECIFIC MEMORY IN SCHIZOPHRENIA *J. Daniel Ragland[1], Robert Blumenfeld[2], Ian Ramsay[1], Marjorie Solomon[1], Stefan Ursu[1], Michael Minzenberg[1], Jong Yoon[1], Cameron Carter[1], Charan Ranganath[3]; [1]UC Davis, Psychiatry and Behavioral Sciences, [2]UC Berkley, Psychology, [3]UC Davis, Psychology* – Although individuals with schizophrenia have severe long term memory (LTM) deficits, they are not densely amnestic. Like frontal lobe lesion patients, individuals with schizophrenia are most impaired when required to generate strategies to organize information during encoding, and to control and monitor search processes during retrieval. There is also evidence for a relative deficit in recollection versus familiarity-based retrieval. This study tests the hypothesis that strategic memory deficits in schizophrenia are due to specific impairment in control of relational processing, whereas item-specific processing is relatively intact. This hypothesis was tested by administering a previously validated relational and item-specific encoding task during fMRI to 16 individuals with schizophrenia and 15 healthy volunteers. Subsequent memory performance was evaluated using signal-detection analysis of receiver operator characteristics (ROC). This revealed predicted group by task interactions. Specifically, controls showed better LTM performance following relational than item-specific processing, whereas patients showed no performance benefit from relational processing. This was true for a standard measure of recognition accuracy (da) and for a measure sensitive to relational binding (Triplet Memory). The ROC analysis revealed that patients had a specific impairment in recollection (R) but not in familiarity (d-prime) following both item-specific and relational encoding. These convergent behavioral results reveal a relative preservation of item-specific encoding and familiarity based retrieval in schizophrenia that has important implications for developing behavioral and pharmacological interventions to target the remaining severe deficits in recollection and relational memory that limit these individuals' daily function.

E11

MEMORY FAILURE AND SLEEP DISRUPTION IN AMNESTIC MILD COGNITIVE IMPAIRMENT *Carmen E. Westerberg[1], Bryce A. Mander[1], Susan M. Florczak[1], Sridhar Jatla[1], Sandra Weintraub[1], M.-Marsel Mesulam[1], Phyllis C. Zee[1], Ken A. Paller[1]; [1]Northwestern University* – Declarative memories are not static. Rather, they undergo a consolidation process whereby memory fragments stored in distinct neocortical zones can become more effectively bound together. If memory processing during sleep contributes to consolidation, poor sleep may exacerbate memory problems in patients with Alzheimer's disease (AD). Sleep disruptions are common in AD, but a direct link between disease-related sleep disruptions and memory dysfunction has not been established. It is unknown whether sleep is also disrupted in amnestic mild cognitive impairment (a-MCI), a condition that may precede AD and that is characterized by circumscribed memory deficits not severe enough to disrupt daily living activities. To explore possible connections between memory dysfunction and sleep, we used polysomnography (PSG) to obtain electrophysiological measures of sleep in patients with a-MCI and cognitively healthy age- and education-matched individuals. Two declarative memory tests (for word pairs and for fictitious biographical facts associated with studied faces) and a priming test (speeded decisions for common-object pictures) were administered prior to sleep and after waking each morning in a 4-night protocol. PSG data revealed reduced stage-2 sleep and reduced sleep efficiency in a-MCI. Across-subject correlations showed that declining sleep efficiency was associated with declining declarative memory accuracy for information learned the previous night, but not with priming. Thus, mild alterations of sleep architecture are present in a-MCI and may interfere with declarative-memory consolidation. Additional findings supporting the possibility that the forgetfulness of a-MCI patients partly stems from deficient memory processing during sleep will also be discussed.

E13

IMAGINING THE PAST AND THE FUTURE: SIMULATION DEFICITS IN HEALTHY AGING *Donna Rose Addis[1], Regina M. Musicaro[2], Ling Pan[2], Daniel L. Schacter[2,3]; [1]The University of Auckland, Psychology, New Zealand, [2]Harvard University, Psychology, Cambridge MA, [3]Athinoula A. Martinos Center for Biomedical Imaging, Charlestown MA* – We recently reported that older adults generate fewer episodic details than younger adults when remembering past events and simulating future events. Moreover, performance on the remembering and imagining tasks was tightly correlated. We suggested that the simulation findings reveal an age-related deficit in recombining episodic details into novel events, but they could also result from older adults simply 'recasting' entire past events as future events. In the current study, we used an experimental recombination paradigm to prevent 'recasting' while imagining, and to compare imagining the future with imagining the past. Eighteen young and eighteen older adults imagined future and past events using event details taken from memories recalled in a prior session and randomly recombined. Subjects also recalled past events. Event transcriptions were segmented into internal (episodic) and external (non-episodic) details. Older adults generated fewer internal episodic details for imagined and recalled events than younger adults. Both groups generated more episodic detail during recall relative to imagining, and more episodic detail for events imagined in the past versus future. We also replicated the finding that older adults generate significantly more external detail than younger adults. Across both groups, imagined future events were associated with more external information than imagined past events. Importantly, the number of internal and external details both showed correlations between recalled and imagined events. This study extends the age-related simulation deficit to conditions of recombination, and shows that deficits in imagining episodic detail are evident for imagined past events, and not specific to imagining the future.

E14

SEMANTIC MEMORY AND TRAUMATIC BRAIN INJURY *Fanpei Yang[1], Navid Khodaparast[1], Kourosh Zakeri[1], Daniel Krawczyk[1,2]; [1]Center for Brain Health, University of Texas at Dallas, [2]University of Texas Southwestern Medical Center, Psychiatry, Dallas* – Figurative language (e.g., irony, metaphor, and idiom) comprehension has been identified as a domain of impairment in adults that have sustained Traumatic Brain Injuries (TBI). Declines in working memory and in figurative language comprehension in TBI patients are inferred based on observed deficits in higher-order comprehension skills, such as inference understanding, as well as a reported correlation between working memory and several types of figurative language in older adults. No previous studies have employed functional neuroimaging techniques in order to test the hypothesis that impaired complex language comprehension is directly dependent on working memory efficacy. In a previous fMRI experiment on metaphor comprehension in normal subjects, we established that the left inferior

frontal gyrus (LIFG) was most involved with novel metaphor comprehension. This finding is consistent with results reported in other imaging studies of complex language processing. The purpose of the present research was to uncover the most influential cognitive factor for TBI patients' deficits in figurative language processing. Our results indicated that patients with TBI, regardless of lesion location, showed lowered LIFG activation, which is a primary control region involved in processing semantic memory representations. We observed no differences in activation related to subjects' working memory ability. Based on the regional activation observed in this study, we suggest that semantic memory rather than working memory may have the greatest efficacy in terms of isolating potential biomarker regions in the brain related to the degeneration of complex language processing due to injuries.

E15

THE S.M STORY: EPISODIC, BUT NOT SEMANTIC, AUTOBIOGRAPHICAL MEMORY IMPAIRMENT IN A HEALTHY PERSON *Daniela Palombo[1,2], Allison Mackey[2], Hedvig Söderlund[2], Namita Kumar[2], Brian Levine[1,2]; [1]University of Toronto, [2]Rotman Research Institute* – We report the case of S.M., a healthy woman who is unable to re-experience her past. S.M.'s development was normal, with no evidence of trauma, psychiatric history or brain injury. Autobiographical memory tests revealed dysfunction of episodic memory (re-experiencing of events), while semantic memory (factual information) was well preserved. Importantly, S.M. did not show any other cognitive deficits, with normal performance on standardized neuropsychological tests. Structural MRI revealed volume loss in a number of brain regions, including extra-hippocampal medial temporal lobe (MTL) structures (i.e., perirhinal and entorhinal cortices). During functional MRI of autobiographical memory retrieval, S.M. showed reduced activation relative to control participants in midline frontal regions and the MTL. These regions have been consistently identified as part of the autobiographical memory network. We also collected event-related potential (ERP) measures of recognition memory. Previous research has shown that ERPs can be used to topographically dissociate recollection and familiarity. Recollection is closely tied to episodic memory, whereas familairity is thought to be an expression of semantic memory. In the present study, S.M. did not show the ERP index associated with recollection, whereas control participants reliably did. By contrast the ERP index of familiarity, was found in both S.M. and control participants. These data provide support for a dissociation between episodic and semantic memory systems. Further, to our knowledge, S.M. is the first reported case of a healthy person to show an episodic memory deficit and, as such, is of great significance in our understanding of the neural correlates of memory.

Memory: Memory systems

E16

AGE-RELATED CHANGES OF ITEM AND SOURCE MEMORY FOR EMOTIONAL FACES: EVENT-RELATED POTENTIAL EVIDENCE *Maria Gruno[1], Sophia Wilhelm[1], Katja Werheid[1], Norbert Kathmann[1]; [1]Institute of Psychology, Humboldt Universität zu Berlin, Berlin, Germany* – Negative emotion boosts episodic memory. However, it is still debated whether negative emotion enhances memory for the central event (item memory) or memory for its contextual details (source memory) and how aging influences the emotion memory coupling. The present study used event-related potentials (ERP) to examine the impact of emotion and age on retrieval processes underlying item and source memory. Young (n = 18; mean age = 25) and older adults (n = 18; mean age = 67) studied negative and neutral faces along with context information. In a later recognition test they were asked to classify faces as studied or non-studied and assign them to their proper context. Results showed enhanced source memory for negative faces in both age groups, despite generally reduced memory performance in the elderly. ERP correlates of source memory were reduced in older compared to younger adults. Moreover, the effects of negative emotion on item and source memory varied as a function of age as reflected in the ERP old/new effects. Thus, these findings suggest that aging affects the action point of negative emotion on source memory.

E17

NEURAL DYNAMICS OF CONTROLLING CONFLICT FROM INTERFERING REPRESENTATIONS DURING LONG-TERM MEMORY RETRIEVAL *Patrick Khader[1], Kerstin Jost[1], Frank Rösler[1]; [1]Experimental and Biological Psychology, Philipps-University Marburg, Germany* – Psychobiological research on long-term memory (LTM) representations primarily focused on brain structures where information is consolidated and reactivated, but paid less attention to processes that control memory retrieval by amplifying relevant and suppressing interfering information. Therefore, we developed an experimental paradigm suited to evoke conflicts between LTM representations. During an acquisition phase words became associated to either a face stimulus, a spatial position, or to both. During recall participants had to decide whether two words are linked to each other via a common association. Prior to every block of six trials a cue indicated the to-be-compared material type. Retrieval conflict arose when the words were associated with two material types, but only one was task-relevant. In an EEG and an fMRI study with the same participants we were able to detect co-activation of the irrelevant associations on a behavioral and neurophysiological level. First, response times were prolonged when irrelevant associations had to be suppressed. Second, the topography of event-related slow potentials differed in a material-specific way depending on the type of irrelevant information. Finally, material-specific fMRI activations were found for the irrelevant material type in posterior brain areas that are assumed to house the representations of positions and faces. In addition to the posterior differences stronger fMRI activation was found in the left prefrontal cortex during conflict trials, suggesting a role of this region for control processes that serve to solve conflict and interference during LTM retrieval.

E18

IMPLICIT SWITCH TO MEMORY RETRIEVAL: A CORTICAL TOOL FOR BOOSTING PERCEPTION *Mor Nahum[1], Luba Daikhin[2,3], Yedida Lubin[4], Yamit Cohen[3], Merav Ahissar[1,2]; [1]Interdisciplinary Center for Neural Computation (ICNC), Hebrew University, Jerusalem, Israel, [2]Hebrew University, Psychology, Jerusalem, Israel, [3]Institute of Medical Sciences, Hadassah Medical School, Hebrew University, Jerusalem, Israel, [4]Hebrew University, Cognitive Science, Jerusalem, Israel* – One of the hallmarks of human perception is our remarkable discrimination ability: numerous studies documented very fine resolution along basic physical dimensions, when two stimuli are compared, with best resolution typically achieved when one of the stimuli is consistently repeated across trails ("reference"). Here we tried to decipher whether this resolution indeed reflects accurate comparison mechanisms, as commonly assumed. We measured subjects' behavioral thresholds and ERPs, while they performed a two-tone frequency discrimination task under different protocols, with the reference stimulus either having a fixed temporal position (first or second), alternating between positions, or eliminated altogether. We found that the advantage of the temporally-consistent reference protocols was quickly obtained, following only a few trials, and resulted in more than a three-fold advantage in thresholds over the no-reference protocol. Although subjects reported comparing the two tones, their ERPs showed that a decision wave (the P3) always followed the informative, non-reference interval, even when it preceded the reference. When the reference alternated between intervals, thresholds (and corresponding P3) were as good only for the reference in the initial interval, indicating that the mere presence of a reference does not suffice. We conclude that best resolution is achieved quickly and implicitly, but only when online comparisons are avoided and replaced with memory-based tagging. Our perceptual system attempts to perform this switch to memory retrieval,

yet cannot track simple temporal structures that boost performance. Such conditions reveal simple heuristics for detecting stimulus consistencies which are necessary for replacing online comparisons with stimulus-response tagging.

E19

SUBSEQUENT MEMORY EFFECTS PREDICTIVE OF SUCCESSFUL CUED RECALL ARE SENSITIVE TO STUDY TASK *Lauren J. Gottlieb[1], Michael D. Rugg[1]; [1]Center for the Neurobiology of Learning and Memory, and Neurobiology and Behavior, University of California at Irvine* – Several studies have demonstrated that encoding-related activity (subsequent memory effects) predictive of successful recognition memory is sensitive to the nature of the study task. However, it is not yet known whether subsequent memory effects predictive of successful cued recall are similarly task-sensitive. The present fMRI study addressed this issue by contrasting the subsequent memory effects associated with successful versus unsuccessful cued recall for items encoded in two study tasks previously shown to generate dissociable effects for recognition. Subjects studied words presented in the context of either a semantic (pleasant/unpleasant decision) or a syllabic (odd/even number of syllables) study task. In the subsequent memory test, subjects used three-letter word stems to attempt to recollect the studied words, completing the stems with the first word to come to mind if recollection failed. They were further required to explicitly endorse each completion as 'old' or 'new'. Subsequent memory effects were estimated for study words associated with successful versus unsuccessful recollection on the recall test. Effects unique to the semantic task were identified in left ventromedial prefrontal cortex and right hippocampus. By contrast, syllabic subsequent memory effects were found bilaterally in posterior cingulate cortex. These findings extend prior observations of task-selective subsequent memory effects to cued recall, and add weight to the proposal that episodic encoding of a stimulus event is supported by enhanced activity in cortical regions engaged during the on-line processing of the event.

E20

ERP CORRELATES OF SOURCE MEMORY: UNITIZED SOURCE INFORMATION INCREASES FAMILIARITY-BASED RETRIEVAL *Rachel A. Diana[1], Wijnand Van den Boom[2], Andrew P. Yonelinas[1], Charan Ranganath[1]; [1]University of California, Davis, [2]Leiden University* – Performance on tests of source memory is typically based on recollection of contextual information associated with an item. Receiver operating characteristic (ROC) analyses have indicated that unitization of item and source information, defined as encoding of source information as a detail of the item being processed, may increase the role of familiarity in source memory (Diana, Yonelinas, & Ranganath, 2008, Journal of Experimental Psychology: Learning, Memory, & Cognition). However, the interpretation of ROC analyses is controversial. To assess converging evidence, we conducted an event-related potential (ERP) study testing the hypothesis that unitization leads to contributions from qualitatively different recognition processes in source memory. Participants studied associations between words and background colors either in a unitized manner ("Imagine this item being red/green") or in a nonunitized manner ("Imagine this item associated with a stop sign/dollar bill"). ERPs were recorded while participants were given a source memory test in which they were shown each studied item and asked to make a confidence judgment about whether it was studied with a red or green background. ERP results revealed two topographically and temporally distinct neural correlates of source recognition, one that was associated with familiarity-based source memory in the unitized condition only and another that was associated with recollection-based source memory in both the unitized and nonunitized conditions. These findings converge with the ROC analyses, indicating that familiarity can contribute to source recognition when item and source information are unitized.

E21

NEURAL CORRELATES OF VISUAL MEMORY FOR SPATIAL AND NON-SPATIAL MATERIALS IN AN OBJECTIVE MANIPULATION PARADIGM *Dorian Pustina[1,2], Boris Suchan[1], Irene Daum[1,2]; [1]Institute of Cognitive Neuroscience, Ruhr-University Bochum, Germany, [2]International Graduate School of Neuroscience, Bochum, Germany* – Previous research has suggested a dual process model of human memory. In behavioural terms subjects exhibit a graded range of memory confidence for the memorized items, which is used to estimate "familiarity" and "recollection" through receiver operating characteristic curves (ROCs). In our paradigm we present morphed stimuli similar to targets in controlled steps of 0% (identical), 20%, 40% or 60% different. By manipulating the stimuli we introduce an objective experimental manipulation which is shown to affect linearly the memory performance. Neural correlates of such manipulation are investigated with magnetic resonance imaging (fMRI) and event related potentials (ERPs). Faces and scenes constitute two types of material under investigation. The classical comparison of Hits vs. Correct Rejections (CRs) is expanded to include Hits0%, Hits20% and Hits40%. There is no difference in Hits for scenes, while the classical dissociation of CRs vs. Hits is significant from N400 to later components. The relation of ERP components to memory performance is thus independent of visual morphing and visual priming doesn't seem to affect ERPs. Face stimuli exhibit e more complex pattern still under investigation. The fMRI results show a preliminary pattern of linear activation of the right hippocampus and bilateral posterior cingulate for scenes, and left hippocampus and left fusiform face area for faces. The behavioural results show a gradual shift both in familiarity and recollection estimates for each morphing step. The existence of a recollection process even at low memory rates is discussed along with physiologic evidence from ERPs and fMRI.

E22

NEURAL ACTIVATION IN SEMANTIC, EPISODIC AND AUTOBIOGRAPHICAL MEMORY RETRIEVAL IN YOUNG AND OLDER ADULTS *Marie St-Laurent[1,2], Hana Burianova[2,3], Cheryl Grady[2,3]; [1]Toronto Western Research Institute, Toronto, Ontario, CA, [2]University of Toronto, Psychology, Ontario, CA, [3]Rotman Research Institute, Baycrest, Toronto, Ontario, CA* – Our goal was to assess the effects of healthy aging on the neural correlates of declarative memory retrieval. Young (age = 21-31) and older adults (age = 63-77) were tested on a functional magnetic resonance imaging paradigm designed to contrast the neural correlates of autobiographical (i.e. personal events), episodic (i.e. events presented in the laboratory) and semantic memory (i.e. general knowledge) retrieval. Memory was cued by a pictorial stimulus, and retrieval demand was manipulated to extract one of the three memory types. A Spatial Temporal Partial Least Square (ST-PLS) analysis was conducted on data from both age groups to identify the patterns of brain activity that best characterized the different task conditions. Brain regions including the left inferior and middle frontal gyri, the thalamus, and the right temporo-parietal junction were activated by all three memory conditions in both groups, although younger adults had more activity than older adults for autobiographical memory. An additional pattern of activity was found in both groups that included activation of the precuneus and the inferior and medial prefrontal cortex for autobiographical, and temporal poles and occipital regions for semantic memory. Activity in these regions differentiated the conditions to a greater degree in young adults. These results suggest that networks recruited during declarative memory may not change markedly with age but degree of activation in these areas is reduced, consistent with less differentiation of function in older adults.

E23

THE ROLE OF FAMILIARITY AND RECOLLECTION IN FAME JUDGEMENTS: A RECEIVER OPERATING CHARACTERISTICS (ROC) ANALYSIS *Ben Bowles[1], Melissa Gordon[1], Stefan Köhler[1]; [1]University of Western Ontario, Psychology* – Recognition memory is supported by two processes, recollection and familiarity. Recollection pro-

vokes recall of contextual detail with respect to a prior episode, and familiarity signals a sense of prior occurrence in the absence of such recall. The experimental study of familiarity and recollection is typically based on the study-test paradigm, in which subjects are required to reference a specific study session when making their recognition judgments. An influential view is that the assessment of familiarity is supported by a signal-detection process whereas recollection relies on a high-threshold discrimination process. Here, we ask whether familiarity and recollection also operate according to these principles when recognition demands lack a discrete reference to any particular study episode. In two experiments, subjects discriminated between famous and non-famous names, and indicated their confidence for each decision. Subsequently, the basis of their fame decisions was probed by examining the availability of specific recollections and of semantic knowledge. ROC analyses showed that recognition of famous names is largely supported by a high-threshold process. This was true even when responses associated with available recollections were excluded from the analysis. To the extent that these memory decisions reflect recognition of prior occurrence without recollection our finding suggests that familiarity contributes to name recognition in a high-threshold manner. Additional analyses revealed that this high-threshold process is closely linked to the availability of semantic knowledge. This suggests that generation of semantic knowledge may contribute to name recognition in a way similar to that of recollection in the typical study-test paradigm.

E24

CONTRIBUTIONS OF THE PERIRHINAL CORTEX TO ASSOCIATIVE MEMORY FORMATION *Bernhard Staresina[1], Lila Davachi[1,2]; [1]New York University, Psychology, [2]Center for Neural Science, New York University* – Many neuroimaging studies using the subsequent memory paradigm have consistently reported a role of the human perirhinal cortex (PrC) in non-associative item encoding. More recently, however, evidence has been accumulating that certain types of associations recruit PrC encoding operations. In particular, PrC activation has been found to correlate with the associative binding of item-related details (Staresina and Davachi, 2006; 2008) and the formation of a unitized representation from two separate elements (Haskins et al., 2008). What is the exact function of PrC engagement during associative encoding, and how does it interact with hippocampal binding operations? One possible mechanism by which PrC contributes to associative encoding is by creating and/or maintaining an item representation from separate constituents, which may then be further processed by the hippocampus. In this fMRI study, we presented objects and a to-be-associated color in three different ways: While the object was always surrounded by a color square, the object itself was presented either intact or scrambled into two or four pieces. Thus, in order to bind the same color detail to the object, the object had to be assembled and maintained in the scrambled condition. Preliminary data from 10 subjects reveal hippocampal, but not PrC, activation correlating with successful binding of the color to intact object representations. Critically, however, for scrambled object presentations, both PrC and the hippocampus appear to correlate with successful object/color binding. This may suggest that the PrC is needed to establish and maintain item representations while the hippocampus effectively binds associated details.

E25

HIPPOCAMPAL CONTRIBUTIONS EXTEND BEYOND LONG TERM MEMORY TO INCLUDE ON-LINE PROCESSING *David Warren[1], Unni Jensen[2], Aashesh Verma[1], Melissa Duff[2], Daniel Tranel[2], Neal Cohen[1]; [1]Beckman Institute, University of Illinois at Urbana-Champaign, [2]University of Iowa Carver College of Medicine, Neurology* – The current research examines the possibility that the medial temporal lobes (MTL), and more specifically the hippocampus, may be involved in aspects of memory critical for processing of certain kinds of information across very brief intervals, perhaps even within the span of processing a single item. Several different experimental paradigms were employed to test the ability of neurological patients with hippocampal damage to generate and maintain on-line representations as compared to healthy comparison participants. Among the stimuli we used were fragmented outlines of familiar objects presented either simultaneously or sequentially, overlapping outlines of novel or familiar objects, and fragmented novel and familiar objects. The patients with hippocampal damage were impaired relative to the comparison group on many measures indicating that they may lack the capacity to maintain complex or fragmentary information normally even within the span of working memory. We suggest that the role in memory of the hippocampus extends across timescales and includes the formation and maintenance of on-line representations critical for processing complex objects.

E26

'MATCH' AND 'MISMATCH' SIGNALS IN THE HUMAN HIPPOCAMPUS: A HIGH-RESOLUTION FMRI STUDY *Katherine Duncan[1], Nicholas Ketz[1], Lila Davachi[1,2]; [1]New York University, Psychology, [2]New York University, Center for Neural Science* – Although it is well established that the hippocampus is involved in both the formation and retrieval of episodic memories, the mechanisms by which it performs these functions are still poorly understood. The degree to which an environment matches previous experience has been found to modulate the response of hippocampal neurons (Lee, 2004). These results are in line with computational models predicting that hippocampal subfields will switch between encoding and recall states depending on the degree of 'match' and 'mismatch' between cues and stored representations (Hasselmo, 1995). We sought to examine the role of different human hippocampal subfields in 'match' and 'mismatch' signals and to further explore the nature of these signals. Using fMRI at conventional resolution, we recently found that 'match' signals in the human hippocampus reflected matches to goal states while 'mismatch' signals were driven by salient perceptual changes (Duncan, in press). The current study uses high-resolution (1.5 x 1.5 x 2mm voxels) fMRI to investigate the contributions of different hippocampal subfields to these complementary signals while further investigating their links to intentional states. To this end, we modulated the number of relational and item changes made to previously studied scenes. Subjects performed two memory tasks while undergoing functional scanning, one based on relational changes and one based on item changes, while ignoring changes to the irrelevant dimension. Preliminary imaging results from ten subjects provides evidence for both 'match' and 'mismatch' signals throughout the hippocampus, but also suggests that the predominate type of signal differs across hippocampal subfields.

E27

THE IMPACT OF DISTRACTION DURING LONG-TERM MEMORY RETRIEVAL *Peter Wais[1], Adam Gazzaley[1]; [1]University of California, San Francisco* – Episodic memory depends upon the retrieval of contextual information that is associated with a specific prior experience. This recall process can be conceived as mental time travel (Tulving, 1985) and as involving mental imagery for a detailed reconstruction of the event from one's past (O'Craven & Kanwisher, 2000). Interference from environmental stimuli can disrupt the mental imagery evoked during recall and, consequently, diminish the fidelity of episodic memory. In our experiment, we tested the hypothesis that visual distraction diminishes recall performance. Participants studied pictures that contained one to four images of a common object and then, after a delay, were probed with auditory cues that either matched a study object or were lures. Participants' recall of the number of study objects was tested in three alternate conditions: eyes held shut (SHUT); eyes open with constant gaze at a solid gray screen; and eyes open with constant gaze at a visual distractor (VD). The behavioral results show that the VD condition was accompanied by reduced recall in comparison to the SHUT condition and, therefore, that recall performance suffers when irrelevant stimulation is not ignored. fMRI data will be presented to explore the hypothesis that interference with mental imagery during recall is diminished by cognitive control processes that

suppress the bottom-up influence from environmental distraction (i.e., top-down modulation).

E28

THE ROLE OF THE INFERIOR PARIETAL LOBULE DURING INCIDENTAL RETRIEVAL *Pamela Perschler[1], Reza Habib[1]; [1]Southern Illinois University, Carbondale* – Most prior research on the role of the inferior parietal lobe (IPL) in episodic memory has focused on intentional retrieval tasks (i.e. recall, recognition). The goal of the present study was to determine, with fMRI, whether activity in the IPL was modulated by stimulus familiarity during an incidental retrieval task. Subjects were scanned while incidentally encoding novel and repeated picture-word associations. Repeated associations were scanned on their second, fourth, and eighth presentation. On half of the repeated trials, the word associated with each picture was replaced with a new word at the time of scanning, resulting in repeated-intact and repeated-new conditions. Relative to novel associations, repeated associations activated bilateral IPL. In addition, activity in the left IPL increased linearly as a function of repetition (8 > 4 > 2) in the repeated-intact but not repeated-new condition. In addition to the well-established role of the IPL during intentional retrieval, these results indicate that activity in the IPL is also enhanced during incidental retrieval (encoding of familiar picture-word associations) and modulated by the relative familiarity of the associative information.

E29

IMPAIRMENT OF SPATIO-SPATIAL ASSOCIATIVE SHORT-TERM MEMORY IN HUMANS WITH HIPPOCAMPAL DAMAGE *Carsten Finke[1], Mischa Braun[1], Florian Ostendorf[1], Christoph J. Ploner[1]; [1]Charité - Universitätsmedizin Berlin* – Increasing evidence suggests an involvement of the hippocampal formation in short-term memory. We recently demonstrated that in patients with post-surgical lesions of the right hippocampus short-term memory of visuo-spatial associations is impaired, while short-term memory of non-associative spatial and visual information is normal. Here, we investigated whether this finding reflects a special role of the human hippocampus for processing of spatial associations in general or its specialization for processing of between-domain associations involving spatial information. Patients with post-surgical lesions of the right hippocampal formation performed memory-guided saccade paradigms (5-s delay) where the memory-cue was presented simultaneously with a spatial reference with unpredictable spatial relationship to the cue. Three variants were tested, requiring either (1) non-associative memory only, (2) non-associative or associative memory, or (3) associative memory only. In contrast to previous ("allocentric") memory tasks, all tasks were purely spatial and did not require the integration of visual and spatial information into a map-like representation of the stimuli. Compared to controls, patients showed a selective impairment in task (3), while performance in tasks (1) and (2) was intact. These results suggest that the right hippocampal formation is particularly involved in spatial associative memory at short delays, even for simple and purely spatial associations. Furthermore, the data provide evidence that non-associative memory can sufficiently compensate for impaired associative memory in situations that allow for both memory strategies. We suggest that the observed deficits may significantly contribute to impaired short-term memory of more complex visuo-spatial material in humans with hippocampal damage.

E30

BEHAVIORAL EVIDENCE FOR COMPETITION BETWEEN PROCEDURAL-LEARNING AND EXPLICIT-RULE CATEGORY LEARNING SYSTEMS *Matthew J. Crossley[1], Amy E. Hadden[1], F. Gregory Ashby[1]; [1]University of California, Santa Barbara* – There is now overwhelming evidence that human category learning is mediated by multiple systems. Much evidence suggests that one system relies on procedural-learning and one system learns to apply explicit rules. Although many studies have reported evidence for separate systems, almost no research has been directed at the question of how these different systems interact. In fact, the only evidence on this issue appears to come from neuroimaging studies that have reported negative correlations between task-related activation in the striatum and medial temporal lobes. This result has been interpreted as support for inhibitory or competitive interaction between procedural-learning and explicit-rule systems. To our knowledge, however, no behavioral data address this question. Two experiments are reported that provide strong behavioral evidence for system competition. Both experiments used hybrid categories in which optimal responding required participants to use explicit rules for some stimuli and procedural learning for others. In Experiment 1, participants inappropriately used simple one-dimensional explicit rules on all stimuli. In Experiment 2, participants first trained on either the procedural-learning rule that they needed to use on some hybrid categorization trials or on the explicit rule they needed to apply on the other hybrid categorization trials. Following this training period, they then all transferred to the hybrid category structures. Despite this difference in initial training, both groups failed to use hybrid strategies on transfer. Thus, it appears that use of an explicit rule on some trials inhibits the use of procedural-learning strategies on other trials.

E31

PATTERNS OF REMOTE MEMORY IMPAIRMENT IN PATIENTS WITH FOCAL HIPPOCAMPAL AND MORE WIDESPREAD TEMPORAL LOBE DAMAGE *Peter Bright[1], Michael Kopelman[2]; [1]Anglia Ruskin University, Cambridge, UK, [2]Kings College, London, UK* – Objectives and Methods: There is considerable controversy concerning the theoretical basis of retrograde amnesia. We compared medial temporal, medial plus lateral temporal, and frontal lesion patients on a new autobiographical memory task and measures of the more semantic aspects of memory. We also present a more detailed analysis comparing individual patients with quantified pathology restricted to specific critical brain structures. Additionally, we employed a range of methods for coding elicited memories to ensure that we successfully differentiated episodic from semantic detail. Results: Only those patients with damage extending beyond medial temporal cortex into lateral temporal regions showed severe impairment on free recall remote memory tasks, and this held for both the autobiographical and more semantic memory tests. We found no clear evidence for remote memory impairment in the frontal group on any test. These findings, in the context of our further detailed analysis of individual cases, raise the possibility that, although medial and temporal regions may form part of a distributed neural network subserving memory retrieval, damage needs to be quite extensive and exceed a certain critical volume before a significant remote memory impairment can be observed. Conclusions: Across all memory coding methods, our results were more consistent with consolidation theory than multiple trace theory. Nevertheless, the findings indicate a more complex characterization of long term consolidation in which a widely distributed network of regions underlies the retrieval of past memories, within which the extent of lateral temporal involvement is critical to the emergence of a severe remote memory impairment.

E32

A REDUCTION IN SUSTAINED HIPPOCAMPAL ACTIVITY UNDERLIES AGE-RELATED DEFICITS IN THE EPISODIC RICHNESS OF AUTOBIOGRAPHICAL MEMORIES *Peggy L. St. Jacques[1,2], David C. Rubin[2], Philip Kragel[2], Roberto Cabeza[1,2]; [1]Center for Cognitive Neuroscience, Duke University, [2]Psychology and Neuroscience, Duke University* – The retrieval of autobiographical memories (AM), memory for our personal past, is a protracted process that allows for the segregation of the spatiotemporal dynamics of retrieval using fMRI. Understanding the time-course of retrieval has important implications in aging, because older adults might be impaired on later elaboration processes rather than initial search processes. Older adults show a reduction in episodic richness in AMs, but the neural mechanisms underlying this deficit are largely unknown. Thus, the goal of the present fMRI study was to examine the neural bases of age-related reductions in the episodic rich-

ness of AMs. We used a self-paced design in which young and older adults searched for an AM elicited by a generic cue word, pressed a key when one was found, and finally elaborated on the memory until the end of the trial. After scanning, participants described the memories for subsequent objective coding of episodic richness. We predicted that episodic richness of AMs would be attenuated in older adults due to a reduction in hippocampal activity during the elaboration phase. Behavioral results indicated that older adults recalled less episodically rich AMs. Consistent with this, the fMRI results revealed a reduction in the sustained response of the hippocampus during elaboration. Furthermore, episodic richness modulated hippocampal activity during elaboration. In sum, these results suggest that the age-related reduction in the episodic richness of AMs is the result of a deficit during elaboration, when older adults fail to sustain hippocampal activity.

E33

ELECTROPHYSIOLOGICAL DISSOCIATION OF CATEGORY LEARNING MECHANISMS *Robert Morrison[1], Paul Reber[1], Ken Paller[1]; [1]Northwestern University, Psychology* – Behavioral, neuropsychological, and neuroimaging evidence has suggested that categories can often be learned via either explicit mechanisms critically dependent on medial temporal and prefrontal brain regions, or implicit mechanisms relying on the basal ganglia and sensory cortex. In this study we used a visual category-learning paradigm (Maddox, Ashby, & Bohill, 2003) in which subjects learn to categorize Gabor patches based on their spatial frequency (i.e., how striped the patch is) and/or spatial orientation (i.e., the angle of the lines in the patch). These features are systematically combined with respect to decision thresholds to build category distributions that encourage participants to use either explicit rule-based or implicit information integration strategies to categorize stimuli. On each trial participants choose whether the Gabor patch is an "A" or "B" and then receive feedback as to whether they were correct or not; they receive no explicit instruction on how to categorize stimuli. We monitored brain activity with scalp encephalography while participants (1) passively observed Gabor patches, (2) categorized patches from one distribution, and, one week later, (3) categorized patches from another distribution. Behavioral observations of learning were similar across the two learning conditions. Analysis of EEG collected during both categorization and feedback using both event-related potentials and time-frequency methods provided evidence for distinct brain mechanisms supporting rule-based versus implicit information integration category learning, New insights into this distinction can thus be obtained by monitoring relevant neurocognitive processes in real time using these methods.

E34

CATEGORY LEARNING, BINDING, AND THE MEDIAL TEMPORAL LOBE: EVIDENCE FROM EARLY ALZHEIMER'S PATIENTS *Jared X. Van Snellenberg[1], Janet Metcalfe[1], Murray Grossman[2], Edward E. Smith[1]; [1]Columbia University, Psychology, [2]University of Pennsylvania School of Medicine* – Despite considerable impairments in explicit memory, patients with medial temporal lobe (MTL) lesions and patients with Alzheimer's Disease (AD) have been shown to have intact learning in a number of implicit learning paradigms, including category learning, suggesting that implicit learning does not depend on the integrity of the MTL. Recent evidence, however, suggests that the implicitness or explicitness of a learning paradigm may not be the critical determinant of learning in individuals with a compromised MTL. One alternative is that a 'binding' process, in which distinct elements of a stimulus or event become associated in memory, is critically mediated by MTL. In a test of this hypothesis, we showed that AD patients are at chance performance, and significantly worse than control participants, on an implicit two-category learning task that requires binding for successful performance. These results indicate that some forms of implicit category learning are not intact in patients with MTL pathology, suggesting that the MTL subserves a binding process in learning and memory rather than explicit forms of learning per se.

E35

DETAILED DESCRIPTION OF ROUTES TRAVELLED, BUT NOT MAP-LIKE KNOWLEDGE, CORRELATES WITH TESTS OF HIPPOCAMPAL FUNCTION IN OLDER ADULTS *Marnie Hirshhorn[1,2], Leorra Newman[1], Morris Moscovitch[1,2]; [1]University of Toronto, Psychology, [2]Rotman Research Institute* – We examined hippocampal contribution to remote spatial memory in older adults by correlating their performance on tests sensitive to hippocampal damage with their description of routes they traversed many times or only once, and with their map-like knowledge of downtown Toronto. We found that performance on table-top tests of spatial location (Smith & Milner, 1984) and on paired-associate learning, and the number of Internal Details on the Autobiographical Interview (Levine et al, 2002) all correlated significantly with the number and type of perceptual details used in describing routes one has traversed, but not with map-like knowledge of Toronto. No significant correlations were found with performance on tests of frontal function (WCST, phonemic fluency, backward digit span). We conclude that the hippocampus is implicated in vivid re-experiencing of a familiar route, but not with map-like knowledge of a large-scale environment. These findings are interpreted as consistent with Multiple Trace Theory, but as problematic for Cognitive Map Theory.

E36

HIPPOCAMPAL, PARAHIPPOCAMPAL AND STRIATAL ACTIVITY PREDICTS OBJECT-LOCATION RECALL DURING ACTIVE NAVIGATION *Oliver Baumann[1], Edgar Chan[1,2], Jason B. Mattingley[1,2]; [1]Queensland Brain Institute, The University of Queensland, [2]School of Psychology, The University of Queensland* – In humans, hippocampal, parahippocampal and striatal circuits have been implicated in object-location memory and navigation, but it remains unclear how these areas contribute to the distinct processes of encoding and retrieval of object-locations in three-dimensional space. We used event-related fMRI to measure neural responses during active navigation within an immersive virtual environment. Healthy male volunteers were asked to encode the location of a single target object relative to three cylindrical landmarks and, following a delay period, to retrieve that location from memory by navigating back to the target's original position. The relative and absolute locations of landmarks and the target object were changed on every trial, and no feedback on accuracy was provided. Within subjects, activity in the right hippocampus, the parahippocampal gyrus bilaterally, and the striatum was strongly correlated with accuracy in navigating back to the original target location during retrieval. Between subjects, accuracy and consistency of responses during retrieval also correlated significantly with levels of activity in the parahippocampal gyrus and basal ganglia. These results provide the first evidence that purely landmark-related learning is mediated by hippocampal, parahippocampal and striatal systems, even within a single trial and without reinforcement. We suggest that activity in the hippocampus reflects an allocentric place computation, whereas activity in the parahippocampus reflects a perceptual representation of the landmarks. The concurrent activity in the striatum probably reflects a procedural component of the learning and retrieval process.

E37

CONTRIBUTIONS OF PARIETAL CORTEX TO ATTENTION AND MEMORY: DIVERGENT PROCESSES OF VISUAL ATTENTION AND EPISODIC RETRIEVAL *J. Benjamin Hutchinson[1], Melina R. Uncapher[1], Anthony D. Wagner[1,2]; [1]Stanford University, Psychology, [2]Stanford University, Neuroscience Program* – Functional neuroimaging studies of humans engaged in retrieval from episodic memory have revealed a surprisingly consistent pattern of retrieval-related activity in lateral posterior parietal cortex (PPC). Given the well-established role of lateral PPC in subserving goal-directed and reflexive attention, it has been hypothesized that PPC activation during retrieval reflects the recruitment of parietal attention mechanisms during remembering. Here, we evaluate this hypothesis by considering the anatomical overlap of

retrieval and attention effects in lateral PPC. Specifically, we briefly review the literature implicating dorsal PPC in goal-directed attention and ventral PPC in reflexive attention, as well as the pattern of dorsal and ventral PPC activation during episodic retrieval. This assessment revealed that apparently divergent subregions of lateral PPC are engaged during acts of episodic retrieval and during goal-directed and reflexive attention, suggesting that PPC retrieval effects reflect functionally distinct mechanisms from these forms of attention. Consistent with this conclusion, we then discuss the findings from a recent fMRI study of episodic retrieval and goal-directed attention that revealed within-subject divergence between parietal retrieval and attention effects. Although attention must play a role in aspects of retrieval, the data reviewed here suggest that further investigation into the relationship between processes of attention and memory, as well as alternative accounts of PPC contributions to retrieval, is warranted.

E38

NEURAL CORRELATES OF FACE MEMORY AS A FUNCTION OF RACE-BASED ATTENTION AND CATEGORIZATION *Heather Lucas[1], Joan Chiao[1,2], Ken Paller[2,1]; [1]Northwestern University, Psychology, [2]Northwestern University, Interdepartmental Neuroscience Program* – Memory for faces from one's own racial group is typically more accurate than memory for faces from another racial group. Recent social-cognitive models suggest an instrumental role of social categorization in this phenomenon. Indeed, neural correlates of attention to social category membership have been identified previously, but the relationship of such measures to recognition memory is unknown. In the present study, event-related potentials were recorded during face encoding and retrieval to examine neural correlates of memory for same-race (SR) and cross-race (CR) faces. CR faces were presented in two conditions that differentially emphasized social-categorical encoding. Faces in the CR1 condition were racially uniform, whereas faces from five racial groups were shown in the CR5 condition such that each face differed in race from the majority of others within the same block. Recognition memory was impaired for both CR conditions compared to the SR condition. Event-related potentials differed between CR faces presented within a homogenous (CR1) and heterogeneous (CR5) context beginning around 150 ms after face onset, reflecting early attentional biases. Subsequent-memory analyses suggest that these race-sensitive potentials index processing that is particularly relevant for later recognition memory for CR faces. Thus, results provide neural evidence linking markers of social-categorical attention at encoding with memory for cross-race faces. Furthermore, FN400-like potentials at retrieval in the CR5 condition suggest that categorical encoding of faces engenders distinct retrieval-related processing. Results are discussed in terms of social-cognitive influences on face memory and the cognitive and mnemonic processes reflected in race-sensitive brain potentials.

E39

DOES LONG-TERM SEMANTIC PRIMING ACTUALLY REFLECT ANTIPRIMING? *Katrina Schleisman[1], Matthew Olson[2], Kim Ahneman[1], Rachel Ryan[1], Nicole Landi[1], Chad Marsolek[1]; [1]University of Minnesota, Minneapolis, MN, [2]Macalester College, St. Paul, MN* – Our previous work indicates that the visual representation of an object is strengthened via small representational changes after the object is identified. These changes are responsible for both facilitating subsequent identification of that object (repetition priming) and impairing subsequent identification of other objects whose representations are superimposed with the representation of the primed object (antipriming). In this study, we investigate whether antipriming extends beyond visual object processing and can also be observed in semantic processing. We measured both priming and antipriming relative to a baseline condition in a long-term semantic priming paradigm. First, we obtained measures of visual word naming performance that were unaffected by repetition priming or antipriming (baseline word naming). Next, participants heard a new set of words and made like/dislike judgments to them. Finally, participants performed another visual word naming task in which half of the words were repeated from the preceding phase (to measure repetition priming) and the other half were new words that were unrelated to any words presented previously (to measure antipriming). As expected, repeated words were named faster than new words, but this difference was due to antipriming and not to priming. That is, the antiprimed words were named slower than baseline, while the primed words did not differ from baseline. This suggests that the same principles responsible for visual object antipriming extend to the processing of semantic concepts. Ongoing event-related potential (ERP) investigations will help to clarify the underpinnings of these effects.

E40

CORTICAL REINSTATEMENT DURING RECOLLECTION- AND FAMILIARITY-BASED MEMORY: A MULTI-VOXEL PATTERN ANALYSIS STUDY *Jeffrey D. Johnson[1], Susan G. Robison McDuff[2], Michael D. Rugg[1], Kenneth A. Norman[2]; [1]Neurobiology and Behavior and Center for the Neurobiology of Learning and Memory, University of California, Irvine, [2]Psychology and Princeton Neuroscience Institute, Princeton University* – Episodic memory retrieval is hypothesized to involve the reactivation (reinstatement) of processing engaged during encoding. Recent fMRI studies have supported the reinstatement hypothesis by demonstrating that the neural correlates of retrieval (recollection) differ according to episodic content, and that content-specific retrieval effects overlap with analogous effects observed during encoding. It remains unclear, however, whether cortical reinstatement is restricted to instances where subjects report recollection of episodic details, or if it also occurs when responses are reportedly based on familiarity. The present study (N=16) used fMRI and multi-voxel pattern analysis (MVPA) to investigate the relationship between reinstatement, recollection, and familiarity. Subjects studied words in one of three encoding tasks and then undertook a recognition memory test. The test employed a modified remember/know procedure, in which subjects designated items as either recollected, or if not recollected, rated the confidence that words were old vs. new using a 4-point scale. fMRI data from the study phase were used to train a pattern classifier to discriminate between patterns of brain activity associated with the three encoding tasks. The classifier was then tested on fMRI data from the test phase to determine the degree to which the encoding-related activity patterns were reinstated. Reinstatement was evident for words that were given remember responses and, in addition, for words judged to be highly familiar, with stronger reinstatement effects observed in the former case. The findings indicate that although reinstatement of encoding-related activity may be necessary for the subjective experience of recollection, it is not sufficient.

E41

FUNCTIONAL MR ACTIVATION DURING ENCODING FOR SUBSEQUENTLY PRIMED CONCEPTUAL AND PERCEPTUAL ITEMS *Wei-chun Wang[1], Charan Ranganath[1], Andrew P. Yonelinas[1]; [1]University of California, Davis* – Does conceptual implicit memory rely on regions within the medial temporal lobe? Although previous research has indicated that encoding related activity in the perirhinal cortex is predictive of subsequent familiarity-based recognition, few studies have specifically explored whether this region contributes to implicit memory at encoding. Neuroimaging and behavioral evidence indicates that familiarity-based explicit memory and perceptually-driven implicit memory may be dissociable, but familiarity and conceptual implicit memory are sensitive to the same kinds of manipulations. Mildly hypoxic amnesic patients that are expected to have relatively restricted hippocampal damage exhibit normal levels of familiarity and conceptual priming, while patients with extensive left hemisphere medial temporal lobe damage including the hippocampus as well as the surrounding perirhinal and parahippocampal cortex show significant deficits in both familiarity and conceptual priming. Moreover, to date no study has specifically examined the neural substrates of conceptual implicit memory at encoding. In the current study, we conducted an event-related functional magnetic

resonance imaging study to examine the neural correlates of conceptual and perceptual priming, in order to test the hypothesis that the perirhinal cortex plays a critical role in conceptual implicit memory. Healthy young adult participants were scanned as they completed a pleasantness rating task. After scanning, they completed conceptual (i.e., category exemplar generation) and perceptual (i.e., word fragment completion) implicit memory tasks. Preliminary analyses revealed medial temporal lobe recruitment during the rating task, and that encoding activity leading to successful conceptual priming could be dissociated from encoding activity leading to perceptual priming.

E42

THE HIGH QUALITY OF VISUAL MEMORY *Ilja G. Sligte[1], H. Steven Scholte[1], Victor A.F. Lamme[1,2]; [1]Cognitive Neuroscience Group, Psychology, University of Amsterdam, [2]Netherlands Institute for Neuroscience, part of the Royal Netherlands Academy of Arts and Sciences (KNAW)* – While we experience a rich and detailed world, we can only represent a few objects in visual short-term memory (VSTM). Based on these observations, many authors have suggested that our mental representations of the world are sparse and lack quality. Here, we test this claim by inspecting the representational quality of iconic memory, VSTM and a recently discovered form of visual memory that lies intermediate of iconic memory and VSTM both in terms of life-time (up to four seconds) and capacity (up to 16 objects). We used a variant of the delayed matching-to-sample paradigm that can measure these three forms of visual memory (Sligte et al., 2008). In the basic design, subjects have to detect changes between sample and match displays across a brief retention interval and changes occur in 50 percent of the trials. After each change trial, we presented an identification display that contained the object present in the sample display, but not in the match display (so-called pre-change item) among three distracter items. On the assumption that high-quality representations support both change detection and identification of the pre-change item, we found that people could represent six high-quality representations in iconic memory, three and a half high-quality representations in the intermediate store and only one high-quality representation in VSTM. This clearly suggests that people build up a much richer internal picture than is evident from VSTM alone and people can access these additional rich mental representations when they direct attention to them.

E43

THE DEVELOPMENT OF NEW CONCEPTS IN THE ADULT BRAIN *Rasha Abdel Rahman[1], Kerstin Unger[1]; [1]Humboldt-University Berlin, Psychology* – The formation of conceptual representations in the adult brain was tracked with event-related brain potentials in a multistep learning procedure, in analogy to the incremental enrichment of the semantic system in children. Adult participants were confronted with pictures of initially unfamiliar objects and received gradually increasing functional information about the objects in consecutive sessions. Each session was followed by a test block in which the newly learned objects were presented randomly alternating with well-known objects. Gradual concept development was investigated with different semantic and nonsemantic tasks. Initially, electrophysiological parameters associated with newly learned and well-known objects were markedly different in amplitude and distribution across tasks. The cumulative enrichment of object concepts was associated with gradually decreasing differences between newly learned and well-known objects until, in the last session, they were indistinguishable. These effects related to the development of new concepts were highly stable over time, as suggested by a follow-up test session six months after learning.

E44

INTENTIONAL FORGETTING AND REMEMBERING OF ANGRY AND NEUTRAL FACES - AN ERP STUDY *Johanna Kissler[1], Bastian Zwissler[1], Anne Hauswald[1]; [1]University of Konstanz, Psychology* – The present study investigated behavioral and electrophysiological mechanisms of intentional forgetting and remembering of faces with angry and neutral expressions using item method directed forgetting. Event-related potentials (ERPs) were recorded as participants viewed random sequences of angry and neutral faces, each face followed by a cue designating the previous face as 'to-be-remembered' or 'to-be-forgotten'. Results from a subsequent forced choice recognition memory task revealed overall superior recognition memory for angry faces. However, the 'forget' instruction reduced memory for both angry and neutral faces. ERPs revealed the following effects: First, during face presentation a parietal positivity between 450 and 700 ms after picture on-set was more pronounced for angry than for neutral faces. Second, an enhanced frontal positivity between 500 and 700 ms after cue on-set appeared selectively for 'forget' cues following angry faces. Third, a parietal positivity between 400 and 550 ms after cue onset was largest for 'remember' cues following neutral pictures. The results suggest two different processes contributing to the behavioral directed forgetting effects for neutral and angry faces: For angry faces, initial superior encoding during face viewing as evidenced by an enhanced parietal positivity may be attenuated by frontally mediated active suppression during presentation of 'forget' cues. By contrast, for neutral faces primarily selective rehearsal during presentation of remember cues, reflected in an enhanced parietal positivity, appears to contribute to the effect.

E45

BLACK AND WHITE ISSUES: COLOR PERCEPTION AND OBJECT COLOR KNOWLEDGE *Nina S. Hsu[1,2], Steven M. Frankland[1,2], Sharon L. Thompson-Schill[1,2]; [1]University of Pennsylvania, [2]Center for Cognitive Neuroscience, University of Pennsylvania* – Various theories of semantic memory suggest that our knowledge about objects is grounded in the same neural substrates responsible for perceiving and acting on those objects. In accordance with this view, color knowledge retrieval has been shown to activate some of the same cortical regions involved in color perception, which are defined as those responding more to chromatic than grayscale stimuli (Simmons et al., 2007). It is unclear, however, whether these regions are also differentially engaged by the retrieval of color knowledge about chromatic and achromatic objects. To address this issue, subjects performed two tasks while undergoing fMRI. First, subjects made lighter/darker judgments on pairs of words that named either chromatic (e.g., BASKETBALL - LEMON) or achromatic objects (e.g., COAL - SNOW). To localize color perceptual regions, subjects saw blocks of the Farnsworth-Munsell 100 hue stimuli in which they judged whether color and grayscale wedges were sequentially ordered. Within those regions responding more to color than to grayscale perceptual stimuli, we compared activation during lighter/darker chromatic judgments to that during achromatic judgments. We report co-localization of chromatic perceptual and chromatic object knowledge retrieval processes in the lingual gyrus. Taken in conjunction with Simmons et al.'s report of co-localization in the anterior fusiform gyrus, our results may help to distinguish between brain regions involved across perceptual and conceptual tasks in hue representation, and those involved in higher-level categorical color processing. This is consistent with a general posterior to anterior, perceptual to categorical, transformation in information representation in ventral occipito-temporal cortices.

E46

ANXIETY MODULATES HIPPOCAMPAL INVOLVEMENT IN CLASSIFICATION LEARNING AND EXPLICIT MEMORY *Ajay Satpute[1,2], Russell Poldrack[1], Bruce Naliboff[1]; [1]University of California, Los Angeles, [2]Columbia University* – BACKGROUND: Memory is characterized by multiple systems with distinct processing capabilities and neural substrates, broadly characterized into declarative and non-declarative systems. Under some circumstances, these systems have been shown to compete with each other in learning and expressing new skills, and this competition can be modulated by factor such as distraction. AIMS: The present study examined whether anxiety may also modulate the relative engagement of these memory systems. METHODS: Participants engaged in two identical, interleaved probabilistic classification learning tasks

either behaviorally or while undergoing fMRI. One task was completed while under a high state of anticipatory anxiety as induced by threat of shock, and the other was completed under no threat ('safe'). A test probe was administered after learning to index memory-related neural activity, since neural activity in the learning portion is confounded with the anxiety manipulation. RESULTS: Behavioral measures, consisting of performance (percent correct) and explicit awareness- a verbal report measure indicating the extent to which participants had awareness of associations obtained while learning, were correlated with neural activity in hippocampus, but only for the task learned under threat of shock. CONCLUSIONS: These results suggest that anticipatory anxiety may modulate hippocampal memory processes, but that it does not increase the reliance upon nondeclarative memory as suggested by some rodent studies.

E47

A COMBINED DTI AND FMRI ANALYSIS OF THE NEURAL CORRELATES OF IMPLICIT PROBABILISTIC SEQUENCE LEARNING *Ilana J. Bennett[1], Jessica R. Simon[1], David J. Madden[2], Chandan J. Vaidya[1], James H. Howard Jr.[1,3,4], Darlene V. Howard[1]; [1]Georgetown University, Psychology, [2]Center for the Study of Aging and Human Development, Duke University Medical Center, [3]The Catholic University of America, Psychology, [4]Georgetown University Medical Center, Neurology* – Implicit probabilistic sequence learning involves distributed neural substrates, including fronto-striatal and possibly medial temporal lobe (MTL) networks. Integrity of white matter connecting these networks may mediate relationships between functional activation and learning. To test this hypothesis, 10 younger adults underwent diffusion tensor imaging (DTI) and three runs of functional magnetic resonance imaging (fMRI) while performing the Triplets Learning Task (TLT). In this task, participants respond to the location of the last stimulus (target) in a series of three stimuli, without knowing that the location of the first stimulus predicts one target location on most trials (High Probability) and another location on remaining trials (Low Probability). Correlations were conducted among TLT learning (regression of triplet probability and reaction time), learning-related fMRI activity (regions more active in High minus Low Probability contrast), and white matter tract fractional anisotropy (FA, degree of directionally restricted water diffusivity). Results revealed that early learning (run 1) was negatively correlated with fMRI activity in the hippocampus and later learning (run 3) was positively correlated with caudate and dorsolateral prefrontal cortical (DLPFC) activity. However, there was no evidence that FA mediated the learning-activation relationships. For example, caudate-DLPFC tract FA was marginally negatively correlated with later DLPFC activity, but it was not correlated with later learning. Instead, caudate-DLPFC tract FA was negatively correlated with learning in run 1, possibly indicating that fronto-striatal integrity interferes with early learning, which was functionally correlated with MTL activity. In general, findings revealed complex interactions between the structure and function of these distinct networks.

Memory: Working memory

E48

RELATIONSHIP BETWEEN INDIVIDUAL DIFFERENCES IN SPATIAL AND WORKING MEMORY AND CORTICAL ACTIVATION DURING A DECEPTIVE TASK: AN FMRI STUDY *Scott W. Meek[1], Michelle C. Phillips[1], Laura Bradshaw-Baucom[1], Jennifer M. C. Vendemia[1]; [1]University of South Carolina* – Individual differences in working memory performance on prefrontal cortical activation during a deception task was studied in 21 participants (M=20.7). Reaction time studies have shown that working memory capacity has a significant effect on deceptive response times (Vendemia, Buzan, & Simon-Dack, 2005). Working memory has been associated with prefrontal cortical activation in the literature (Rypma, Berger, & D'Esposito, 2002). Baddeley's model of working memory includes a central executive, a phonological loop, and a visual spatial sketchpad (Baddeley & Hitch, 1974). We hypothesize that deception is associated with the phonological loop in order to maintain relevant deceptive information in memory. Participants viewed questions in which they were randomly prompted to respond truthfully (20%) or deceptively (80%). Data were collected from two tests of working memory, the verbal recognition memory (VRM) and spatial span (SSP) tasks, found in the CANTAB neuropsychological test battery. Activation scores across deception were analyzed for all participants and then correlated against VRM (M=8.587, SE=0.189) and SSP (M=7.065, SE=0.132) scores. Analysis indicates that participants who deceived to a higher number of trials showed stronger frontal lobe activation when lying than when telling the truth, specifically in the right and left superior and middle frontal gyrus (BA 8 and 46). The data show that greater activation for lying than truth telling when repeatedly deceiving can be explained by individual variations in verbal working memory (p=.007), supporting our hypothesis that the phonological loop is more heavily involved in deception than in truth telling.

E49

NEURAL CORRELATES OF WORKING MEMORY TRAINING IN OLD AGE *Yvonne Brehmer[1], Helena Westerberg[1], Anna Rieckmann[1], Lars Bäckman[1]; [1]Aging Research Center, Karolinska Institute, Stockholm, Sweden* – Working memory (WM) is essential for many higher-order cognitive functions and is anatomically related to a widespread fronto-parietal network. WM declines in old age. These WM deficits underlie decline in other cognitive domains (e.g., episodic memory, reasoning) seen in old age. Prior research demonstrates that WM can be improved by intense training in children as well as in younger adults. The aim of the current project is to investigate whether older adults can benefit from intensive WM training, and how the related brain-activity patterns change following training. Twenty-four older adults (M = 63.7) participated in a five-week computerized training study. To test the effectiveness of the WM training program, half of the sample received adaptive training (i.e., individually adjusted task difficulty to bring individuals to their performance maximum), whereas the other half served as active controls (i.e., fixed low-level practice). Individuals' brain activity was measured before and after training with functional magnetic resonance imaging (fMRI), while performing a WM task under two task-difficulty levels. Results indicate that (a) individuals improve their WM performance through training, (b) adaptive training as well as low-level practice result in decreased brain activity in task-relevant regions (frontal, parietal, and temporal), and (c) under the high task-difficulty condition, adaptive training results in larger decreases in right frontal areas compared to the active control group. To conclude, intensive WM training improves older adults' functioning and neural efficiency. However, the advantage of adaptive training is most apparent under high task difficulty conditions.

E50

TEMPORAL DYNAMICS OF RESOURCE ALLOCATION IN VISUAL WORKING MEMORY *Paul Bays[1,2], Nikos Gorgoraptis[1,2], Raquel Catalao[1,2], Masud Husain[1,2]; [1]Institute of Cognitive Neuroscience, University College London, UK, [2]Institute of Neurology, University College London, UK* – Our ability to remember what we have seen is remarkably limited. A longstanding model of visual working memory states that storage is limited to a fixed number of memory 'slots' - usually four - each holding one visual item. However there has been little investigation of the resolution with which visual information is maintained. Using a discrimination task, we recently probed the precision of subjects' memory for object locations and orientations (Bays & Husain, Science, 2008). We found that precision declines rapidly with increasing number of items, even when this number is well below the proposed limit. Rather than being stored in separate slots, these results suggest there is a common memory resource which must be distributed between visual objects. Allocation of this resource is flexible, so that salient items are stored with enhanced preci-

sion. Here, we probe the temporal dynamics of visual working memory by varying the presentation time of multi-item displays, followed by pattern masks. For very brief exposures (<100ms), we find that recall is limited by incomplete encoding; but at the longest exposures, recall becomes limited by the working memory resources available for each item. Intermediate presentation times reveal the dynamic allocation of visual resources to items in the scene. Accurate recall of an item depends not only on maintaining precise representations of its individual features, but also correctly storing features that belong to the same object together. Further analysis of our data demonstrates that precision and binding independently influence our ability to remember objects in the visual scene.

E51

AGE EFFECTS ON EVENT-RELATED POTENTIAL AND CARDIOVASCULAR PARAMETERS IN A WORKING MEMORY TASK *Sergei A. Schapkin[1], Gabriele Freude[1]; [1]Federal Institute for Occupational Safety and Health, Berlin, Germany* – Working memory (WM) is considered to be quite susceptible to age (e.g. West, 1996) that may cause problems in older employees who are occupied with complex work requiring WM. Under WM load older employees were hypothesised to involve controlled processing sub-served by frontal lobes to prevent performance decline and that enhanced frontal activity can provoke maladaptive cardiovascular reactions to changing task demands. 21 younger (28±3 years) and 21 older (54±3 years) employees had to perform a visual oddball and n-back tasks. In the 2-back task older employees responded slower and less accurately than younger, while no age affects in oddball task were found. In younger employees the target P3 of the event-related potential was progressively reduced from parietal to frontal sites, while more evenly distributed P3 upon the scalp in older employees was found. P3 latency was shorter in younger than in older employees. Heart rate (HR) was higher, both heart rate variability (HRV) and baroreflex sensitivity (BRS) were lower in older than in younger employees. Older employees showed lower responsivity of BRS, HRV and HR to task demands and delayed cardiovascular recovery as compared to younger employees. The results suggest that WM load in older employees can impair target categorization and lead to compensatory involvement of frontal lobes to enhance controlled processing and mental effort. In turn, the increase in frontal activity can induce maladaptive functioning of cardiovascular system in terms of a reduced responsivity to alternating task demands and a delayed recovery in healthy older employees.

E52

VERBAL WORKING MEMORY MAINTENANCE DEPENDS ON LANGUAGE PRODUCTION SYSTEMS: A FUNCTIONALLY-GUIDED TMS INVESTIGATION *Daniel Acheson[1], Bradley Postle[1]; [1]University of Wisconsin - Madison* – The emergent-property perspective of working memory (WM) states that the same brain regions involved in long-term processing of different types of information also subserve WM maintenance. Consistent with this view, several recent studies have demonstrated a critical role for the posterior superior temporal gyrus (pSTG), a region that has also been implicated in phonological ordering processes in language production, in verbal WM maintenance. We explored the functional relationship between language production and verbal WM by targeting language production regions with functionally guided repetitive transcranial magnetic stimulation (rTMS). First, functional magnetic resonance imaging (fMRI) was used to elicit activity in pSTG and middle temporal gyrus (MTG), respectively, during two stages of production: phonological ordering and lexical-semantic retrieval. Next, these regions were targeted with rTMS during three tasks: rapid paced reading; picture naming; and delayed serial recall (i.e., verbal WM). We hypothesized that rTMS of pSTG would alter phonological ordering processes, and would thus disrupt both rapid reading and serial recall of nonwords, but would only minimally impact lexical-semantic processes (picture naming); rTMS to the MTG would produce the opposite pattern. The results confirmed the theoretically critical prediction that rTMS applied to the pSTG increases errors in rapid reading and in delayed serial recall, whereas rTMS to the MTG has no effect on these tasks. Picture naming (the control task) was sensitive to rTMS to both brain regions. Verbal WM maintenance may thus be nothing more than speech production processes (specifically, phonological ordering) "looping" for the duration of the delay period.

E53

PRECISION OF VISUAL WORKING MEMORY FOR SEQUENTIALLY PRESENTED STIMULI *Nikos Gorgoraptis[1,2], Paul M Bays[1,2], Masud Husain[1,2]; [1]Institute of Cognitive Neuroscience, [2]Institute of Neurology, University College London, UK* – Recent work has shown that visual working memory capacity is not fixed by number of items, but rather is a limited resource, flexibly allocated across space (Bays & Husain, Science, 2008). Importantly, these findings emerged when investigators probed the precision with which visual information is maintained, rather than using change detection as an index of memory capacity. Here we investigate the allocation of visual working memory resources across time, using a discrimination rather than change detection task. We assess the precision of subjects' memory for the orientation of sequentially-presented visual stimuli (coloured bars) all displayed at central fixation. Precision is very high for a single item, but decreases as increasing numbers of stimuli are presented after that item. Memory for the intervening items falls with increasing sequence length but importantly delay length itself is not able to account for these effects. When a predictive cue is given for one of the stimuli (62.5% validity), recall for this item is considerably enhanced. Precision for non-cued items shows a corresponding reduction compared to trials where no cue is present. The findings support the concept of a limited resource that can be allocated to maintaining items in working memory. The allocation of this resource is flexible, not only across space but also over time, and can be modulated according to the relevance of stimuli to task goals.

E54

POSTERIOR PARIETAL CORTEX MEDIATES ENCODING PROCESSES IN CHANGE BLINDNESS *Philip Tseng[1], Tzu-Yu Hsu[2,3,4], Neil Muggleton[5], Ovid Tzeng[2,3,4,6], Daisy Hung[2,3,4], Chi-Hung Juan[2,3]; [1]University of California, Psychology, Santa Cruz, CA, [2]Institute of Cognitive Neuroscience, National Central University, Jhongli, Taiwan, [3]Laboratories for Cognitive Neuroscience, National Yang-Ming University, Taipei, Taiwan, [4]Institute of Neuroscience, National Yang-Ming University, Taipei, Taiwan, [5]Institute of Cognitive Neuroscience & Psychology, University College London, London, United Kingdom, [6]Institute of Linguistics, Academia Sinica, Taipei, Taiwan* – It is commonly accepted that right posterior parietal cortex (PPC) plays an important role in updating spatial representation, directing visuospatial attention, and planning actions. Recent change blindness studies in combination with functional magnetic resonance imaging (fMRI) and transcranial magnetic stimulation (TMS) techniques from Beck and colleagues (2001 & 2006), however, suggest that right PPC is also a critical component of processes that are "more conscious", such as detecting a change between two pictures (picture A and A') in a change blindness paradigm. The present study seeks to apply TMS in briefer and different time intervals to investigate the process of which the right PPC is involved. Since change detection requires proper encoding of visual features during viewing of picture A and successful comparison between the features during viewing of picture A', we applied TMS pulses either during the presentation of picture A (early TMS) or A' (late TMS) in a one-shot change blindness paradigm in order to selectively disrupt the encoding or comparison processes, respectively. Our results show that right PPC TMS was most effective during the encoding phase, thus suggesting that the right PPC is responsible for encoding visual features into our visual short-term memory. In addition, our change blindness paradigm did not alter any spatial components of the stimuli. Therefore, contrary to the belief that the right PPC is only responsible for the spatial aspect of a stimulus, our results imply that it is also involved in encoding certain identity-based information.

E55

WHEN 'WHAT' IS NEGLECTED BASED ON 'WHERE' IN NEGLECT PATIENTS *Arnaud Saj[1,2,3], Patrik Vuilleumier[1,2,3]; [1]Neuroscience, University of Geneva, [2]Center for Neuroscience, University of Geneva, [3]University Hospital, Neurology, Geneva* – Recent findings in healthy subjects indicate that memory capacity for spatial locations but not colors may increase when the items are separated between the two visual fields, rather than presented within the same hemi-field. This observation suggests some independence between the two hemi-fields for encoding spatial locations. We used a similar task to test patients with right hemispheric brain lesion with or without neglect syndrome. To examine whether a complete independence of the two visual fields can be observed, the squares could appear in two frames from the same hemi-field; or in two frames from different hemi-fields. In the two first experiments, participants indicated whether colors or locations of the squares in the test display were the same as, or different from, the ones in the sample display. In a last experiment, the task was similar to exp 1 but the squares also changed locations (but locations were always task irrelevant). Altogether, our results demonstrate that patients with spatial neglect have impaired spatial working memory capacity for location, whatever the visual field. However, no deficit was found for color capacity unless there was a concomitant change of location in left space. In conclusion, an independence between the two hemi-fields was not present in neglect patients, and their working memory showed selective impairment for location but not color in both fields. The deficits found in exp 3 suggest an inability to code for object properties across different spatial locations which may contribute to exploratory deficits spatial, typically observed in right-brain-damaged patients with spatial neglect.

E56

WORKING MEMORY CAPACITY AND INHIBITION IN AX-CPT *Yukio Tsuchida[1], Harumitsu Murohashi[2]; [1]Graduate School of Education, Hokkaido University, [2]Faculty of Education, Hokkaido University* – Individual differences in working memory capacity (WMC) reflect the ability to control attention. This ability is related to response inhibition as a Stroop task, meanwhile is not related to simple response inhibition as a stop-signal task. We examined the relationship between two types of response inhibition and individual differences in WMC by ERPs. Participants were low- and high-WMC group assessed in a reading span test. We used an AX-CPT paradigm that consisted of cue and probe pairs. The probability of A-X trial was 70%, other trials (A-nonX, nonA-X, and nonA-nonX) was 10%, respectively. In the no-go condition (simple response inhibition), participant was asked to press a button when X followed A. In the 2-choice condition (response inhibition and selection), participant was asked to press one button when X followed A, and another button for all other letters. P300 amplitude for the cue in both conditions was larger for the high-WMC group than for the low-WMC group. However, there was no difference in P300 amplitude for all probes. N200 amplitude for the A-nonX probe in the 2-choice condition was larger in the low-WMC group than in the high-WMC group. There was no difference in N200 amplitude for other probes. These results suggest that response inhibition per se was not related to WMC. Rather, WMC is related to the ability to maintain an appropriate state of readiness based on the processing of cue information. Therefore, the enhanced N200 amplitude in the low-WMC group may suggest a deficiency of appropriate readiness.

E57

SEARCHING FOR TARGETS WITHIN VISUAL SHORT-TERM MEMORY *Bo-Cheng Kuo[1,2], Anling Rao[1], Jöran Lepsien[3], Anna Christina Nobre[1]; [1]Experimental Psychology, University of Oxford, UK, [2]National Taiwan University, Psychology, Taipei, Taiwan, [3]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany* – Recent studies have revealed that the internal representations that we construct from the environment and maintain in visual short-term memory (VSTM) to guide behavior are highly flexible, and can be selectively modulated and accessed by attentional mechanisms according to our task goals and expectations. However, how these attentional mechanisms operate upon VSTM representations is largely unknown. In the current experiment, we investigated whether VSTM representations contain an intrinsic spatial layout that is related to that in the perceptual array from which it is constructed; and tested whether searching for relevant target items from within VSTM representations involves spatially specific, retinotopic biasing of neural activity in a manner analogous to that which occurs during visual search for target items in perceptual arrays. Two ERP experiments revealed that selection of a target object within a search array maintained in VSTM proceeds through similar mechanism as that in the perceptual domain. In line with previous results, an N2pc potential was obtained when targets were identified within a perceptual visual-search array. Interestingly, a similar N2pc was also elicited when target items were identified within a VSTM representation. The N2pc in the visual and VSTM domains had equivalent time-courses and topographies, suggesting a large degree of overlap in the spatially specific neural mechanisms of target selection in the two cases.

E58

ANXIETY MODULATES NEURAL EFFICIENCY OF PROCESSING IN WORKING MEMORY *Ulrike Basten[1,2,3], Christine Stelzel[1,2,3], Christian J. Fiebach[1,2,3]; [1]University of Heidelberg, Psychology, Germany, [2]University of Heidelberg, Neuroradiology, Germany, [3]University of Heidelberg, Neurology, Germany* – It has been postulated that anxiety impairs the efficiency of performance in cognitive tasks, specifically in tasks requiring the processing of information in working memory (WM) as opposed to pure WM maintenance. In comparison to non-anxious individuals, it is assumed that anxious individuals reach a given level of performance only by the investment of additional effort, which makes processing less efficient. In the present study, we used functional magnetic resonance imaging (fMRI) to explore how state anxiety is associated with neural efficiency, measuring BOLD activation in tasks addressing different processing functions of WM, i.e. monitoring, updating, and manipulation of information. We hypothesized that activation in dorsolateral prefrontal cortex (DLPFC) - a brain region critically involved in the processing of WM contents and executive functioning - shows a positive correlation with state anxiety (measured using Spielberger's state-trait anxiety inventory, STAI). During the task phase of a delayed response task, N = 48 subjects either monitored, updated, or manipulated a memory set of four letters. A conjunction of task-related BOLD activation revealed that bilateral DLPFC was commonly activated by the different conditions. In right DLPFC, activation was modulated by anxiety. Specifically, in all three conditions individuals scoring higher on state anxiety showed stronger DLPFC activation, independent of their performance. We interpret this result as evidence for a lower degree of neural efficiency in anxious individuals. The finding suggests that anxiety affects neural processes common to different component processes of WM that require the handling and processing of contents in WM.

E59

GENE-GENE-INTERACTION OF COMT VAL158MET AND DRD2 POLYMORPHISMS ON UPDATING BUT NOT MAINTENANCE *Christian Fiebach[1], Ulrike Basten[1], Christine Stelzel[1], Christian Montag[2], Martin Reuter[2]; [1]University of Heidelberg, Psychology, Neuroradiology, and Neurology, Germany, [2]University of Bonn, Psychology, Germany* – Imaging genetics recently investigated how dopamine gene polymorphisms, particularly the Catechol-O-Methyltransferase Val158Met polymorphism, influence working memory (WM) performance, mostly relying on one behavioral paradigm, the n-back task. Dopaminergic influences on cognition, however, are multigenetic in nature, and WM involves different component processes not separable in the n-back task, such as maintenance of information in WM, and updating of WM contents. We explored how two polymorphisms related to dopaminergic activity, Val158Met and the DRD2/ANKK1-TaqIa receptor gene polymorphism, modulate maintenance vs. updating. 12 participants were randomly drawn for each of four genotype groups, Val+/A1-, Val+/A1+, Val-/A1-, Val-/A1+.

While genotype group had no influence on performance, fMRI responses revealed task specific genotype effects in prefrontal cortex (PFC). When maintaining four letters, no gene-gene interactions were observed in PFC. Maintenance of six letters, as well as updating, elicited a COMT/DRD2 interaction of activity in left DLPFC. Updating of WM contents additionally showed a COMT/DRD2-modulation of activity in the right inferior frontal junction area, known to be involved in the prefrontal control of executive task demands. Both gene-gene interactions showed increased activation for a genetic equilibrium, i.e., when high levels of dopamine concentration meet an increased receptor density, or when lower dopamine levels coincide with reduced receptor densities. These results suggest that dopamine system activity influences the efficiency of prefrontal cognitive processing, that these effects depend on multiple genetic factors related to dopamine, and that distinct prefrontal component processes such as maintenance and updating are differentially modulated by the activity of the dopamine system.

E60

IT'S NOT WHAT THEY DO BUT THE WAY THAT THEY DO IT: EXPLORING DIFFERENCES IN VERBAL WORKING MEMORY IN PARENTS OF CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT *Johanna Barry[1], Beate Sabisch[1], Jens Brauer[1], Angela Friederici[1]; [1]Max Planck Institute for Human Cognition and Brain Sciences* – Children affected by Specific Language impairment (SLI) typically demonstrate deficits in verbal working memory (VWM). SLI is highly heritable and, since parents of these children have a higher prevalence of poor VWM than parents of typically developing children, it has been suggested that this serves as heritable risk factor for the disorder. In this study, we used fMRI to tease apart factors contributing to the poorer VWM in parents of children with SLI. We included 32 parents; 16 parents of affected children and 16 of typically-developing children. We simultaneously presented verbal stimuli in both the auditory and visual modalities (encoding phase) and participants were required to subvocally rehearse either the seen or the heard stimuli for an extended period of time before performing a recognition task. We predicted similar cortical responses in both groups during the encoding phase of the task, with differences in activations emerging later, during the rehearsal and recognition phases and being localised to the inferior frontal gyrus, and the Sylvian-parieto-temporal and supramarginal areas. Preliminary results largely confirm these predictions. Notably, however, little evidence was found for deviant information-processing in the parents of children with SLI, instead group differences reflect considerably reduced levels of activation particularly across the frontal lobes in these adults.

E61

THE EFFECT OF RETRO-CUEING ON AN ERP MARKER OF VSTM MAINTENANCE *Alexandra Murray[1], Bo-Cheng Kuo[1], Mark Stokes[1], Anna Christina Nobre[1]; [1]University of Oxford, Experimental Psychology* – Previous research has found that Contralateral Delay Activity (CDA) is correlated with the number of items maintained in Visual Short Term Memory (VSTM) from one visual field (VF) (Vogel & Machizawa, 2004). CDA is usually elicited by a to-be-remembered array after a prospective cue (pro-cue) signalling the relevant side of the visual display, and is interpreted as a putative electrophysiological signature of WM maintenance. Attention can also be directed to the contents of VSTM, after the presentation of a visual array, using a retroactive cue (retro-cue) (Nobre, Griffin, & Rao, 2008). Because retro-cueing directs attention within a memory trace, potentially reducing the load of items to be maintained, we hypothesised that this would significantly attenuate the CDA. Participants were initially presented with a spatial pro-cue which reduced the number of to-be-remembered items to one side. After a delay, a memory array of either four (low load) or eight (high load) items was displayed. A retro-cue then cued participants to one location within the relevant VF, further reducing the load of to-be-remembered items; or provided no information, requiring participants to hold all items in the relevant VF. At the end of the trial, participants performed a same/different judgement on a test stimulus. Retro-cues significantly improved VSTM performance. Unexpectedly, the CDA was abolished by the presentation of both spatially predictive and neutral cues, independently of the VSTM load participants had to maintain.

E62

CATEGORICAL AND COORDINATE SPATIAL RELATION PROCESSING IN WORKING MEMORY, AN FMRI STUDY *Ineke van der Ham[1], Mathijs Raemaekers[2], Richard van Wezel[2], Anna Oleksiak[2], Albert Postma[1]; [1]Helmholtz Institute, Experimental Psychology, Utrecht University, [2]Helmholtz Institute, Functional Neurobiology, Utrecht University* – Spatial relations can be subdivided into two main types; categorical relations concern the more abstract, qualitative relations like "left of", while coordinate relations entail more metric relations such as "two meters away". Previous theoretical and experimental claims have been made about hemispheric lateralization dissociating the two types: categorical processing is suggested to show a left hemispheric advantage, while coordinate processing is proposed to show a right hemispheric advantage. Furthermore the brain areas suggested to be involved in this type of processing mainly lie within the parietal cortex. To expand the limited imagery data on this topic we have attempted to address this issue with an fMRI study using a new experimental paradigm. The design involves a match-to-sample working memory setup to assess activity during categorical and coordinate processing at different retention intervals (500 ms and 2000 ms). Behavioural data indicate the hypothesized double dissociation of hemisphere and task. Imaging data reveal a clear involvement of parietal regions, mainly during categorical processing, while some frontal activity is also found, related more to coordinate processing. One effect of laterality has also been found, limited to the superior parietal cortex and the 2000 ms retention interval. We therefore conclude that lateralization is not as strong as some previous studies have suggested. However, there is evidence that in certain circumstances categorical processing has a left hemispheric advantage, while coordinate processing shows a right hemispheric advantage.

E63

THE ROLE OF HIPPOCAMPAL THETA OSCILLATIONS IN WORKING MEMORY *Nathan Cashdollar[1,2], Ulrike Malecki[3], Fergus J. Rugg-Gunn[4], John S. Duncan[1,4], Emrah Duzel[2,3]; [1]Institute of Neurology, UCL, London, UK, [2]Institute for Cognitive Neuroscience, UCL, London, UK, [3]Institute of Cognitive Neurology and Dementia Research, O.v.G University, Magdeburg, Germany, [4]National Hospital for Neurology & Neurosurgery, UCL, London, UK* – The relative contribution of the hippocampal formation to short-term working memory is currently under debate. In a series of working memory experiments using Magnetoencephalography (MEG) we investigated cortical synchronization within the theta band during the active maintenance of configural or non-configural visual stimuli in delayed-match-to-sample tasks (DMS) in healthy adults and patients with bilateral hippocampal lesions. Object-based maintenance of non-configural information enhanced theta coupling along fronto-parietal sensors. However, the active retention of spatial configurations engaged a characteristically alternative network of occipito-temporal and fronto-temporal theta synchrony. This pattern was abolished in patients with bilateral hippocampal injury who displayed selective impairments in configural DMS tasks, but intact visual discrimination of complex scenes. Additional behavioral testing after configural and non-configural DMS tasks revealed increased long-term recognition memory performance for configural stimuli compared to non-configural in healthy controls. Enhanced recognition memory performance for configural stimuli was evident in epilepsy patients with structurally intact hippocampi where no differences were found in patients with bilateral hippocampal atrophy. These results conclude that hippocampal integrity is critical to the process of actively maintaining spatial configurations over a delay and in turn results in more successful long-term memory. Overall, this suggests that occipito-temporal/fronto-temporal theta synchrony reflects recruitment of regions conventionally thought of as a long-term working mem-

ory system, and is necessary to support this form of working memory maintenance by orchestrating a qualitatively different neural network than fronto-parietal object maintenance.

E64

COMBINING ELECTROENCEPHALOGRAPHY AND NEAR-INFRARED SPECTROSCOPY TO EXPLORE INSTANTANEOUS AND CONTINUOUS MENTAL WORKLOAD STATES *Krysta Chauncey[1], Leanne Hirshfield[2], Erin Solovey[2], Audrey Girouard[2], Robert Jacob[2], Angelo Sassaroli[3], Sergio Fantini[3]; [1]Neurocognition Laboratory, Tufts University, [2]Human-Computer Interaction Laboratory, Tufts University, [3]Biomedical Engineering, Tufts University* – Electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRs) are complimentary to each other in both temporal and spatial resolution, and both have been used to classify participants' working memory load; however, they have yet to be integrated in a way that takes advantage of the millisecond-by-millisecond temporal resolution of EEG and the millimeter-fine spatial resolution of fNIRS. This work explores ways that these two methods can be combined by creating a subsegmentable task, which can be informative when examined using either the timeframe of EEG or that of fNIRS. Participants viewed trials of rows of red and blue airplanes (only one row was visible at a time), and were asked to keep track of the total number of each color for blocks of 60 seconds. Working memory load was manipulated by the number of planes per row (two, eight, or variable). EEG analysis was done on a trial-by-trial basis, and fNIRS analysis was done by blocks of 60 seconds. EEG data showed increased event-related synchronization (ERS) to increasing memory load at the single-trial level, while fNIRS data showed increased blood oxygenation to increasing memory load in continuous load conditions, but could not differentiate between the variable-load blocks and the high-load blocks. These findings will be discussed in the context of current models of working memory and task management.

E65

MDMA AND POLYDRUG USE ERP EFFECTS IN MEMORY SCANNING *Brian Lopez[1], John Polich[1]; [1]The Scripps Research Institute* – Short-term memory processing was assessed with a memory scanning paradigm in substance-using college students. Substance use was categorized into two groups: (1) MDMA users who primarily have used ecstasy with no or very little other substance use, and (2) polydrug users who have used many substances in addition to ecstasy. A third group consisting of non-using controls was also assessed. A total of 12 females and 12 males comprised each drug use-group. Participants were instructed to memorize a list of two, four, or six digits and were subsequently presented with single probe digits that were either present or absent in the preceding memory set. Participants responded to the probes while event-related brain potentials (ERPs) were recorded in the three memory-load conditions. Consistent with classic memory scanning findings, response time to positive and negative probes increased with memory set size and were shorter for positive probes versus negative probes. However, no performance differences were observed among drug-use groups. P300 amplitude decreased and latency increased as set size increased. Within each condition, positive probes yielded larger P300 component size and shorter peak latency than negative probes. No reliable differences in P300 amplitude or latency were observed among the three drug-use groups. MDMA and polydrug use does not appear to affect behavioral performance or neuroelectric assessment of short-term memory scanning.

E66

BACK TO THE FUTURE: DISTRACTION REVEALS PREEMINENCE OF PROSPECTIVE VS. RETROSPECTIVE REPRESENTATIONS IN VISUAL WORKING MEMORY *Jarrod Lewis-Peacock[1], Bradley Postle[1]; [1]University of Wisconsin-Madison* – Delay-period activity in inferior temporal (IT) cortex of the monkey can represent both retrospective and prospective information, and by one account only the latter is robust to interference (Takeda et al., 2005). We explored the effects of visual distraction on the short-term retention of information in humans. First, subjects performed delayed recognition in the fMRI scanner and a pattern classifier learned to identify delay-period activity associated with the retention of faces, scenes, and objects. Second, subjects learned (offline) arbitrary cross-category pairings of stimuli from the original set. Third, subjects returned to the scanner to perform delayed paired-associate recognition with distraction from irrelevant stimuli, and the pattern classifier was used to decode delay-period activity. Half of the subjects were instructed to concentrate on the initial target stimulus during the delay period (and thus engage a retrospective code), and half to concentrate on the anticipated memory probe (a prospective code). Performance was near ceiling. Delay-period classification results from the "prospective" group indicated that prospective representations in IT cortex (and other posterior brain regions) were eclipsed while distractors were on the screen, but re-emerged following the offset of distraction. In "retrospective" subjects, however, these regions were seemingly unable to sustain a retrospective representation across distracted delay periods, instead switching over to a prospective code with the onset of distraction. Thus, the pattern of robust prospective coding vs. mutable retrospective coding extends to humans. More generally, it is consistent with the view that the brain prioritizes preparing for the future over remembering the past.

E67

VISUO-MOTOR REPRESENTATIONS VARY AS A FUNCTION OF ONLINE FEEDBACK: VISUALLY-GUIDED VERSUS MEMORY-GUIDED TRACKING *Joseph Geeseman[1], Matthew Schlesinger[1]; [1]Southern Illinois University, Carbondale* – Visual information is typically available both prior to and during visually-guided behaviors such as reaching and pointing (i.e., offline and online, respectively). The current study investigated the conditions under which subjects exploit offline information that is available before movement begins. Accordingly, neural activity was measured with functional MRI as subjects tracked and "intercepted" a moving target. Prior to each trial, the path of the target was cued by briefly presenting four points along the target's trajectory. Online feedback was manipulated by occluding the center portion of the target's trajectory on half of the trials (i.e., Occluded vs. Visible). As expected, availability of online feedback influenced the observed pattern of neural activation. In particular, a comparison of Occluded and Visible trials revealed higher activity during the Occluded trials in parietal and frontal regions versus higher activity in occipital areas during Visible trials. This pattern suggests that subjects may rely less on offline or pre-movement information when visual feedback is available during the movement.

E68

INFLUENCE OF SPEED OF PROCESSING TRAINING ON WORKING MEMORY IN OLDER ADULTS *Anne S. Berry[1], Theodore P. Zanto[1], Aaron M. Rutman[1], Wesley C. Clapp[1], Joseph L. Hardy[2], Adam Gazzaley[1]; [1]University of California, San Francisco, Neurology and Physiology, [2]Posit Science Corporation, San Francisco* – Computer-based training programs designed to improve cognition have been utilized with apparent success in the auditory modality for children with autism and for older adults. These results have inspired interest in plasticity-based training approaches targeted at other modalities, such as vision to improve perception, attention, and working memory (WM). The burden of such studies is in demonstrating that training-related gains transfer to independent tasks and that these improvements are associated with neural change. The goal of this electroencephalography (EEG) study was to assess whether older adults receiving extensive training on a basic motion perception discrimination task (a module in Posit's InSight TM visual training package) show improved perceptual discrimination and WM performance on an independent visual motion task. To evaluate improvement associated with training, behavioral performance and neural recordings were collected at two time points for training (before and after training) and no-contact control groups. WM improvement was

tested using a delayed match to sample task with and without distractors. So that differences in motion direction discrimination between individuals was not a factor in WM task performance, perceptual discrimination was tested using a perceptual thresholding procedure prior to the WM experiment. Preliminary results reveal training improves perceptual discrimination and WM memory performance compared to controls. Interestingly, WM enhancement may only be present when post-training participants are tested at their pre-training threshold. These results suggest improved perceptual processing drives WM improvement. Spectral and event-related potential results for the cue period suggest more efficient visual processing after training.

E69

VISUAL WORKING MEMORY AND CONSCIOUS AWARENESS *Weiwei Zhang[1], Steve Luck[1,2]; [1]University of California, Center for Mind & Brain, Davis, CA [2]University of California, Psychology, Davis* – Researchers have proposed working memory representations are tightly tied to awareness. To explore this hypothesis, we combined a color recall paradigm with a confidence rating procedure. Participants viewed briefly presented arrays of colored items and recalled one of the colors after a 900-ms delay. They then used a 7-point scale to indicate their confidence. We found that observers tended to have high confidence levels when they were holding the tested item in working memory. When observers were not holding the tested item in working memory, they exhibited a reduced likelihood of indicating the highest level of confidence (level 7). These results indicate that the presence of a representation in working memory is associated with awareness of a representation. In addition, when the item was present in working memory, observers were able to use the whole confidence scale in a meaningful way, providing further evidence of a close tie between the presence of a representation and awareness of the representation. However, when the item was not present in working memory, observers could not use levels 1-6 of the scale in a meaningful way, suggesting that the absence of a representation does not provide any details that can be represented in awareness. Finally, although observers were aware of the presence of working memory representations, they did not have meaningful information about the accuracy of the representations that were in memory. Thus, awareness is linked to the presence but not the accuracy of working memory representations.

E70

THE EFFECTS OF MEDIAL TEMPORAL LOBE DAMAGE ON PROACTIVE INTERFERENCE *Craig Brozinsky[1], David Badre[2], Mark DEsposito; [1]University of California Berkeley, [2]Brown University* – Recent findings demonstrate that patients with medial temporal lobe damage have subtle deficits on short-term item recognition tasks. Their deficits could reflect dysfunctional maintenance and storage processes, or they could reflect a reduced ability to resist interference that has built up across a test session. We tested this latter hypothesis by using a variant of Monsell's recent probes task, which has previously been related to prefrontally mediated processes such as inhibitory control and episodic retrieval. On this task, normal subjects perform more slowly and less accurately on trials where a memory probe was not a member of the current rehearsal set, but was a member of the previous trial's rehearsal set. We hypothesized that, under normal circumstances, recollection helps to reject these familiar lures. Accordingly, we predicted that patients with focal hippocampal damage, who tend to have impaired recollection and relatively normal familiarity, would be heavily susceptible to interference from previous trials. In patients with more extensive medial temporal lobe damage (unilateral hippocampus, perirhinal, and entorhinal cortices), who tend to have both familiarity and recollection deficits, we predicted that familiarity would minimally be generated, and thus protect against interference effects. The two patient groups were compared to controls on a letter and a shape version of the recent probes task. Despite having lower baseline recognition accuracy and slower reaction times, the focal hippocampal patients did not have magnified interference effects. These results suggest that cross-trial interference does not mediate short-term recognition deficits in focal hippocampal patients.

E71

RETRIEVING INFORMATION FROM A NEW EVENT SELECTIVELY ACTIVATES THE MEDIAL TEMPORAL LOBES *Jeffrey M. Zacks[1], Khena M. Swallow[1], Deanna M. Barch[1], Denise Head[1], Corey J. Maley[1], Derek Holder[1]; [1]Washington University in Saint Louis* – When watching others' activities, observers segment it into meaningful events. For example, when watching another person make tea, an observer might segment the activity into filling a mug with water, heating the water, and putting a tea bag in the mug. Event Segmentation Theory (EST, Zacks et al., 2007, Psychological Bulletin) proposes that retrieving information across an event boundary should rely more on episodic retrieval systems and medial temporal lobe structures than retrieving information within an event. Using functional MRI, we measured participants' brain activity while they watched movie clips in which a variety of objects appeared. Five seconds after an object left the screen the movie paused for a recognition test and participants distinguished between the object that was in the clip and a new object that had not appeared in the clip. An independent group of observers identified event boundaries by watching the clips in their entirety and dividing them into discrete units of activity. Brain activity during the recognition test was analyzed based on whether an event boundary occurred during the 5-s delay between object presentation and test. Thus, information was either retrieved across an event boundary or from within the current event. As predicted, the medial temporal lobe showed greater activity when participants retrieved information across an event boundary than when they retrieved information from within the current event. These differences were observed despite the equivalent delay across conditions. These data provide compelling evidence that event boundaries act as a form of control over some memory processes.

E72

NEUROPLASTICITY-BASED COGNITIVE TRAINING IMPROVES WORKING MEMORY IN SCHIZOPHRENIA PATIENTS: BEHAVIORAL AND FMRI ASSESSMENTS *Sophia Vinogradov[1], Karuna Subramaniam[1], Tracy Luks[1], Stephanie Aldebot[1], Adelaide Hearst[1], Arul Thangavel[1], Melissa Fisher[1], Gregory V. Simpson[1], Srikantan Nagarajan[1]; [1]UCSF* – Previous research has demonstrated that schizophrenia patients show impairments in attention, working-memory (WM) and cognitive control functions, and show decreased activation in DLPFC when performing these tasks compared to healthy controls (HCs). Here, we investigated whether neuroplasticity-based cognitive training would improve working memory functions in schizophrenia patients. We used fMRI to measure brain activity in 24 patients and 12HCs while they performed three N-Back tasks, of increasing levels of WM load (0,1,and 2-Back tasks). Twelve patients were then randomly assigned to 16 weeks of computerized targeted cognitive training (TCT) focusing on auditory and visual processing, affect recognition, and mentalizing tasks, while the remaining 12 control patients played computer games (CGs). All subjects repeated the fMRI task after 16 weeks. BOLD fMRI activity was measured on a 3T-GE scanner before and after intervention. Whole-brain analyses of the N-back task focused on regions showing greater activation on the 2-back compared to the 0-back task. At baseline, HCs demonstrated greatest activation in the right middle/inferior frontal gyrus (M/IFG). After 16 weeks of training compared to baseline, the TCTs had increased activation in the right M/IFG, while CGs did not show any change. These fMRI results indicate a possible "restorative" effect of training in schizophrenia subjects, not observed in control patients, where behavioral performance improved and fMRI activity increased in the right M/IFG during a WM task. These findings suggest that training generalizes to improve working memory functions in schizophrenia patients.

E73

NEURAL MEASURES OF AGE DIFFERENCES IN VISUAL WORKING MEMORY: THE ROLE OF FILTERING EFFICIENCY *Kerstin Jost[1], Rick Bryck[2], Edward K. Vogel[2], Ulrich Mayr[2]; [1]Philipps-University Marburg, [2]University of Oregon* – It is well-known that working memory (WM) functions decline with age. The reasons for this decline, however, are not completely understood. Here we tested whether the ability to prevent irrelevant information from being stored is a critical factor for age differences in WM. In order to address this question we compared younger (18-30 years) and older (65-80 years) adults' performance in a visual WM task. In each trial participants were presented with an array of colored rectangles and had to remember only the red ones. During the retention interval the so-called contralateral delay activity (CDA) of the EEG was recorded. The CDA allows an online measurement of the number of active representations, because its amplitude increases with the number of stored items. Participants who are good in filtering should show CDA amplitude increases for red items only, whereas the amplitude for participants who are not good in filtering should depend on the numbers of both relevant and irrelevant items [see Vogel, E.K. et al. (2005). Nature 438, 500-503]. In both groups filtering efficiency, quantified by CDA amplitudes, substantially varied across individuals and was correlated with WM capacity: individuals with low capacity were less efficient in filtering out irrelevant information than high-capacity individuals. Although filtering efficiency seems to be responsible for interindividual differences, it did not explain the obtained age effects in WM capacity. This suggests that a filter deficit is not responsible for the age-related WM decline.

E74

REPRESENTATION OF KEY IN NONVERBAL WORKING MEMORY: AN EVENT-RELATED POTENTIAL STUDY *Laura Manning[1], Edward Golob[2]; [1]Tulane University, Psychology, [2]Tulane University, Program in Neuroscience* – Long-term memory (LTM) can influence verbal working memory via knowledge of language. Similarly, LTM may influence nonverbal working memory via knowledge of musical key. Here we tested the hypothesis that key repetitions across trials facilitates encoding of musical chords in a working memory task. Event-related potentials (ERPs) were measured at encoding to determine if key repetition affected sensory processing (early auditory ERPs) and/or top-down processing (late slow waves: 400-600 ms). Participants (N=15; ages 19-25; 6M/9F) heard trials consisting of 3 different chords followed by a maintenance period (2 sec) and a probe chord. Participants pressed buttons to indicate whether the probe was a match or nonmatch to any member of the initial 3 chord set. Chords within a trial were in the same key, but key either changed each trial (random) or remained the same for 3 consecutive trials (consistent). Accuracy was comparable among conditions (~77%). Auditory ERP measures (P50, N100, P200) did not differ between consistent and random conditions. However, in the consistent condition late frontal slow wave amplitudes were more negative for consistent trials 2 and 3 vs. the first trial ($p<.05$). Late slow wave amplitudes in the random condition and consistent trial 1 were comparable. Results suggest the influence of key develops over trials, and is most evident in longer-latency, possibly top-down activity rather than early sensory processing.

E75

DRIVEN FROM DISTRACTION: IMPROVING VISUAL SHORT-TERM MEMORY IN OLDER ADULTS WITH ATTENTIONAL SELECTION *Maha Adamo[1], Carson Pun[1], Susanne Ferber[1]; [1]University of Toronto, Psychology* – One cognitive faculty that declines with age is visual short-term memory (VSTM), or the ability to hold visual information in mind after it is no longer physically present. Specifically, older adults typically show lower VSTM capacity estimates than do young adults. This age-related decline, however, may be a derivative of increased distractibility: Older adults' memory performance may be impaired not because of reduced storage capacity per se, but due to interference from additional items within VSTM. We used a "retro-cue" paradigm to test whether attentional enhancement of information held in VSTM reduces interference, manifesting as improved capacity estimates. We presented a memory array of 1-6 colored circles for 1000ms, followed by a blank period of 1000ms. Then, on "retro-cue" trials, we presented a central arrow for 100ms pointing to the to-be-remembered location, followed by another blank display for 400ms. Finally, we presented a probe display containing only the cued item, and participants indicated with a button press whether the probe was the same color as the item presented at that location previously. The comparison condition also included a cue, which was presented simultaneously with the probe display after the first blank period ("simu-cue"). Both young and older adults showed improved estimates for retro-cue trials relative to simu-cue trials; critically, older adults' performance improved to the level of young adults. Thus, providing a cue for attentional selection of an item already held in VSTM reduces the typically observed age-related decline, suggesting that reducing distraction improves older adults' memory.

E76

EARLY VISUAL COMPONENT DURING MENTAL IMAGERY GENERATION WAS AFFECTED BY MEMORY ORDER *Keiko Yamazaki[1], Junichi'Katayama[1]; [1]Graduate School of Education, Hokkaido University* – ERP P2 reflected visual process of mental imagery generation in our previous study. In this study, we examined whether the P2 amplitude was affected by memory order of shape or not. There were four kinds of shape to be memorized, two of which were SIMPLE shape composed of three segments, and the others were COMPLEX shape of five segments. 16 Participants memorized SIMPLE shape as "a" and "b" at first, and COMPLEX shape as "c" and "d" next (SIMPLE first group). Another 16 participants memorized COMPLEX shape as "a" and "b", SIMPLE shape as "c" and "d" (COMPLEX first group). They memorized these shapes with sequence of the segments to be drawn. In the experiment, 5 x 5 grids with the name of shape in the central cell, and with an "X" probe mark in another cell, were presented. Participants decided whether or not the probe mark fell on the visualized shapes. Half of the trials were ON trials where the mark fell on the shape. The significant P2 effect was observed in the SIMPLE first group, which was consistent with our previous study, but not in the COMPLEX first group. They showed significant P1 effect, which was larger for the SIMPLE trials than in the COMPLEX trials. These results indicated that early visual components were affected by both complexity of shape and memory order, and that these components might be first signal to the visual areas from memory.

E77

INDIVIDUAL DIFFERENCES IN WORKING MEMORY CAPACITY: AN FMRI STUDY *Vivek Prabhakaran[1], Veena Nair[1]; [1]University of Wisconsin School of Medicine and Public Health, Radiology* – Working memory capacity is defined as the extent of resources available to perform on-line cognitive processing involving both working memory storage and working memory rehearsal. Lesion studies have posited that posterior brain regions are involved in working memory storage while prefrontal brain regions are involved in working memory rehearsal(D'Esposito and Postle, Neuropsychologia 1999). To identify whether individual differences in working memory capacity is secondary to increased working memory rehearsal or increased working memory storage, we conducted a fMRI study of working memory known to invoke working memory capacity in which subjects(n = 12) perform an item recognition paradigm where subjects maintain six letters over a delay period versus a no-delay period. Working memory capacity is measured in each of these subjects using a Digit span task. To isolate areas involved working memory capacity, we correlate individual differences in working memory capacity with activity in brain regions involved in the maintenance of working memory. Overall, maintenance of working memory information involved a prefrontal-posterior network. Prefrontal brain regions showed greater activity with greater working memory capacity across individuals. This suggests that individual differences in working memory capacity is secondary to increased working memory rehearsal.

E78

WORKING MEMORY AND SEMANTIC COMPETENCE IN OLDER ADULTS' COMPLEX LANGUAGE COMPREHENSION *Claire Simpson[1], Fan-Pei Gloria Yang[1], Carlos Marquez de la Plata[1,2], Kourosh Zakeri[3], Daniel Krawczyk[1,2]; [1]Center for Brain Health, University of Texas at Dallas, [2]University of Texas Southwestern Medical Center at Dallas, Texas, [3]The University of Texas at Dallas* – Previous aging studies suggest that declining working memory is the primary cognitive factor that contributes to impaired comprehension of complex linguistic sentences. This is based on the reported correlation between working memory and several types of figurative language that use conventional neuropsychological batteries. These studies have not considered other cognitive confounds such as familiarity of the stimuli and semantic competence which we observed to have an impact on neural activations in our previous imaging study. The goal of the proposed study is to investigate the correlation between these cognitive factors and complex language processing. Sentences were presented on a computer screen and older adults were asked to judge the valence of sentences by pressing buttons on the keyboard. Some of the sentences were conventional and only assessed subjects' verbal competence whereas novel metaphors tested their reasoning ability. We also conducted several neuropsychological measures for working memory (e.g.,Trails and Digit Span) and for semantic competence (e.g., Nelson-Denny). Subjects' reaction times demonstrate that novel sentences were most difficult to process compared with conventional expressions. This indicated that familiarity was a crucial factor for aging population's language processing. We also found that, with verbal ability controlled, subjects with declining working memory performed worse on novel expressions but not on conventional metaphors. This suggests that familiarity instead of figurative language (e.g., metaphor) has an impact on working memory. We suggest that a combination of computerized tasks and neuropsychological measures can give a more accurate assessment of older adults' language performance and cognitive functions.

Perceptual processes: Auditory processing

E79

HARMONY WANTS TO SIT IN THE FRONT *Eduardo A. Garza Villarreal[1,2], Elvira Brattico[3], Sakari Leino[3], Leif Ostergaard[1,4], Peter Vuust[1,2]; [1]Aarhus University, Center for Functionally Integrative Neuroscience, [2]Royal Academy of Music, Aarhus, Denmark, [3]University of Helsinki and Helsinki Brain Research Center, Cognitive Brain Research Unit, Psychology, Finland, [4]University Hospital of Aarhus, Neuroradiology* – Deviations from auditory regularities elicit early negative electric potentials distributed over the frontal regions of the scalp. The mismatch negativity (MMN) is elicited when local regularities of the auditory stimulation are violated and is also affected by the familiarity with the stimuli, whereas the early right anterior negativity (ERAN) appears when sounds diverge from a hierarchically organized musical regularity. In this study we wished to further disentangle the functional roles of these two brain processes associated with the detection of local vs. hierarchical musical violations by studying the localization of the underlying generators. To this aim, fifteen subjects listened to musical sequences constituted by seven chords. Each sequence contained harmonically congruous chords, harmonically incongruous chords, or harmonically congruous but mistuned chords. Simultaneously, an electroencephalography (EEG) was recorded and afterwards brain electric source analysis (BESA) was performed. Incongruous chords violating the rules of harmony elicited a bilateral early anterior negativity (ERAN), the amplitude of which depended on the degree of the harmony violation as expected, while mistuned chords violating the local rules of relations between the sounds, elicited a bilateral mismatch negativity (MMN) within chord sequences. We found that the dominant transcerebral sources for the ERAN were localized in Broca's area and its right homologue. The MMN signal was instead localized on the bilateral auditory cortex. These findings demonstrate the predominant role of the auditory cortices in detecting local auditory regularities and of the prefrontal cortex in parsing hierarchical regularities in music.

E80

WHEN SOUNDS BECOME OBJECTS *Lisa D. Sanders[1], Rachel E. Keen[2], Richard L.. Freyman[3]; [1]University of Massachusetts, Psychology and Neuroscience and Behavior Program, Amherst, [2]University of Virginia, Psychology, [3]University of Massachusetts, Communication Disorders, Amherst* – The ability to isolate a single sound source among concurrent sources and reverberant energy is crucial for understanding the auditory world. Our ability to localize sounds despite these echoes has been explored with the precedence effect: identical sounds presented from two locations with a short stimulus onset asynchrony are perceived as a single source with a location dominated by the lead sound. We recently found that event-related potentials (ERPs) elicited by click pairs near echo threshold differ when listeners do and do not report hearing the lag sound as a separate source. Specifically, when participants report hearing two sounds, we observe a negativity 100-250 ms, previously termed the object-related negativity (ORN). From previous research it is not possible to determine if the early neurosensory processing differences indexed by the ORN reflect variability in subcortical representations that result in a one- or two-sound interpretation or top-down influences. We measured ERPs elicited by physically identical sounds in contexts that resulted in listeners reporting either one or two sources. Repeating a lead-lag sound pair several times made participants less likely to report hearing the lag sound as a separate source. Presenting several lead-only sounds before the pairs resulted in behavioral responses similar to those for pairs presented in isolation. Sounds perceived as two auditory objects elicited an ORN and a posterior positivity 250-500 ms. These results indicate that recent experience with the spatiotemporal properties of sound allows listeners to form complex models of room acoustics that affect early auditory object processing.

E81

DISCRIMINATION OF NATIVE AND NON-NATIVE VOWEL CONTRASTS IN TURKISH-GERMAN AND GERMAN CHILDREN: INSIGHT FROM MISMATCH NEGATIVITY *Tanja Rinker[1,2,3], Paavo Alku[4], Sibylle Brosch[2], Markus Kiefer[1]; [1]Section for Cognitive Electrophysiology, Psychiatry, University of Ulm, Germany, [2]Section for Phoniatrics and Pedaudiology, ENT, University of Ulm, Germany, [3]Transfercenter for Neuroscience and Learning, University of Ulm, Germany, [4]Laboratory of Acoustics and Auditory Signal Processing, Helsinki University of Technology, Finland* – The development of native-like memory traces for foreign phonemes can be measured by using the Mismatch Negativity (MMN), a negative deflection of the auditory event-related potential. Previous studies have shown that the MMN is sensitive to changes in neural organization depending on language experience. In this study we measured the MMN-response in five year-old monolingual German children and in bilingual Turkish-German children growing up in Germany. MMN was investigated to a German vowel contrast and to a Turkish vowel contrast. The results show that while an MMN is elicited in German children to the German vowel contrast, there is no MMN present in Turkish-German children. Moreover, the early MMN-response to the Turkish contrast is more prominent in monolingual German children. Only in a later time window, Turkish-German children show a more prominent response to the Turkish contrast. The temporal onset of the MMN is delayed in the Turkish-German children for both vowel contrasts. Overall, the results suggest that the Turkish-German children have not yet fully acquired the German phonetic inventory despite being immersed in a German environment and that their phonetic inventory in Turkish is affected by their bilingualism as well. Furthermore, the delay in the MMN-response may reflect a slight general slowing due to the cognitive demands of processing two languages.

E82

NEURAL CODING OF FRICATIVE SPEECH SOUNDS WITH AND WITHOUT HEARING AIDS *Sharon Miller[1], Yang Zhang[1,2]; [1]Speech-Language-Hearing Sciences, University of Minnesota, Minneapolis, MN, [2]Center for Neurobehavioral Development, University of Minnesota, Minneapolis, MN* – The present study used auditory event-related potential (ERP) measures to investigate how the adult brain differentially processes fricative speech sounds with and without the use of a hearing aid. Three questions were addressed: (1) whether wearing a hearing aid makes a significant difference in the ERP components, (2) whether the ERP responses to fricatives consistently differ in both aided and unaided conditions, and (3) whether phonological context significantly affects the ERP responses. Eleven right-handed adult listeners with normal hearing participated in the study. ERP responses were recorded in an electrically shielded sound booth for digitally-edited /sa/, /sha/, /as/, and /ash/ stimuli in unaided and aided conditions using a randomized block design. At least 160 trials per stimulus were averaged for each subject. The results showed that (1) the basic ERP responses significantly differed between the unaided and aided conditions, (2) the N1 amplitudes and latencies to /s/ and /sh/ significantly differed in both unaided and aided conditions as well as in syllable-initial and syllable-final positions, and (3) phonological context significantly affected the N1 responses. These results confirm that hearing aids alter neural coding of speech. Unlike previous findings, however, there is strong evidence that the basic information for fricative contrast perception through a hearing aid is not entirely lost at the cortical level.

E83

MAPPING HUMAN AUDITORY CORTEX ACCORDING TO BOLD FMRI RESPONSE TO CLICK-TRAIN STIMULI VARYING IN PRESENTATION RATE AND BINAURAL-LEVEL CONFIGURATION *Susan A. McLaughlin[1], G. Christopher Stecker[1]; [1]Speech and Hearing Sciences, University of Washington* – Due to the highly distributed nature of mammalian auditory cortex (AC) processing, no single stimulus characteristic has proven sufficient to completely differentiate AC fields on a physiological basis. Mapping human AC with non-invasive methods remains a particular challenge. The goal of our study was to discriminate and identify human AC fields using a "multiple functional marker approach," mapping regional variation in BOLD fMRI response along multiple dimensions. Human AC responses to variation in stimulus level, presentation rate, and interaural level difference were measured using a sparse imaging paradigm (TR = 12 s, 32 slices, 3.0 x 3.0 x 4.5 mm, 3 T). Narrowband click-train stimuli were delivered in 12-second blocks, and varied pseudorandomly by 1) binaural-level configuration (sound or silence in one or both ears [sound levels at each ear varied independently over a 30-dB range across blocks]) and 2) presentation rate (fast or slow: 40 brief trains or 5 longer trains per second, respectively). Listeners monitored stimuli for rare changes in inter-click interval. Consistent with previous reports, overall activations (sound minus silence) of the superior temporal plane were greatest for slow (vs fast) presentation, contralateral to the stimulated ear. Additional focal activations exhibited regional and subject-to-subject variation in parametric sensitivity to overall level, binaural interaction, and presentation rate. The results are consistent with the view that neural populations vary along multiple dimensions of stimulus sensitivity, and that these parameters can be used to define a set of functional markers useful for mapping AC field structure. Supported by NSF IOB-0630338.

E84

LISTENING STRATEGY MODULATES NEURAL CORRELATES OF AUDITORY RHYTHM PERCEPTION *Amanda Pasinski[1], Devin McAuley[2], Joel Snyder[1]; [1]University of Nevada, Psychology, Las Vegas, [2]Bowling Green State University, Psychology* – Two fundamentally different mechanisms have been hypothesized to underlie listeners' perception of rhythm: 1) A beat-based mechanism synchronizes with the rhythm, similar to the beat people tap while listening to music, and listeners use this synchronized pattern to generate expectations for the onset times of new events; and 2) An interval-based mechanism calculates time intervals between consecutive events and listeners use the calculated time intervals to compare with time intervals formed by new events. Recent psychophysical evidence using a novel tempo discrimination paradigm has shown that some individuals use a beat-based mechanism while others use an interval-based mechanism, even for the same rhythmic pattern and set of instructions. This paradigm therefore presents a unique opportunity to identify brain processes underlying the two strategies. We used this paradigm while measuring event-related potentials (ERPs) in 38 participants. Strongly beat-based and weakly beat-based listeners showed no difference in sensory-evoked ERPs (N1, P2, N2). In contrast, the two groups showed a marginal difference in the contingent negative variation elicited by expectation of the final tone in the pattern and a significant difference in the late positive component after the end of the pattern, with larger responses in the more strongly beat-based listeners. These results demonstrate that stronger beat-based listening is accompanied by enhanced neural processing of tempo changes at the end of a rhythmic pattern.

E85

SENSITIVITY TO WITHIN-GROUP AND BETWEEN-GROUP SPEECH CATEGORIES IN EARLY, INTERMEDIATE, AND LATE SPANISH-ENGLISH BILINGUALS WITH VARYING PROFICIENCY LEVELS *Pilar Archila[1], Arturo Hernandez[1], Jason Zevin[2]; [1]University of Houston, [2]Weill-Cornell Medical College* – The purpose of this study was to examine differences in the categorization of speech in bilinguals who varied in age of acquisition and proficiency level in the second language. Spanish-English bilinguals (n=100) were classified as early (<5 years), intermediate (6-9 years), or late (>10 years) for a syllable discrimination task. Monolingual controls were used. Participants were asked to rate, on a 4-point scale, the level of dissimilarity between two pairs of naturally produced English syllables /saf, sef, sof, suf/ consecutively presented. The perceptual responses to these syllables were analyzed using multidimensional scaling (MDS). Consequently, the perceptual distances within and between clusters of stimuli indicated that early and high-proficient bilinguals more closely resemble monolinguals, whereas late and low-proficient bilinguals show dissimilar patterns of perception. Separate regression analysis demonstrated that proficiency is a significant predictor for the accurate categorization of between-group stimuli, while age of acquisition is a better predictor for within-group stimulus distances. Altogether, the results suggest that early learners of a second language are particularly adept at attending to the phonemic boundaries between vowel speech sounds and ignoring the minute variations within a vowel sound. Yet, high proficiency, in intermediate and late bilinguals, can favorably increase differentiation between vowel sounds, thus resulting in better categorization. In the near future, we plan to investigate how age of acquisition and proficiency affect the neural specialization of bilingual adults.

E86

PURE WORD DEAFNESS A NEUROLINGUISTIC STUDY *Ravi Nehru[1], Amit Batla[2], Farah Kanam[3]; [1]DM Neurology DNB Psychiatry Professor and Incharge Neurobehaviour Clinic and Neurolinguistics lab, Neurology GB Pant Hospital, New Delhi, India, [2]MD (Medicine) Senior Resident Neurology G B Pant Hospital, New Delhi, India, [3]MA Psychology and PhD student, Neurology G B Pant Hospital, New Delhi, India* – Background: Pure word deafness is caused by superior temporal gyrus lesions in the dominant hemisphere that isolate Wernicke's area from incoming auditory information. Most cases are reportedly caused by stroke. Aims and Objects: To describe a 16 year old boy who developed pure word deafness and study the case as an example of representation of speech in human brain. Methods: The patient developed bilateral temporal lobe infarction. With recovery, a speech comprehension defect became evident by the 6th month. He was completely deaf for spoken speech, but could identify and localize all environmental sounds and recognize voices. His

speech was normal and he could read and write correctly. Audiometry revealed high frequency deafness. His BAER was normal. He had particular difficulty perceiving initial consonants, but did extremely well with vowels. He used his ability to recognize vowels in listening to letters and numbers. Reading aloud and reading for comprehension, writing spontaneously and naming to confrontation were normal. Conclusions:. Pure word deafness serves as a model to understand localization of speech in the temporal cortices. It appears that a selective phonemic perceptual deficit results in pure word deafness. This case serves to prove that there is a fine grained highly selective representation of phonemes at cortical level.

E87

EARLY AUTOMATIC CATEGORIZATION OF SPEECH SOUNDS IS NOT MISLED BY CHANGES IN THE SURFACE FORM *Heidrun Bien[1], Lothar Lagemann[2], Christian Dobel[2,3], Pienie Zwitserlood[1,3]; [1]Institute for Psychology II, University of Muenster, Germany, [2]Institute for Biomagnetism and Biosignalanalysis, University of Muenster, Germany, [3]Otto-Creutzfeldt Center Center for Cognitive and Behavioral Neuroscience, University of Muenster, Germany* – During speech perception, sound is mapped onto abstract phonological categories. Assimilation of place or manner of articulation, which is quite common in connected speech, challenges this categorization. Does assimilation result in categorizations which need to be corrected later on, or does the system get it right in the first place? We presented participants with isolated nasals, extracted from naturally produced German sentences. The nasals differed in their place of articulation (/m/ labial, /n/ alveolar, and /n'/ regressively assimilated towards labial). Behavioural two-alternative forced-choice tasks showed that participants were able to correctly categorize the isolated /n/s and /m/s. The assimilated nasals were predominantly categorized as /m/, suggesting a changed place of articulation in the surface form. The categorizations were also linearly influenced by a pitch variation. In a MEG experiment, we analyzed the N100m component elicited by the same stimuli, with no categorization task on the nasals. In sharp contrast to the behavioural data, this early, automatic brain response ignored the assimilation in the surface form and reflected the underlying category (/m/ elicited a smaller amplitude than /n/, independent of the presence or absence of assimilation). These phonemic differences were processed exclusively left-laterally (both in temporal and in parietal areas), while the pitch variation was processed in temporal regions bilaterally. In conclusion, explicit categorization draws attention to the surface form - to the changed place and acoustic information such as pitch. The N100 reflects automatic categorization, which exploits any hint of an underlying feature.

E88

EMOTIONAL SPEECH INTELLIGIBILITY: NOT JUST A MATTER OF THE RIGHT HEMISPHERE *Sonja A. Kotz[1], Friedemann Szymanowski[1], Jonas Obleser[1], Stuart Rosen[2], Sophie K. Scott[3]; [1]MPI for Human Cognitive and Brain Sciences, Leipzig, Germany, [2]UCL, Division of Psychology and Language Sciences, London, UK, [3]UCL, Institute of Cognitive Neuroscience, London, UK* – Speech perception is tightly linked to activation of auditory association areas in the temporal lobes with a particular role of the left anterior superior temporal sulcus (STS) in the perception of intelligible speech (Scott et al., 2000; 2006). In the current study we extended this approach to investigate emotional speech intelligibility with noise-vocoded speech as previous evidence with filtered emotional speech (Kotz et al., 2003; 2006) and non-speech vocal sounds (Belin et al., 2004) suggest a role of the right anterior STS in processing paralinguistic aspects of vocal expression (i.e., age, gender, emotional state; see also Schirmer & Kotz, 2006). We confirm a speech intelligibility network consisting of the IFG (BA 45) and the anterior STS/MTG bilaterally, the left STG (BA 41), and the left inferior parietal lobe (BA7). Emotional speech intelligibility involved the anterior STS/MTG bilaterally, the left STG (BA 41), and the right posterior STG (BA 22). The data suggest that speech intelligibility - whether neutral or emotional - relies on the bilateral anterior temporal STS/MTG, while emotional speech additionally recruits the posterior STG. The data will be discussed in relation to models of vocal and non-vocal expression in neutral and emotional speech.

E89

IT'S ONLY IN YOUR HEAD: HOW EXPECTANCY OF AVERSIVE AUDITORY STIMULATION MODULATES AUDITORY CORTICAL ALPHA ACTIVITY *Thomas Hartmann[1], Winfried Schlee[1], Nathan Weisz[1]; [1]University Konstanz* – INTRODUCTION: Recent publications have shown that modulations of alpha oscillations play an essential role in information processing. E.g. anticipation of target stimuli lead to a desynchronization of alpha oscillations in the respective sensory modalities. These top-down effects are usually induced using differing stimuli or instructions. METHODS: In the current study we set up a fake auditory frequency discrimination task, in which always the same sound was presented to the left ear. Participants were instructed that one sound (the high-pitch sound) would be followed by an aversive noise. Over the experiment the expectancy which sound subjects perceived fluctuated systematically. Oscillatory brain activity was acquired using a 64 channel EEG system. RESULTS: 12 out of 16 subjects were included in the analysis (4 men; mean age 22.25; all right handed). We found a significant relationship between the number of previous equal feedback and expectancy thus confirming the validity of the task. Time-frequency analysis using a multitaper FFT approach revealed an overall 20% stronger alpha-desynchronization during sounds for which an aversive noise was expected. Statistical analysis using a nonparametric permutation test revealed one significant cluster over right-temporal regions. Source-localization using a beamformer-approach localized the difference at right auditory cortical regions. CONCLUSION: Extending previous research, we were able to show that alpha-oscillations originating from auditory areas can be "purely" modulated by top-down influences.

E90

A REVERSE STROOP EFFECT IN ABSOLUTE PITCH POSSESSORS *Lilach Akiva-Kabiri[1,2], Avishai Henik[1,2]; [1]Ben-Gurion University of the Negev, Psychology, Beer-Sheva, Israel, [2]Zlotowski Center for Neuroscience, Beer Sheva, Israel* – Absolute pitch (AP) is the ability to identify and produce musical pitch tones without using an external reference tone. The present study examined how automatic such identification is. Eight participants with AP and eight musically trained controls participated in two auditory-visual Stroop-like tasks. In a given trial, participants were presented with an auditory tone and a tone name (e.g., do, re) or a note. In separate blocks, they were asked to respond to the note or the word and ignore the auditory tone or to respond to the auditory tone and ignore the visual display. The irrelevant dimension could be congruent, neutral or incongruent with the relevant dimension. In the pitch-tone naming task, only controls showed a significant congruity effect and were slower in identifying tones in the incongruent conditions. In contrast, in the note reading task, only those with AP showed a significant congruity effect. These results are in contrast with those of the original reverse Stroop task (Stroop, 1935) where no effect was found when participants were asked to read the color name and ignore the ink color. These findings demonstrate that pitch tones are processed automatically in those with AP. Moreover, the AP participants showed a unique asymmetrical congruity effect, with a greater influence of the auditory dimension on the visual dimension.

E91

FUNCTIONAL COUPLING BETWEEN AUDITORY AND MOTOR REGIONS IS MODULATED BY THE PERCEPTUAL DIFFICULTY OF SPEECH *Conor Wild[1], Matt Davis[3], Alexis Hervais-Adelman[3,4], Ingrid Johnsrude[1,2]; [1]Centre for Neuroscience Studies, Queen's University, Kingston, ON, Canada, [2]Queen's University, Psychology, Kingston, ON, Canada, [3]MRC Cognition and Brain Sciences Unit, Cambridge, UK, [4]Cambridge University, Physiology, UK* – A number of recent neuroimaging studies have suggested that cortical motor activity is essential for successful speech perception (for reviews see Davis and Johnsrude 2007, Poeppel et al., 2008). We suggest that this may be particularly true for degraded or masked

speech. In this study, we used functional magnetic resonance imaging (fMRI) to examine whether interactions between auditory and somatomotor brain regions are stronger during the perception of degraded, relative to clear, speech. We presented subjects with English sentences that were processed as clear speech, 3-band noise-vocoded speech (NVS), or rotated 3-band noise-vocoded speech (rNVS). Whereas NVS is somewhat intelligible to naïve listeners, rNVS is unintelligible. Whole brain fMRI data were gathered from 19 subjects with a sparse-imaging paradigm and analyzed using a beta-series functional connectivity method (Rissman et al., 2004). We observed an increase in the functional coupling between motor cortex and peri-auditory regions during presentation of NVS speech, compared to either clear speech or rNVS; in other words, these areas demonstrate significantly increased correlation of activity when speech is hard to understand, compared to when it is unintelligible, or when it is clear and easily understood. The modulated auditory response was localized to belt and/or parabelt regions of auditory cortex immediately surrounding Heschl's gyrus. These results suggest that auditory cortex may recruit motor cortex in situations of high auditory perceptual uncertainty; or, alternatively, that motor cortex modulates lower-level auditory processes under these conditions.

E92

BILINGUAL AND MONOLINGUAL VOWEL PERCEPTION: AN ERP STUDY *Monika Molnar[1,2], Shari Baum[1,2], Linda Polka[1,2], Lucie Ménard[2,3], Karsten Steinhauer[1,2]; [1]School of Communication Sciences & Disorders, McGill University, Canada, [2]Centre for Research on Language, Mind, & Brain, McGill University, Canada, [3]Université du Québec à Montréal, Canada* – In the present study, we addressed the question of whether being a native speaker of one or two languages affects automatic speech sound processing. Specifically, we investigated vowel perception patterns of monolingual (English, French) and simultaneous bilingual (English/French) speakers using an auditory oddball paradigm. The auditory discrimination abilities of each language group were measured in response to four vowels: English /u/, French /u/, French /y/, and a control /y/. The vowels were created using the Variable Linear Articulatory Model (VLAM) (cf. Boë & Maeda, 1998) which simulates realistic vowels in terms of articulatory-to-acoustic relationships. In line with previous behavioral and electrophysiological findings, monolingual speakers exhibited increased sensitivity to the phonemic status of the vowels than to the acoustic properties differentiating the sounds. For instance, monolingual French speakers showed an early and robust mismatch negativity (MMN) effect when discriminating between two native vowels; however, monolingual English speakers responded with a later and smaller MMN to the same vowel contrast. Also, monolingual speakers were able to detect subtle within-phonetic-category differences (i.e., English /u/ vs. French /u/) which elicited relatively late MMN components. Bilingual speakers, on the other hand, revealed a different type of processing pattern. They demonstrated overall slower discrimination responses to all sounds, but showed almost equal sensitivity to phonemic and acoustic differences. Compared to the performance of the monolingual speakers, the overall results suggest that bilingual speakers exhibit a more flexible but less uniquely-specified perceptual pattern.

E93

PHONEMIC PERCETION IN ENGLISH AS A FIRST AND SECOND LANGUAGE: EVIDENCE FROM EVENT RELATED POTENTIALS *Pauline Peri[1], Cheryl Frenck-Mestre[1], Christine Meunier[1]; [1]Université de Provence* – The present study investigated phonemic perception of American-English vowel categories by French-English advanced learners, French monolinguals and native English speakers. Specifically, we examined the discrimination of different vowel categories specific to English and the amount of attentional resources allocated to these contrasts. A three stimulus oddball paradigm was used: /E/ as standard; /ae/ as target and /I/ as deviant in the first experiment; /ae/ as deviant and /I/ as target in the second experiment. In both experiments, early ERP responses (N100) showed discrimination of the three vowels for all groups, based on acoustic differences. In contrast, ERP responses associated to attentional and categorization updating processes (N200-P300) showed differences between vowel categories across groups. In the first experiment, all the participants showed a categorization response for the vowel /ae/ against /E/. An "N2-P3" complex was also elicited for native English speakers and advanced learners in response to the deviant /I/ but not for French monolinguals. In the second experiment, native English speakers showed a larger N2-P3 response for the /I/ vowel. Advanced learners showed a larger N2-P3 response when focusing their attention on /I/ and a smaller response to the deviant /ae/. These results suggest a difficulty for advanced learners to deal with the three categories at the same time. Finally, French monolinguals show a small response to the /I/ vowel when it acts as a target. Results are fur...ther discussed in terms of attentional demands and the influence of the mother tongue when processing American-English vowel categories.

E94

MEANINGFUL NOVELTY PROCESSING DURING SLEEP IN HUMANS *Perrine Ruby[1], Jean-Baptiste Eichenlaub[1], Dominique Morlet[1]; [1]INSERM U821, Lyon, France* – Up to which extent does the sleeping brain process modifications in its sensory environment? To address this issue, we investigated brain reactivity to meaningful sounds during sleep in healthy subjects. EEG, EOG and EMG were recorded during wakefulness and all-night sleep, while a passive oddball paradigm (standards, deviants and rare novels) was applied. Novel sounds were first-names uttered by a neutral voice: the subject's own name OWN and an unfamiliar first-name OTHER. During wakefulness recordings, subjects watched a silent movie with subtitles. During sleep recordings, stimuli were presented continuously. During wakefulness, OWN and OTHER evoked N1 and P3a components. The P3a component peaked significantly earlier (15 ms) for OWN. OWN only, evoked a large parietal positivity peaking at 550 msec. An enhanced response to OWN was also detected during sleep (stages 2, 4 and REM sleep), at late latencies, with a similar topography as the one observed during wakefulness. Theses results demonstrate that, during wakefulness, OWN induces an earlier reorientation of attention than OTHER, possibly due to its greater familiarity or to its meaning. OWN subsequently evoked a late positivity which may be interpreted as a complex cognitive processing e.g. recall of memory associated to the own name. Only late positivities were found in sleep stages 2, 4 and REM for OWN, suggesting that only the latter effect is preserved during sleep. In conclusion this study demonstrates verbal discrimination for the first time in all sleep stages and suggests a possible preservation of stimulus-driven recollection during sleep.

E95

PURE WORD DEAFNESS FOLLOWING LEFT HEMISPHERE STROKE WITH PRESERVED INTERHEMISPHERIC CONNECTIVITY *L. Robert Slevc[1], Philip C. Burton[2], A. Cris Hamilton[1], Randi C. Martin[1]; [1]Rice University, [2]University of Minnesota* – Pure word deafness (PWD) is characterized by severely impaired speech perception despite good hearing ability and preserved functioning in other language domains (e.g., reading, writing and speaking). Despite its rarity, PWD has attracted considerable attention because of its specificity to speech sounds. 'Pure' cases of PWD show dissociations not only between speech perception and other types of linguistic processing but also between perception of speech stimuli and other complex auditory stimuli. The case reported here shows exactly this pattern: severely impaired speech perception despite relatively preserved reading, writing and speaking ability, as well as preserved perception of complex environmental sounds (Saygin, Dick, & Bates, 2005) and musical pitch. The patient has particular difficulty with stimuli characterized by rapid temporal transitions (i.e., consonants), supporting accounts of PWD resulting from an underlying deficit in rapid spectrotemporal processing (cf. Stefanatos, Gershkoff, & Madigan, 2005). Although PWD typically results from bilateral damage to the posterior superior temporal lobes, or more rarely from damage to the left superior temporal lobe combined with damage to

inter-hemispheric connections, this patient has only unilateral left temporal and parietal lobe damage, including superior temporal gyrus, supramarginal gyrus, and angular gyrus. Not only does he have an intact right hemisphere, but he also has preserved white matter tracts connecting the two hemispheres as shown by diffusion tensor imaging. These data thus imply a crucial role played by the left superior temporal regions in the processing of rapid temporal aspects of the speech signal and constrain bilateral accounts of speech perception.

E96

LATE PARIETAL POSITIVE WAVES TO A SUBJECT'S OWN NAME IN NON-COMMUNICATIVE PATIENTS *Dominique Morlet[1,4], Irena Holeckova[2,3,1], Perrine Ruby[1,4], Jean-Baptiste Eichenlaub[1,4], Catherine Fischer[3,1]; [1]INSERM U821, Lyon, France, [2]Medical Faculty Plzen, Charles IV University Prague, Czech Republic, [3]Neurological Hospital, Clinical Neurophysiology, Lyon, France, [4]Université Lyon 1, Lyon, France* – We report a series of findings from passive oddball paradigms including the subject's own name (SON) presented as a novel (p ? 0.03) in healthy awake subjects and in comatose patients. In a first experiment (15 subjects), the SON was randomly uttered either by an unknown or by a familiar voice in the same stimulation block. A late parietal positive wave (LPP) appeared after the novelty P3 (nP3) in response to the familiar voice. In a second experiment (10 subjects), the unknown voice and the familiar voice were presented in separate blocks. No LPP could be observed in either condition. In a third experiment (11 subjects), the SON and another proper name were randomly presented in the same block. A large LPP followed nP3 only in response to the SON. In 50 severe comatose patients (on average 20 days after coma onset), an oddball paradigm including the SON uttered by an unknown voice was applied. The SON elicited a central-parietal P3 response in 21 patients, of whom 17 awoke within the next 3 months. In 12 patients (of whom 11 woke up), we observed an additional component with more pronounced parietal predominance, significantly prolonging the duration of the P3 response. In healthy subjects, the presence of LPPs in response to SON depends highly on the stimulation context. This result questions about the cognitive counterpart of these components. Moreover, LPPs could also be observed in supposedly unconscious patients in whom they could highlight some residual cognitive functions.

E97

MENTAL ABILITY AND THE EFFECT OF PATTERN CHANGE ON P300 AND MISMATCH NEGATIVITY *Lauren Sculthorpe[1], Robert Stelmack[1], Kenneth Campbell[1]; [1]University of Ottawa* – In previous research using event-related potential (ERP) recording procedures, compelling evidence of a relation between intelligence and speed of auditory discrimination was presented. During an auditory oddball task with backward masking, higher ability participants (HA) displayed more accurate discriminations, faster response time, larger P300 amplitude, and shorter P300 and mismatch negativity (MMN) latency than lower ability participants (LA). The temporal effects suggested that the speed of accessing short-term memory is faster for HA than LA. Since the MMN occurs without focused attention, these effects were interpreted to reflect differences in preattentive processing. We attempted to extend previous sensory discrimination effects to higher-order cognitive mechanisms by examining mental ability and variation in pattern change discrimination as indexed by P300 and MMN. HA and LA participants were presented with a two-tone alternating pattern (ABABAB...) with occasional deviant repetitions (ABABBBAB...). The two tones of the pattern were separated by 1 or 6 semitones in different blocks, under both 'ignore' (reading) and active response conditions. HA achieved better performance than LA, particularly in the more difficult 1 semitone condition. This was mirrored by a larger P300 and shorter P300 latency for HA than LA in the 1 semitone condition. MMN amplitude was larger for HA than LA across both semitone conditions. These results suggest that mental ability is related not only to sensory discrimination, but also to higher-order cognitive processes of rule extraction that operate even at a preattentive level.

E98

THE INFLUENCE OF COMPETING STIMULI ON AUDITORY SELECTIVE ATTENTION: A BEHAVIORAL AND ELECTROPHYSIOGICAL STUDY *Aparna Rao[1], Yang Zhang[1], Sharon Miller[1]; [1]Speech-Language-Hearing Sciences, University of Minnesota* – This research work investigates the neurophysiologic mechanisms involved in selective listening. Behavioral and electrophysiological data were obtained from 12 subjects with normal hearing in a selective attention task (Garner filtering condition). In this paradigm, subjects were required to identify signals that co-occurred with competing stimuli. Pure tones mixed with filtered noise at a signal-to-noise ratio of +15 dB were used as stimuli. In separate blocks, subjects judged the pitch of tones while ignoring the random variation in filtered noise and vice versa. Results were compared for the two conditions, i.e., when subjects classified the pitch of tones and when subjects classified the pitch of filtered noise. Behavioral results indicated higher response accuracy and shorter reaction times when subjects attended to tones ($p<0.01$). Electrophysiologic findings revealed greater amplitudes for P1, N1 and P2 when subjects identified the pitch of tones ($p<0.01$). N2 was larger when subjects attended to the pitch of filtered noise ($p<0.01$). More importantly, significant interactions ($p<0.05$) were obtained between tone classification, noise classification and attention condition for all behavioral and electrophysiological measures, except the amplitude of N2. The effects of auditory interference were asymmetric. Results suggest that behavioral and electrophysiological responses to signals are altered by the presence of competing stimuli.

E99

AREA SPT IN THE HUMAN PLANUM TEMPORALE SUPPORT SENSORY-MOTOR INTEGRATION FOR SPEECH PROCESSING *Gregory Hickok[1], Kayoko Okada[1], John Serences[2]; [1]Center for Cognitive Neuroscience, University of California, Irvine, [2]University of California, Psychology, San Diego* – Processing incoming sensory information and transforming this input into appropriate motor responses is a critical and ongoing aspect of our moment-to-moment interaction with the environment. While the neural mechanisms in the posterior parietal cortex (PPC) that support the transformation of sensory inputs into simple eye or limb movements has received a great deal of empirical attention - in part because these processes are accessible to study in non-human primates - little work has been done on sensory-motor transformations in the domain of speech. Here, we used fMRI and multivariate pattern classification analysis techniques to demonstrate that a region of the planum temporale (Spt) shows distinct spatial activation patterns during sensory and motor aspects of a speech task. Our results demonstrate that just as the PPC supports sensorimotor integration for eye and limb movements, Spt is part of a sensory-motor integration circuit for the vocal tract.

E100

ELECTROPHYSIOLOGICAL CORRELATES OF ECHO SUPPRESSION IN HUMANS *Kristina C. Backer[1], Kevin T. Hill[1,2], Lee M. Miller[1,2,3]; [1]Center for Mind and Brain, University of California, Davis, [2]Neuroscience Graduate Group, University of California, Davis, [3]Neurobiology, Physiology, and Behavior, University of California, Davis* – In everyday reverberant environments, the auditory system encounters an acoustically complex scene, consisting of primary sounds and their spatially-scattered echoes. In order to localize an auditory object, the brain suppresses directional information from echoes occurring within a short delay of the primary soundóa phenomenon known as the precedence effect. In this study, we aimed to characterize the temporal evolution of neural processes mediating the precedence effect. In a behavioral calibration session, we presented subjects with clicks from two locations in virtual acoustic space (+/- 45°) with varying delays between them: a primary (left) and an echo (right) click. On each trial, subjects reported whether or not they heard a click on the echo side. This allowed us to determine each subject's echo-suppression threshold. In a follow-up EEG session, subjects (n = 9, 4 males) were presented with either a single click

in the primary click location, an obvious double-click pair (delay of 35 milliseconds), or a near-threshold click pair (delay based on the calibration, appx. 5ms). For near-threshold click trials, the right-lateralized N1c ERP component was larger in amplitude when the echo was suppressed compared to when the echo was audible. This suggests that enhanced processing in lateral auditory cortex within 150ms of sound onset may underlie the perceptual suppression of echoes.

E101

PERCEPTION OF PITCH DIRECTION IN NATIVE SPEAKERS OF TONE AND NON-TONE LANGUAGES *Edith Kaan[1], Bethany Rowlings[1], Ratree Wayland[1]; [1]University of Florida* – Tone languages such as Thai and Mandarin Chinese use pitch differences to distinguish lexical meaning. The aim of the present study was to investigate the effects of language background on both involuntary and attentive perception of linearly rising and falling syllables, abstracting over differences in average pitch. Native speakers of American English (a non-tone language) and of Mandarin Chinese (a tone language) participated in a passive EEG oddball paradigm, and behavioral discrimination and oddball detection tasks. Seventeen rising and seventeen falling tokens of the syllable [ba:] were generated, differing in overall pitch to mimic different speakers. The critical stimuli, to which ERPs were recorded, were always in the mid range of the pitch frequencies used. The English group (n=14) was better at actively discriminating falling tokens from rising tokens than vise versa. Preliminary data from the native Chinese speakers (n=4) showed no differences. Both groups were faster at detecting falling oddball tokens among rising standards than vise versa. Both groups showed a later negativity (600-800ms) for deviants versus standards in both rising and falling conditions. However, ERPs for the deviant versus standard stimuli showed a mismatch negativity (MMN) for the rising deviants in the English group only. This confirms the view that different experiences with pitch contours through language affects both involuntary and conscious perception of pitch direction.

E102

NEURAL ACTIVITY UNDERLYING PASSIVE PERCEPTION OF NATIVE VS. NON-NATIVE PHONETIC CONTRASTS *Ran Liu[1,2], Jeremy Skipper[1], Bruce McCandliss[1,2], Jason Zevin[1,2]; [1]Sackler Institute for Developmental Psychobiology, [2]Weill Cornell Medical College* – Early language experience shapes neural processing of phonetic contrasts in a manner that promotes distinction between contrasts that are meaningful in one's native language and generalization across those that are not. As a result, second language learners often have difficulties learning, or even perceiving, differences between phonemes that are non-contrastive in their native language. To investigate the neural basis of this phenomenon, we used fMRI to scan 28 native Japanese speakers (all with extensive naturalistic exposure to English) while they passively listened to two English phonetic contrasts: one that is contrastive in Japanese (/d/ vs. /g/) and one that is not (/r/ vs. /l/). Subjects heard trials of these speech sounds in succession, each trial consisting of either four repetitions of the same standard stimulus or three repetitions of the standard followed by one deviant stimulus. The deviant > standard comparison reflects neural processing of the phonetic contrast present in the deviant trials. Results reveal activity in left posterior superior temporal gyrus and anterior supramarginal gyrus responding specifically to change across the /d/-/g/ contrast (native-language relevant) but not to the /r/-/l/ contrast (native-language irrelevant). This suggests that neural responses to speech contrasts may be susceptible to a sensitive period such that, even after extensive naturalistic exposure, adult second language learners do not activate regions typical of native speakers' during passive listening to non-native contrasts.

E103

AUDITORY CORTEX SENSITIVE TO F1-F2 INTERACTION: EVIDENCE FROM MEG *Pedro M. Alcocer[1], Brian Dillon[1], William Idsardi[1,2]; [1]Linguistics, University of Maryland, [2]Neuroscience and Cognitive Science Program, University of Maryland* – We report magnetoencephalographic (MEG) evidence that the M100 response is sensitive to interactions between first and second vowel formant (F1, F2) frequencies. Two F1 (500Hz, 700Hz) and two F2 values (1100Hz, 1900Hz) were chosen and crossed to give four different American English vowel categories: /^/ (500Hz/1100Hz), /E/ (500Hz/1900Hz), /a/ (700Hz/1100Hz), and /ae/ (700Hz/1900Hz). Four synthetic tokens were generated from these crossings. Comparison of subjects' M100 responses to these stimuli revealed a significant effect of F2 and a significant interaction of F1 and F2 values. Subsequent pair-wise comparisons revealed the source of the effects: /ae/ was significantly delayed relative to /a/, and there were additional marginally significant delays of /E/ and /^/ relative to /a/. The pattern of results suggests that neither F1 nor F2 is the primary factor modulating M100 latency. Rather /a/ tentatively appears to have a privileged status with respect to the other vowels in the study. If the view that the tonochronic properties of the M100 are largely predicated on formant structure is to be maintained, then the current set of results suggests a hypothesis that is grossly consistent with the view outlined by Ohl and Scheich (1997) and Diesch and Luce (2000), where it is claimed that the auditory cortex does not specifically resolve different formant peaks, but rather that the auditory cortex tracks a single value that represents a transform of the F1 and F2 values.

E104

AUTOMATIC VERSUS CONTROLLED PROCESSING OF TEMPORAL STRUCTURE *Michael Schwartze[1], Maren Schmidt-Kassow[1], Sonja A. Kotz[1]; [1]MPI CBS, Leipzig, Germany* – Recent years have seen substantial progress in the specification of the functional and the neural bases of temporal processing. It has been suggested to dissociate between two timing systems. An automatic one, involved in short range, discontinuous timing, and a controlled one, dependent on attention, and involved in longer range, continuous timing (Buhusi & Meck 2005). To investigate this position, the Electroencephalogram (EEG) of 24 subjects was recorded in a first session (MMN), in which attention was directed away from tonal stimuli towards a muted video, and in a second (P300) session, in which attention was directed towards the tonal stimuli. Subjects listened to pseudo-randomized non-chunked as well as binary chunked (CH) auditory oddball sequences consisting of 512 standard (600 Hz) and 128 deviant (660 Hz) equidurational (300 ms) sinusoidal tones that were presented with either isochronous (ISO) or random (RAN) pause durations. For the P300 session, results show a significantly reduced event-related response (ERP) to deviant tones in the RAN as opposed to the ISO condition, whereas no such difference occurs when attention is distracted in the MMN session. Chunking produces comparable results, but also reveals different ERP patterns as a function of deviant position. Thus, the temporal structure of a stimulus sequence has direct influence on ERPs evoked in auditory oddball paradigms. The results support a separation of automatic and controlled timing systems. Furthermore, the facilitating effect of temporal predictability can be interpreted in favour of models that assume dynamic, stimulus-driven allocation of attention (Barnes & Jones 2000).

E105

MODELING VOCAL PITCH PRODUCTION WITH PERTURBED AUDITORY FEEDBACK *Anja Hohmann[1], Psyche Loui[1,2], Gottfried Schlaug[1,2]; [1]Beth Israel Deaconess Medical Center, [2]Harvard Medical School* – Tone-deafness is a disorder whose phenotypical expression is characterized by an inability to sing in tune. Recent data suggests an underlying auditory-motor disconnection, resulting in an inability to benefit from or adjust to altered auditory perceptual feedback. Analogous studies in perceptuomotor feedback in vision have used the technique of altered feedback as in studies investigating prismatic adaptation. Using transposed

auditory feedback, we tested the hypothesis that normal-hearing individuals may be sensitive to feedback perturbation. We presented subjects with pure tones within their vocal range and asked them to reproduce these pitches by humming. Fundamental frequency of subjects' produced pitch was extracted and played back in real time via headphones. In 50% of trials, the feedback was transposed (perturbed) in frequency. The level of perturbation was adapted to each participant's individual, psychophysically-defined pitch-discrimination threshold. We recorded subjects' vocal production and applied pitch-extraction offline. Similar to EEG/ERP methods, data was artefact-rejected, baseline-corrected, and averaged across trials and subjects. Results were plotted as percent deviation from a preperturbation baseline. Results demonstrated frequency-shifted vocal production in the opposite direction of the applied perturbation for the duration of altered feedback. This opposing response shows that persons with intact pitch perception are sensitive to perturbed auditory feedback and compensate if given the impression of being out of tune. Pilot data from tonedeaf subjects suggest a lack of feedback-sensitivity. The perturbed auditory feedback paradigm can be adopted to further investigate behavioral markers of tone-deafness and also the general development of auditory-motor connectivity.

E106

ABNORMAL RESPONSE DYNAMICS DURING COGNITION-RELEVANT AUDITORY INFORMATION PROCESSING IN SCHIZOPHRENIA *Corby L. Dale[1,2], R. Alison Adcock[3], Anne M. Findlay[1], Alex Genevsky[2], Mary Vertinski[2], Tracy L. Luks[1], Gregory V. Simpson[1], Srikantan S. Nagarajan[1], Sophia Vinogradov[2,4,5]; [1]University of California, Radiology, San Francisco, [2]NCIRE, San Francisco VA Medical Center, [3]Duke University Medical Center, Psychiatry, [4]San Francisco VA Medical Center, Psychiatry Service, [5]University of California, Psychiatry, San Francisco* – Accumulating evidence suggests that schizophrenia is associated with neurocognitive impairments in both higher order cognitive functions and fundamental properties of sensory representations. Following on the premise that disorganized sensory representations are more vulnerable to interference and perceptual errors, we investigated the effect of speech-spectrum noise on the perception and representation of successively-occurring speech sounds by characterizing magnetoencephalographic (MEG) responses to syllable pairs. Patients diagnosed with schizophrenia and healthy comparison subjects performed a syllable discrimination task in both the presence and absence of noise. Statistical analyses of the M100 response over Superior Temporal cortex indicate that schizophrenia subjects, relative to healthy comparison subjects, show smaller amplitudes during the auditory M100 response to the first syllable and larger amplitudes to the second syllable in the presence of noise. In contrast, syllable discrimination without noise produces relatively equal responses in patients and comparison subjects during the first syllable, and a reduced response to the second syllable in patients. Taken together, these data suggest that perceptual interference leads to a less well-integrated response to the first syllable in schizophrenia patients, with a subsequent lack of attenuation in the response to the second syllable. Findings are consistent with "noisier" cortical-based representations of sensory information and their interactions with higher order cortex in schizophrenia patients, leading to faulty predictive processes and cognitive deficits. Results will be discussed with respect to the application of cognitive training to improve auditory information processing and its potential effects on physiological markers of sensory processing dysfunction in schizophrenia.

E107

AN EVENT-RELATED POTENTIAL INVESTIGATION OF THE PHONEMIC RESTORATION EFFECT *David Groppe[1], Marvin Choi[1], Ben Topkins[1], Marta Kutas[1,2]; [1]University of California, Cognitive Science, San Diego, [2]University of California, Neuroscience, San Diego* – The phonemic restoration effect (Warren, 1970) refers to the tendency for people to hallucinate a phoneme within a word replaced by a non-speech sound (e.g., tone). The level of processing at which this illusion occurs is unknown. One event-related brain potential (ERP) study (Sivonen et al., 2006) suggests that it begins within 120-180 ms of the onset of the non-speech sound, but the result was confounded by physical stimulus differences. In our study, absent this confound, participants read a word and then heard a word; the two were identical on half the trials. Additionally, for half the trials a tone replaced a non-initial phoneme in the spoken word; for the other half, the spoken word and tone were coincident (overlapped). Participants indicated if the written and spoken words were identical and whether or not the tone replaced part of the spoken word. When the written and spoken words were identical (versus non-identical), participants more frequently reported that the tone did not replace part of the word, whether or not it did. When the spoken and written words were identical, a large late positivity beginning before tone offset obscured other possible effects of the prior written word. High-pass filtering, however, dampened this positivity and revealed that the N1 to the replacement tone is enhanced when the written and spoken words are identical (vs not). This suggests that phonemic restoration begins early in auditory processing and that linguistic context can affect early phases of speech processing.

E108

FUNCTIONAL SIGNIFICANCE OF P50 AND N100 SENSORY GATING NEUROPHYSIOLOGY *Carly A. Yadon[1], Aubrey J. Anthony[1], Julie M. Bugg[2], Marlisa Isom[2]; [1]Colorado State University, [2]Washington University in St. Louis* – The P50 auditory event-related potential is used to measure sensory gating. This is typically in a paired-click paradigm in which amplitude to the second click (test (T) click) is "gated" or suppressed compared to the first click (conditioning (C) click) when measured by a T/C ratio. Sensory gating is dramatically reduced in individuals with schizophrenia and is highly variable among neurologically typical adults. For healthy adult participants, there is some evidence to suggest that P50 suppression varies with personality characteristics (schizotypy) and endorsement of sensory disturbances. However, the functional significance of poor P50 sensory gating is not well understood for either group. The goal of the present study was to better understand the functional implications of poor gating in a healthy adult sample. Toward this end, we examined the relationships between participants' (N = 30) scores on the Schizotypal Personality Questionnaire-Brief version, self-reported sensory processing as measured by the Sensory Gating Inventory, and neurophysiological measures of sensory processing (e.g. P50 and N100 amplitude, latency and suppression) . Interestingly, for the P50 wave, latency but not suppression related to most of the subscales of the Schizotypal Personality Questionnaire and the Sensory Gating Inventory whereas suppression but not latency related to most of the subscales for the N100 wave (all data from electrode Cz). We consider several explanations for the differential patterns we observed for the P50 and N100 measures.

Poster Session F

Attentional processes: Visual

F1

ATTENTION AND REWARD: INDEPENDENT OR INTEGRATIVE MECHANISMS? *Stephanie Baines[1], Anling Rao[1], Anna C. Nobre[1]; [1]University of Oxford* – Attention has been widely demonstrated to modulate perceptual processing. Advance information as to the location of a target stimulus provides benefits to accuracy and reaction times. Event-related potentials (ERPs) have shown neural responses to be facilitated from early perceptual responses (e.g., visual P1 and N1). Reward has been shown to influence decision-making and motor processing, but there has been little investigation with regards to its possible effects upon perceptual processing. We investigated whether reward was able to influence information processing at the perceptual stage, and asked whether reward utilised the attentional system or an independent mechanism to influence behaviour and perception. We manipulated the probability of target location and reward availability to investigate how changing spatial and motivational expectations influence perceptual judgments. The task required speeded orientation discriminations of peripheral Gabor stimuli, presented to the left or right of fixation. Spatial and reward expectations modulated behavioural performance in different and non-interactive ways. Spatial attention shortened response times and improved performance accuracy. Reward expectations also shortened response times, in an additive fashion, but had no effect upon accuracy. ERP recordings charted the relative time-courses for the modulation of neural processing by spatial and reward expectations, and determined the stages at which the two sources of top-down biases interacted.

F2

ORIENTING ATTENTION BASED ON LONG-TERM MEMORY IMPROVES PERCEPTUAL DISCRIMINATIONS *E. Zita Patai[1], Anling Rao[1], Jennifer Summerfield[1], Anna Christina Nobre[1]; [1]The University of Oxford* – The role of attentional orienting in daily life is to selectively deploy both behavioural and neural resources towards events, based on continually changing task goals and expectations, in order to optimize performance. In the following experiment, we show that attentional orienting is influenced by long-term memories in a perceptual discrimination task. In the learning phase, participants were trained on 120 ecologically valid natural scenes, of which 80 contained a target. Their task was to locate the target (a small key) on the screen by clicking on it with the mouse. One or two days later, participants completed a cued perceptual discrimination task. The same scenes that were studied before, but without any targets, were presented as cues (50 ms duration), followed, after a delay (450ms), by the scene again with or without the target (200ms). Participants discriminated covertly whether the key was present or absent from the second scene. There were three conditions: valid (key in learning and discrimination task was in same location), invalid (key in learning and discrimination task were in different location) and neutral (there was no key in learning phase). Behavioural results indicated that memory-guided attention benefits both the sensitivity (d') and speed of target identification within natural scenes. A replication of the study is being carried out with event-related potentials to chart the neural modulations that accompany the perceptual enhancements observed behaviourally.

F3

AN ERP EXAMINATION OF THE DIFFERENTIAL EFFECTS OF SLEEP DEPRIVATION ON ENDOGENOUSLY CUED AND EXOGENOUSLY CUED ATTENTION *Logan T. Trujillo[1], Caitlin S. Tenison[1], Natalie S. Dailey[1], David M. Schnyer[1]; [1]University of Texas, Psychology, Austin* – Moderate sleep deprivation (SD) is generally thought to have the greatest impact on high-level cognitive functioning. Here we show that SD can also affect relatively early-stage selective attention. Twenty three human subjects performed modified Attentional Network Tasks (ANTs) that used exogenously and endogenously cued letter target stimuli to index brain networks underlying orienting attentional functions. Event related potentials (ERPs) were recorded as subjects performed the ANTs on 2 days separated by 24 - 36 hours of total sleeplessness. Typical orienting effects were found on each day for both endogenous and exogenous tasks. Reaction times (RTs) to correctly categorize targets were significantly shorter for Spatial Cue trials (targets preceded by a 100% predictive cue) vs. Neutral Cue trials (targets preceded by a non-predictive cue) and Spatial Cue vs. No Cue trials. Additionally, the posterior N1 component of the ERP was enhanced, and the P3 component diminished, for Spatial vs. Neutral/No Cue trials. Sleep deprivation led to slowed RTs in both tasks. Nevertheless, this RT slowing was greater for the endogenous ANT, which exhibited faster RTs than the exogenous ANT during the fresh condition, but not during the fatigued condition. Furthermore, SD affected ERPs in the endogenous ANT only. The N1 was diminished and P3 enhanced in response to endogenously cued targets during fatigued vs. fresh conditions. Additionally, the N1 response to endogenous cue stimuli was also diminished with SD. These findings suggest that endogenously directed attention is differentially affected by as little as 24 hours of SD.

F5

IMPAIRED EARLY VISUAL PROCESSING IS ASSOCIATED WITH HIGH DISTRACTIBILITY IN CHILDREN WITH ADHD *Risa Sawaki[1,2,3], Sharon Coffey-Corina[1], Junîichi Katayama[2], Blythe Corbett[1], George Mangun[1]; [1]University of California, Davis, [2]Hokkaido University, [3]Japan Society for the Promotion of Science* – Attention-deficit/hyperactivity disorder (ADHD) is thought to involve high distractibility. However, it is still unclear whether high distractibility in children with ADHD is due to impaired cognitive control at late stages of processing, or rather it stems from impaired early sensory processing. We recorded event-related brain potentials from ADHD and typically developing children while they performed a simple visual discrimination task in which target or non-target stimuli were serially presented at a central location. Participants were asked to respond to target stimuli and ignore infrequent deviation. In the change condition, task-irrelevant features of central stimuli were infrequently changed. In the appearance condition, distractors infrequently appeared around central stimuli. Compared to typically developing children, ADHD children showed a smaller P1 for all stimuli in both conditions. Furthermore, although typically developing children did not show significant differences in P3 between change and appearance deviations, ADHD children showed a larger P3 for appearance deviation than for change deviation. The P1 response reflects an early stage of visual processing in visual cortex and its amplitude can be affected by spatial attention, while the P3 response reflects a later stage of attentional allocation. These findings suggest that children with ADHD have reductions (perhaps perceptual or attentional) in early visual processing, which are associated with high distractibility by salient deviations. One interpretation could be that the reduced P1 reflects their difficulty in focusing spatial attention on

the to-be-attended zone of visual space, which then permits irrelevant stimuli to induce greater distraction.

F6

CONTROL OF A SMART HOME WITH A BRAIN-COMPUTER INTERFACE *Christoph Guger[1], Clemens Holzner[1], Günter Edlinger[1], Chris Groenegress[2], Mel Slater[2]; [1]g.tec medical engineering GmbH/Guger Technologies OEG, Austria, [2]Centre de Realitat Virtual, Universitat Politècnia de Catalunya, Spain* – An EEG based Brain-Computer Interface (BCI) measures and analyzes the electrical brain activity (EEG) in order to control external devices. Such a BCI system can be controlled e.g. by the P300 EEG response. Therefore different characters are arranged on a computer screen and are highlighted in a random order. If the subject is focused on one specific character that is flashing up the P300 response is induced and the BCI system is able to recognize this response and therefore the character. The P300 based BCI system was connected to a Virtual Reality system and three subjects participated in the experiment. The virtual 3D representation of the smart home had different control elements (TV, music, windows, heating system, phone,...) and allowed the subjects to move through the apartment. Therefore special control masks (arrangement of specific icons on the screen) for the BCI system were developed containing all the different commands. The experiment for the P300 smart home control was divided into 3 parts with 15, 11 and 16 decisions respectively. One task was e.g. to go to the living room, to switch on the TV and to select a specific channel, ... The three subjects achieved an accuracy between 83 and 100 % depending on the control mask. The experiment yielded 2 important new facts: (i) instead of displaying characters and numbers to the subject also different icons can be used, (ii) the BCI system must not be trained on each individual character. Funded by EU project PRESENCCIA.

F7

SUPPRESSION OF TASK IRRELEVANT INFORMATION AS MECHANISM OF TASK SET INDUCED ATTENTIONAL CONTROL IN THE STROOP TASK *Sascha Purmann[1,2], Christian J. Fiebach[1,2], Mark D.Esposito[1]; [1]Helen Wills Neuroscience Institute and Psychology, University of California, Berkeley, [2]University of Heidelberg, Psychology, Neurology, and Neuroradiology* – Using fMRI, we examined the neural mechanisms of goal-directed, task-set induced top-down control of information processing. We had participants perform a color-word Stroop task under two task sets, i.e., color naming in some task blocks vs. word naming in others, using identical stimuli in both tasks. Consistent with the literature, we found increased activity in a fronto-parietal network comprising the anterior cingulate cortex (ACC), dorso-lateral prefrontal cortex (DLPFC), inferior frontal gyrus (IFG), and parietal cortex, when contrasting color naming with the less demanding word naming blocks. Most importantly with respect to task-set induced top-down control, we found decreased activity for word relative to color naming in color area V4, and decreased activity for color relative to word naming in the visual word form area (VWFA), suggesting that implementation of task sets involves the sustained suppression of task-irrelevant sensory representations. Additionally, in a connectivity analysis the right IFG, left DLPFC, and left superior lateral occipital cortex (LOC) showed a negative correlation with VWFA. In contrast, the right supramarginal gyrus and left inferior LOC showed such a relationship with V4.

F8

THE ELECTROPHYSIOLOGICAL SIGNATURE OF PHOSPHENE PERCEPTION: COMBINED ONLINE TRANSCRANIAL MAGNETIC STIMULATION AND EVENT RELATED POTENTIAL EVIDENCE *Paul Taylor[1,2], Vincent Walsh[2], Martin Eimer[1]; [1]School of Psychology, Birkbeck College, [2]Institute of Cognitive Neuroscience and Psychology, University College London* – We present electrophysiological evidence of trial-by-trial changes in the sensitivity of human primary visual cortex and of its causal role in visual perception. Transcranial magnetic stimulation (TMS) was applied to the right primary visual cortex of 12 participants so that they perceived phosphenes (brief flashes of light). Participants reported whether phosphenes were present or absent with a manual button press. By stimulating at the phosphene threshold intensity, phosphenes were reported as present or absent on approximately equal numbers of trials. We simultaneously recorded the event related potentials (ERPs) evoked by each TMS pulse. Comparing the ERPs on trials where participants did or did not see phosphenes ('phosphene-present' or 'phosphene-absent' trials) revealed statistically significant differences reflecting changes in underlying visual cortical activity. The ERP elicited by the phosphene - the 'phosphene-related potential' - showed positive deflections on phosphene-present compared to phosphene-absent trials starting from 160ms after the TMS pulse. This positive shift was present earlier or more strongly in parieto-occipital cortex in the stimulated hemisphere than in the left hemisphere or in frontal cortex. The position of the TMS coil was confirmed using stereotactic registration to each participant's magnetic resonance imaging structural scan. The phosphene-related potential was also clearly distinguishable from the ERP produced after TMS to a control site in more dorsal parietal cortex when phosphenes were not perceived, and to that on trials without any TMS. This phosphene-related potential offers an index of visual cortical sensitivity that can be used as a tool in future studies of cortical interactions and attention.

F9

SPATIAL SELECTION OF VISUAL REPRESENTATIONS IN PERCEPTION AND WORKING MEMORY: EVIDENCE FROM LATERALISED POSTERIOR EVENT RELATED POTENTIALS COMPONENTS *Silvia Dalvit[1], Martin Eimer[1]; [1]School of Psychology, Birkbeck College, University of London* – Selective attention can be allocated to sensory representation of currently present visual stimuli, and to representations of previously seen stimuli in visual working memory (Awh et al, 2006). Event Related Potentials (ERPs) were used to contrast the attentional selection of representations in perception and in working memory. The N2pc and SPCN components were measured as indicators of allocating attention to perceptual and working memory representations, respectively. In a temporal integration task, participants were asked to combine information from temporally separated visual displays. In both displays, two semicircles, whose orientation was randomly selected, were presented in the left and right visual hemifield. The interval separating both displays varied between 0 ms and 900 ms. The task was to detect the location where the combination of the two successive semicircles resulted in a complete circle. We observed the expected U-shaped pattern with high accuracy in the shortest and longest intervals and low accuracy with intermediate intervals. The N2pc was most prominent for the shortest interval, and the SPCN was present for longer intervals. Lateralised posterior ERP components were smallest for intermediate intervals where performance was poor. These results suggest that the allocation of attention to perceptual representations and to visual working memory representation can be dissociated with ERP measures.

F10

A HIGH-LOADED HEMISPHERE SUCCESSIVELY IGNORES DISTRACTORS *Ritsuko Nishimura[1], Kei Kuratomi[2], Kazuhito Yoshizaki[2]; [1]Japan Society for the Promotion of Science / Aichi Shukutoku University, [2]Aichi Shukutoku University* – We investigated whether a distractor that is presented to high-loaded visual-field/hemisphere (high-loaded hemisphere condition) is rejected more effectively, using a response competition paradigm. This question is motivated by both the findings derived from the studies on interhemispheric interaction which suggested two hemispheres have a separate resource and works in parallel (e.g., Banich, 1998; Friedman & Polson, 1981) and load theory of selective attention (Lavie, 2005). Our previous study (Nishimura et al., 2008, CNS) demonstrated that a distractor under high-loaded hemisphere condition is rejected more effectively. However, there was a procedural shortcoming which allows for an alternative explanation of the finding. The present study retested this finding with an improved paradigm. We asked right-handed participants to identify a target among a briefly presented set of

five task-relevant letters and three noises (non alphabets), while ignoring a peripheral distractor. We presented one task-relevant stimulus and three noises in one visual-filed (low-loaded visual-field), and the remaining four task-relevant letters in the opposite visual-field (high-loaded visual-field). We manipulated the visual-field where a distractor was presented (low-loaded versus high-loaded visual-field), as well as compatibility of target and distractor. In the low-loaded visual-field condition, a distractor was presented in the low-loaded visual-field, whereas the high-loaded visual-field condition, it was presented in the high-loaded visual-field. We found a compatibility effect in the low-loaded visual-field condition, but not in the high-loaded visual-field condition. These results supported our previous findings, suggesting that the distractor is processed in the low-loaded hemisphere, in which more processing resources are typically available.

F11

EFFECTS OF EXOGENOUS ATTENTION ON CONSCIOUS DETECTION AND PERCEPTUAL DISCRIMINATION *Ana Chica[1,2], Juan Lupianez[3], Stefano Lasaponara[4], Fabrizio Doricchi[4], Paolo Bartolomeo[1,2]; [1]INSERM-UPMC UMR, Paris, France, [2]Hopital de la Salpetriere, Paris, France, [3]University of Granada, Spain, [4]Università degli Studi di Roma* – Introspection suggests that when we attend to an object we become conscious of it. However, recent evidence suggests that at least endogenous attention is independent of conscious perception (Koch & Tsuchiya, 2007). Nevertheless, neuropsychological evidence suggests that exogenous attention might instead be crucial for conscious perception. Neglect patients do not consciously perceive information contralateral to their lesion; exogenous attention is biased in these patients, with a relative sparing of endogenous attention (Bartolomeo & Chokron, 2002). In the present research we explored the relationship between exogenous attention and conscious perception in neurologically intact observers. A non-informative peripheral cue precedes a target (a gabor stimulus oriented to either the left or right) that was not consciously perceived in a proportion of trials. Participants were asked to first discriminate the orientation of the gabor, or to give their best guess if they did not see it (discrimination response); and then to indicate whether they saw or not the gabor (awareness response). Discrimination accuracy and conscious detections were greater for cued than for uncued targets. Thus, exogenous attention enhanced perceptual discrimination and also increased the probability of consciously detecting the stimulus. However, there was no interaction between the two effects, suggesting that exogenous attention improved discrimination responses and consciousness independently: More targets were correctly discriminated when exogenously attended, no matter whether they were consciously detected or not. Our data support the role of exogenous attention in perceptual discrimination and demonstrate that unlike endogenous orienting, exogenous attention might be crucial for conscious perception.

F12

ATTENTION SHIFT TO A TASK-IRRELEVANT FACE IS INHIBITED BY PRESENTING AN ADDITIONAL FACE: AN ERP STUDY *Kanghee Lee[1], Yang Seok Cho[1], Hyun Taek Kim[1]; [1]Korea University, Psychology, Seoul, Korea* – The interference effect caused by a task-irrelevant face distractor is decreased simply by adding a face, but not an object. To see the role of attention shift in this dilution effect, we used event-related potentials (ERPs). Subjects were asked to categorize the occupation of a presented famous name (target) while ignoring a distractor, which was a face of an individual person from the same occupational category of the target (congruent) or another occupational category (incongruent). A face distractor was presented alone, or it was presented with an anonymous face in Experiment 1 or a scene of house in Experiment 2. N2pc, the component that is related to attention shift, was measured at contralateral electrode site (T5 or T6) to a distractor face. The behavioral data showed a decreased interference effect, which was not significant, when the anonymous face was presented with the name and the face distractor. For the ERP data, when the famous face and the name were presented without an anonymous face or a house scene, N2pc appeared with a more positive peak followed by a sharp negative peak. The change of N2pc indicated that the distractor captured attention. When a house scene appeared with them, a delayed positive change with no negative rebound was observed. When an anonymous face appeared, however, N2pc was not observed. These results imply that the presence of the anonymous face inhibits attention shift to the distractor face indicated by a diminished N2pc, causing a decreased interference effect.

F13

ERP CORRELATES OF ENHANCED VISUO-SPATIAL ATTENTION ALLOCATION UNDER DIFFICULT TASK DEMANDS *Stefanie Kehrer[1,2], Stefan P. Koch[1], Antje Kraft[1], Kerstin Irlbacher[1], Herbert Hagendorf[2], Norbert Kathmann[2], Stephan A. Brandt[1]; [1]Charité, Neurology, Berlin, [2]Humboldt University, Institute of Psychology, Berlin* – Recent studies provide evidence that more difficult target selection lead to stronger attentional top-down control thereby reducing arising conflicts (Lavie & Fox, 2000; Kehrer et al., in press). In order to test this assumption we combined the location negative-priming (NP) paradigm with a probe-technique (Kim & Cave 1999). Selection difficulty was manipulated by comparing an easy and a difficult discrimination task. The probe stimulus appeared in one of four possible stimulus locations in half of the trials. It was equally distributed on a previous distractor (DT), target (TT) or blank (BT) prime location. Subjects (N=52) had to detect the probe stimulus by pressing a foot-pedal. Event-related potentials (ERP) were recorded from 64 electrodes. A significantly delayed reaction time (RT) for NP- as compared to control-trials, i.e. NP-effect, was only evident in the easy task. Further, we found generally faster detection rates for probe stimuli in the difficult than in the easy task, indicating stronger attention allocation. For probe locations RTs were faster in TT followed by BT and DT in both tasks. ERP-analysis revealed a reduced frontal P2-component for the difficult compared to the easy task. The N2pc, an index for attentional allocation, was differentially modulated by probe conditions with reduced amplitudes for DT compared to TT and BT. In sum, these findings are consistent with our theory that increasing task demands lead to stronger top-down control, thus reducing conflicts in visuo-spatial attention.

F14

ATTENTION ENHANCES THE NEURAL PROCESSING OF RELEVANT FEATURES AND SUPPRESSES THE PROCESSING OF IRRELEVANT FEATURES IN HUMANS: AN FMRI STUDY OF THE STROOP TASK *Thad Polk[1,2], Robert Drake[2], John Jonides[1,2], Mason Smith[1], Edward Smith[3]; [1]University of Michigan, Psychology, [2]University of Michigan, Neuroscience Program, [3]Columbia University, Psychology* – We present a functional MRI experiment investigating the neural basis of feature-based attention in humans using the Stroop task. Cortical areas specifically involved in color processing and word reading were first identified in individual participants using independent tests. These areas were then probed during the Stroop task (in which participants must selectively attend to the font color of a word while ignoring the word itself). We found that activation in functionally-defined color areas increased during the task relative to a neutral color-naming task while activation in functionally-defined word areas decreased. These results are consistent with a biased competition model of feature-based attention in which the processing of attended features is enhanced and the processing of ignored features is suppressed. (This work was supported by NIH Grant R01-MH60655-01A1 and by the National Science Foundation.)

F15

SENSORY CONSEQUENCES OF DIRECTING ATTENTION AND ACTION TO OPPOSITE LOCATIONS *Elena Gherri[1], Martin Eimer[1]; [1]School of Psychology, Birkbeck College, University of London* – Previous event-related-potential studies have demonstrated that preparing an action at a specific location selectively enhances the processing of visual stimuli at that location, as demonstrated by enhanced N1 components to visual probes presented close to the hand involved in a currently pre-

pared response. These effects were similar to those previously found observed as a result of covert spatial attention, suggesting that attention and action both result in spatially selective modulations of visual processing. If this is the case, the attentional processing of visual stimuli on one side should be less efficient when participants simultaneously prepare an action directed to the opposite side. To test this prediction, we cued participants to shift their attention to the left or right side, and to simultaneously prepare to lift the index finger of their left or right hand. Imperative stimuli were either a central Go signal, requiring execution of the prepared manual response, or a peripheral visual stimulus, which required a visual target-nontarget discrimination only when presented on the cued side. An enhanced N1 was elicited by visual non-target stimuli on the task-relevant attended side only when attention and action were directed to the same side. In contrast, no such attentional N1 modulation emerged when they were directed to opposite locations. These results demonstrate that selecting a visual stimulus on one side is less efficient when simultaneously preparing an action on the opposite side, and thus supports the hypothesis that shared mechanisms are involved in the control of attention and action.

F16

GENDER DIFFERENCES IN ATTENTION TO SOCIAL AND NON-SOCIAL STIMULI: AN ERP STUDY *Anna Kresse[1], Yenchen Chang[1], Heather Ford[1], Nga Nguyen[1], Kelly Snyder[1]; [1]University of Denver, Psychology,* – Young infants exhibit gender differences in attention to social and non-social stimuli (e.g., faces vs. mechanical mobiles). Specifically, females attend more to social than non-social stimuli, whereas males show the opposite effect (Luchmaya & Baron-Cohen, 2002; Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000). Previous work in our lab found that 6-month-old females, but not males, showed better long-term memory for social stimuli (i.e., objects with faces such as people, pets, stuffed animals, etc.) compared to non-social stimuli (e.g., objects without faces such as furniture, toy cars, etc.). One possible explanation for these gender differences in memory is that they result from differences in attention at encoding, where greater attention toward one class of stimuli (e.g., people) results in deeper encoding and thus better memory for those stimuli. In the present study, we used high-density electrophysiology to examine gender differences in attention to, and memory for, social and non-social stimuli. Six-month old infants viewed 25 pictures of unfamiliar people and 25 pictures of unfamiliar cars, each presented twice in immediate succession, while event-related potentials (ERP) were collected. Preliminary analyses indicate that females exhibit larger (i.e., more negative) amplitudes of a mid-latency negative component (Nc) thought to index attention in response to people (M = -18.8 uV) compared to cars (M = -11.5 uV), whereas males show no difference in Nc amplitude to people and cars. This pattern of findings suggests that females direct more attention toward social than non-social stimuli, consistent with the findings from previous behavioral work.

F17

VERTICAL AND HORIZONTAL LINE LENGTH COMPARISON IN LEFT NEGLECT *Pom Charras[1,2], Paolo Bartolomeo[2], Juan Lupiáñez[1]; [1]University of Granada, [2]INSERM 610 - Hôpital Pitié Salpêtrière* – Patients with left unilateral neglect usually show a rightward bias when bisecting horizontal lines. This effect has been accounted for by postulating a distortion of spatial coordinates with a progressive enlargement from the right to the left (Bisiach et al, 1996). However, Urbanski et al (2008) have demonstrated that the rightward bias was decreased or even nullified by having patients explore lines from the left endpoint. Their results support a biased competition account, according to which an attentional orienting dysfunction due to a lesion of a right parietal-frontal network emphasizes the right part of the horizontal line, so that it would be overestimated in comparison to its left counterpart. In this study, we explored another aspect of left-right competition, involving horizontal and vertical lines. We asked patients with left neglect to draw a horizontal segment having the same length of a vertical segment. Horizontal lines had to be drawn either on the left or right of the sample vertical line. Results showed that horizontal lines were drawn as longer when on the left side (as in a reversed L), as compared to when they had to be drawn on the right side of the sample (as in a canonical L). This result suggests that the sample line was overestimated when presented on the right and underestimated when presented on the left, and thus extends the findings by Urbanski et al, by showing that even vertical lines may participate to the left-right competition resulting in biased line estimation in neglect.

F18

THE RELATIONSHIP BETWEEN FRONTAL EYE FIELD SELECTIVITY AND REACTION TIME IN CORRECT AND ERRANT BEHAVIOR *Richard Heitz[1,2,3], Jeremiah Cohen[1,2,3], Geoff Woodman[1,2,3], Jeffrey Schall[1,2,3]; [1]School of Psychology, [2]Vanderbilt Vision Research Center, [3]Center for Integrative and Cognitive Neuroscience* – Research suggests that neurons in the frontal eye field (FEF) are part of a frontal network that integrates sensory evidence and discriminates contextually relevant targets. Using a neuron-antineuron approach, we have studied this using Target Discrimination Time (TDT): the moment target-related neural activity becomes significantly larger than distractor-related neural activity. Recent work shows that variance in TDT is related to task difficulty, providing a mechanism for related delays in behavioral reaction times. The current work extends these findings in two routes. First, we examined how TDT relates to set size in a T/L visual search task. Second, we looked at TDT during error trials. Our results provide contrasting support for current theory regarding the nature of FEF. On the one hand, neuron TDT is delayed as set size increases; in accord with current thinking and extant data, this supports the viewpoint that FEF is directly involved in target selection and decision processing. Likewise, TDT on error trials is earlier than TDT on correct trials, mimicking the behavioral effects. In opposition to this, neural activity for most neurons on error trials tended to select the saccade endpoint rather than the target itself (Thompson et al., 2005). Evidence for two other neuron types were also observed: a small proportion of cells continued to select the target on error trials, and another small proportion initially selected the target, only to represent the saccade endpoint a short while later.

F19

A SINGLE CLASSIFIER PREDICTS THE DIRECTION OF SPATIAL ATTENTION, WORKING MEMORY, AND MOTOR INTENTIONS *Clayton Curtis[1], Adam Riggall[1]; [1]New York University, Psychology & Neural Science* – We recently demonstrated that neural activity in the same frontal and parietal cortical areas persists when humans 1) maintain a location in working memory, 2) covertly maintain attention peripherally, and 3) maintain a spatially directed motor intention. We concluded that spatial working memory, attention, and intentions share a common neural mechanism that is implemented in these areas. To further test these conclusions, here, we use multivoxel pattern classification of fMRI data to test two hypotheses. First, we can predict the location of a working memory representation, the direction of covert attention, and the target of a motor intention based on the multivariate pattern of delay period activity. Indeed, we find that frontal and parietal cortex activity can correctly classify whether subjects are remembering, attending, and planning a movement to the right or left hemifields. Second, we show that the classifiers generalize across tasks. We trained classifiers on one task (e.g., working memory) and tested its predictive validity on the other tasks (e.g., spatial attention and motor intention). Remarkably, despite that subjects were performing a different task, we observe robust cross-task classification. A classifier trained to discriminate the position of a working memory representation can predict the direction of one's attention and the goal of one's motor intentions. These results suggest that the information contained within these areas during delay periods is not dependent on working memory, attention, or intentions. Instead, it argues that these areas implement a common mechanism that supports a variety of spatial cognitions.

F20

SELECTION IN ENUMERATION: NEURAL EVIDENCE OF INDIVIDUAL DIFFERENCES IN THE SELECTION OF MULTIPLE ITEMS *Trafton Drew[1], Jason Fair[1], Edward K. Vogel[1]; [1]University of Oregon* – How many objects can be simultaneously selected at once? While there is an enormous literature devoted to understanding search for one target amongst distractors, there is a relative paucity of research on selecting multiple targets. Certainly, there must be an upper limit on the number of objects than can be simultaneously selected, but it is not currently clear what this limit is. When asked to judge the number of items, there is behavioral evidence that people can select between 3 and 4 items in parallel and generally have to count additional items in serial. Our lab has developed a procedure that allows us generate an electrophysiological index of the number of items that a subject selects. Previously, this index has indicated that individual differences in the initial selection phase of the multiple object tracking task strongly predict tracking ability (Drew & Vogel, Journal of Neuroscience 2008). In the current set of studies, we extended this finding by showing that when subjects are simply asked to count the number of targets, this electrophysiological index of selection (the N2pc) once again reflects individual differences in the ability to select multiple items. Furthermore when subjects are asked to count the number of targets, this index increases from one to three targets and asymptotes between three to five items.

F21

EVIDENCE FOR A HIGH-THRESHOLD CAPACITY LIMIT IN VISUAL PERCEPTION *Edward Ester[1], Keisuke Fukuda[1], Edward Awh[1]; [1]University of Oregon, Psychology* – Recent research has suggested that capacity in working memory (WM) is best described by a high threshold model, in which some information is available for a discrete number of items, while zero information is retained regarding items that exceed this "slot limit" (e.g., Rouder et al., 2008; Zhang and Luck, 2008). Alternatively, signal detection models suggest that WM is supported by a pool of resources that can be flexibly allocated across much larger numbers of items, with declining resolution as the number of stored items increases. The goal of the present research was to examine which of these models best describes performance in an encoding-limited procedure that required memory for only a single item. Subjects in our study were required to monitor multiple locations in a masked visual display with the goal of discriminating the orientation of a lone target amongst distractors. Performance in this task was well described by a high-threshold model, suggesting that subjects could simultaneously monitor a small number of locations, while encoding no information from others. Moreover, individual capacity estimates from this task were strongly correlated with a separate measure of working memory capacity for the same kinds of stimuli. These data suggest that both perceptual encoding and storage in working memory depend upon a common high-threshold system that allows monitoring or storage of a highly-limited, discrete set of positions or items.

F22

AN EVENT-RELATED POTENTIAL STUDY OF THE EFFECT OF INVOLUNTARY SPATIAL ATTENTION ON RESPONSE-SELECTION RELATED PROCESSES *David Prime[1], Pierre Jolicoeur[1]; [1]University of Montreal* – There has recently been renewed interest and controversy regarding the effect of involuntary attention on target processing. In the present study we utilized event-related potentials (ERPs) to investigate the effect of involuntary attention on response-selection related processes. In a visual cue-target experiment with a short cue-target stimulus-onset asynchrony (SOA) participants were required to make speeded responses to frequent Go-targets and to withhold responses from infrequent NoGo-targets. In addition to the typical effect of involuntary attention on response time, we found that cue validity affected the latency of the fronto-central ERP peaks related to response-selection and executive control. The peak latencies of the fronto-central P2, N2, and P3 peaks elicited on NoGo trials were delayed when the target was presented at an uncued location relative to when the target was presented at a cued location. However, cue-validity did not effect the amplitude of either the P2 or N2 component. In contrast, Prime and Jolicoeur (in press) found that the inhibition of return (IOR) effect found at long cue-target SOAs was associated with a large increase in N2 amplitude for targets presented at uncued locations relative to targets presented at a cued locations. The present results indicate that involuntary attentional can facilitate the speed of post perceptual processing starting at a latency of approximately 200 ms. Furthermore, these results combined with the results of Prime & Jolicoeur (in press) indicate that involuntary attention and IOR have different effects on post perceptual processes.

F23

NEUROPHYSIOLOGICAL SHIFTS IN ATTENTION USING VALID AND INVALID PERIPHERAL CUES *Nikki Pratt[1,2], Dennis Molfese[3]; [1]Psychological & Brain Sciences, University of Louisville, [2]VA Northern California Health Care System, Martinez, CA, [3]Birth Defects Center, University of Louisville* – Electrophysiological responses (P1, N1) were analyzed to track the neural underpinnings associated with voluntary and involuntary attention. The task consisted of a modified Posner attention paradigm that used valid and invalid cues to elicit effortful or automatic orientation. The P1 (80 to 120 ms) and N1 (120 to 170 ms) were analyzed with respect to valid and invalid cues in the two attention orientation conditions. The results indicated that the P1 response was associated with activity in the lingual gyrus and was greater to targets that appeared in the voluntary attention compared to targets in the involuntary attention condition. This finding extends previous research by Doallo et al. (2004) that reported peripheral cues in a voluntary attention task decreases the amplitude of the P1 when valid targets are presented. On the other hand, the N1 response, located within the inferior parietal and medial temporal gyrus, was larger to invalid targets compared to valid targets. This suggests that the N1 reflects attention shifts from the incorrect cue location to a location where the target is presented. Both electrophysiological findings indicate that early attention processes are sensitive to effortful and automatic shifts in attention orientation using only peripheral cues.

F24

VISUAL VIGILANCE TRAINING ENHANCES HEMISPHERIC ASYMMETRIES IN GLOBAL AND LOCAL PROCESSING *Albert K. Hoang Duc[1], Thomas Van Vleet[1,2]; [1]University of California, Berkeley, [2]Veterans Affairs, Martinez* – Studies of neurologically impaired patients have shown right hemisphere (RH) dominance for global processing and left hemisphere (LH) dominance for local processing. Likewise, studies of event-related potentials in healthy subjects have revealed right parietal and left temporal activity with attention shifts to global and local forms, respectively. In addition to global processing specialization, neuroimaging studies point to the crucial role of RH in vigilance and sustained attention. Here we show that a short visual vigilance training (VVT) task significantly enhances hemispheric asymmetry in global/local processing. Healthy subjects are asked to identify the global and local aspects of compound stimuli, pre- and post-VVT. Training consists of performing a discrimination task in which subjects withhold response to an infrequent target, but respond to all non-target scene pictures. In a control experiment, the VVT task is substituted with a change blindness task containing similar scene pictures. Following VVT, subjects demonstrate dramatic reduction of local and an increase of global interferences while attending to global and local forms, respectively. On the other hand, change blindness task does not produce any similar effects. Given evidence supporting hemispheric asymmetries in vigilance, targeting this attention domain exclusively may have provided more focuses activation of the RH. Indeed, the detection of low frequency events has been proven to modulate right neuronal network. Since restoring the balance between RH and LH is critical to cognitive recovery, our findings pave the way for developing novel rehabilitation protocols to reduce cognitive disorders associated with RH lesions, such as unilateral spatial neglect.

F25

AN EVENT RELATED POTENTIAL STUDY OF INHIBITION OF RETURN IN YOUNGER AND OLDER ADULTS *Nora Gayzur[1,2], Stephanie Simon-Dack[1,2], Alyson Saville[1,2], Linda Langley[1,2], Wolfgang Teder-Salejarvi[1,2]; [1]North Dakota State University, [2]Center for Visual Neuroscience, Psychology* – The purpose of this study was to examine age differences in inhibition of return (IOR) using event related potentials (ERPs). IOR has been defined as a delayed return of attention to a previously searched location and is indexed by a slowed response on Posner's spatial cuing paradigm to a valid location compared to an invalid location. The time course of IOR is altered with age, with IOR developing at longer cue-target intervals for older adults as compared to younger adults. In this experiment, younger (18-35 years) and older adults (55 years and older) were tested using a single-cue paradigm (cue-target interval: 425ms-625ms). Reaction time (RT) analysis revealed that younger adults showed IOR response patterns, but older adults did not. Consistent with previous research, younger adults showed a P2 reduction for valid trials, thought to reflect an inhibition of attention to the searched location. Younger adults showed a P2 for invalid trials, but older adults did not. P3 differences were found, with older adults having larger P3 amplitudes to invalid trials, and younger adults having larger P3 amplitudes to the valid trials. The P3 patterns may reflect age differences in expectations for valid and invalid targets. Validity differences in the P2 and P3 effects may reflect attentional processing in two populations showing different IOR response patterns.

Higher level cognition: Disorders

F26

MINDBLINDNESS IN RELATION TO ONESELF: NEURAL RESPONSE TO SELF-REFLECTIVE MENTALIZING IN AUTISM AND NEUROTYPICAL ADULTS *Michael Lombardo[1], Bhismadev Chakrabarti[1], Ed Bullmore[2], Susan Sadek[1], Greg Pasco[1], Sally Wheelwright[1], John Suckling[2], Simon Baron-Cohen[1], MRC AIMS Consortium[3]; [1]Autism Research Centre, University of Cambridge, [2]Brain Mapping Unit, University of Cambridge, [3]Institute of Psychiatry, Kings College London; University of Cambridge; University of Oxford* – "Mindblindness" is a term used to characterize the impairments in understanding mental states by individuals with autism spectrum conditions (ASC). Most research however, has tested mindblindness in relation to other's minds. More recently, work has begun to focus on the self-referential cognitive difficulties in ASC. With fMRI, we assessed adults with and without a diagnosis of ASC for differences in the neural systems engaged during reflective mentalizing or physical representations about the self or others. Reflective mentalizing deficits were apparent in mentalizing/simulation circuits consisting of posterior superior temporal sulcus (pSTS) and secondary somatosensory cortex (SII). Ventromedial prefrontal cortex (vMPFC) was less active in ASC during self-reflection. Specific deficits for self-mentalizing were observed in middle cingulate cortex (MCC). Variability in dorsomedial prefrontal cortex (dMPFC) differentially predicted the degree of alexithymia and autistic traits depending on diagnostic status. Neurotypical individuals activated dMPFC more with increasing alexithymia and autistic traits while individuals with ASC activated dMPFC less with increasing alexithymia and autistic traits. Thus, mindblindness in ASC occurs across a distributed neural network implicated across various circuits for social cognition. Understanding the abnormal organization or interactions between this distributed neural system may shed light on the mechanisms underlying the social impairments in ASC.

F27

NON-VERBAL AUDITORY COGNITION IN PATIENTS WITH EPILEPSY BEFORE AND AFTER UNILATERAL ANTERIOR TEMPORAL LOBECTOMY *Aurelie Bidet-Caulet[1], Xiaoli Ye[2], Patrick Bouchet[1], Marc Guénot[3], Catherine Fischer[1,2], Olivier Bertrand[1]; [1]INSERM, U821, Lyon, France; University Lyon 1, Lyon, France, [2]Neurological Hospital, Functional Neurology and Epileptology, Lyon, France, [3]Neurological Hospital, Neurosurgery, Lyon, France* – For patients with pharmaco-resistant temporal epilepsy, unilateral anterior temporal lobectomy (ATL) - i.e. the surgical resection of the hippocampus, the amygdala, the temporal pole and the anterior part of the temporal gyri - is an efficient treatment. There are growing evidence that anterior regions of the temporal lobe are involved in the integration and short-term memorization of object-related sound properties. However, non-verbal auditory processing in patients with temporal epilepsy has raised little attention. To assess non-verbal auditory cognition in patients with temporal epilepsy both before and after unilateral ATL, we developed a set of non-verbal auditory tests, including environmental sounds. Auditory semantic identification, acoustic and object-related memory, and sound extraction from a sound mixture were evaluated. We compared the performances of 26 patients with temporal epilepsy before and/or after ATL to those of 18 healthy subjects. Epileptic patients before or after ATL showed similar deficits in pitch retention, and in identification and memorisation of environmental sounds, whereas not being impaired in basic acoustic processing. Furthermore, the more the resection was encompassing the superior temporal gyrus, the more patients were impaired in pitch retention of pure tones. It is most likely that the deficits we observed after ATL reflect removal of already dysfunctioning tissue in the anterior temporal regions because of the epileptic neuropathological manifestations (epileptic spikes and/or atrophy). Therefore, in patients with drug-resistant temporal epilepsy, ATL significantly improves seizure control without producing additional auditory deficits.

F28

BRAIN ACTIVITY PRECEDING INHIBITORY ERRORS IN CHILDREN WITH AND WITHOUT ATTENTION DEFICIT/ HYPERACTIVITY DISORDER *Tess Nelson[1], Roma Vasa[1,2], Eunice Awuah[1], Stewart Mostofsky[1,2]; [1]Kennedy Krieger Institute, Baltimore, MD, [2]Johns Hopkins University School of Medicine* – Attention Deficit/Hyperactivity Disorder (ADHD) is characterized by deficits in response inhibition, increased reaction time variability, and decreased neural activity during response inhibition tasks such as the Go/No-go task. No studies, however, have examined whether a specific pattern of brain activity precedes inhibitory errors in children with ADHD. Evidence in healthy adults indicates that increased default mode network activity predicts errors, which suggests that momentary lapses of attention are related to subsequent error commission. In this study, event-related fMRI and a Go/No-go paradigm were used to explore whether this same neural circuit precedes error trials in children with and without ADHD. We examined group differences in brain activity during trials prior to commission errors compared with trials preceding correct inhibition of response in 13 children with ADHD and 17 typically developing (TD) controls. On trials prior to errors, TD children demonstrated relatively greater activity in the precuneus, a central region in the default mode network, compared to children with ADHD. Children with ADHD, however, demonstrated no such predictive activity in the precuneus or other regions of the default mode network. These data suggest that brain activation patterns immediately preceding inhibitory errors in children with ADHD differ from those in TD children. While TD children activate the precuneus, suggesting that momentary lapses of attention precede errors, the errors in children with ADHD may be mediated by different circuits, such as those involved in motor response control.

F29

FIRST-EPISODE SCHIZOPHRENIA PATIENTS EXHIBIT PREFRONTAL GAMMA BAND DEFICITS DURING COGNITIVE CONTROL *Alana Firl[1], Michael Minzenberg[1], Andrew Watrous[2], Jong Yoon[1], Daniel Ragland[1], Cameron Carter[1]; [1]University of California-Davis, Psychiatry, Davis California, [2]University of California-Davis Neuroscience Graduate Group* – Schizophrenia is characterized by deficits in cognitive control. Schizophrenia patients have shown impairment in the gamma

band (30-80Hz) during cognitive control and perceptual processing tasks. This study examined differences between a patient group and a control group in a cognitive control paradigm. The POP task was used to compare a high control condition with a low control condition. Data was recorded in a shielded room using 128 channel, NSL layout Neuroscan Quik-caps, at a 1000 Hz sampling rate. Electrode impedances were maintained below 5 kOhms. Data was later imported into EEGLAB, average referenced, downsampled to 250 Hz, high-pass filtered at 0.5 Hz, epoched -400 to 1700 ms with 0 ms being cue onset, and artifact rejected. ICA was used to isolate and remove ocular artifacts, primarily blinks. After removal of the ocular component, data was again artifact rejected at a threshold of +/- 50 microvolts. To examine the gamma band from 30-80 Hz, data was analyzed in the time-frequency domain using a complex Morlet wavelet with a c-value of 6. Results included main effect of group when comparing differences between the high control condition and the low control condition, as well as group-by-region-by-condition effects when electrodes were parsed into clusters according to scalp topography. Cognitive control related gamma band activity was specifically reduced across prefrontal sites. These findings suggest that induced gamma band deficits are present in schizophrenia patients at the first episode and point to a possible neural mechanism underlying impaired cognitive control in the illness.

F30

PREVAILED COGNITIVE IMPAIRMENT PLAYS A SIGNIFICANT ROLE FOR MENTAL HEALTH FUNCTIONING IN MAJOR DEPRESSIVE DISORDER - RESULTS FROM A FOLLOW UP STUDY *Guro Årdal[1], Åsa Hammar[1,2]; [1]Biological and Medical Psychology, University of Bergen, Norway, [2]Division of Psychiatry, Haukeland University Hospital, University of Bergen, Norway* – Significant evidence suggests that depression is characterized by cognitive impairment in the acute phase of illness, and some studies indicate that this impairment persists despite symptom reduction. Disability in mental health functioning is another serious feature concerning the disease, and a number of studies suggests that Major Depressive Disorder (MDD) is associated with significant disability and poorer quality of life. However, the knowledge about the relationship between cognitive impairment and mental health functioning in MDD patients is scant. The aim of this study was to examine the degree to which cognitive functioning, independent of mood symptoms, is related to mental health functioning in a 6 months follow up. 20 patients diagnosed with recurrent MDD and 20 healthy individually matched controls were tested at two occasions, at inclusion and after six months. Inclusion criterions were a Hamilton depression rating scale score at > 18, and a history of more than 2 episodes of MDD. The test battery consisted of experimental tests measuring attention in a visual search paradigm. Mental health functioning was measured using the SF-36 health survey. The results show that prolonged cognitive impairment, independent of mood symptoms, is related to poor mental health functioning in MDD in a six months follow up. In conclusion, these data indicate that prolonged cognitive impairment plays an important role for mental health functioning in MDD.

F31

DOPAMINE, DECISION MAKING AND RISK IN PARKINSON'S DISEASE *Victoria Singh-Curry[1], Nico Bunzeck[1], Richard Perry[2], Peter Bain[2], Emrah Duzel[1], Masud Husain[1,2]; [1]Institute of Cognitive Neuroscience and Institute of Neurology, University College London, [2]Imperial College London* – The role of dopamine in modulating decision making and risky behaviour was investigated in patients with Parkinson's disease (PD). Recent studies implicate dopaminergic medication in pathological risk-taking in PD, yet most patients do not develop such symptoms. We investigated how 28 PD patients responded to novelty and their willingness to take risks, compared to healthy controls. Participants were assessed on two versions of an oddball task, each containing 3 types of infrequently occurring stimulus: targets, perceptually salient standards and novels. In one version of the experiment (task N) subjects were instructed to respond only to targets and novels; while in another version (task P) responses to targets and perceptually salient standards were required. Akinetic-rigid PD patients were significantly quicker to respond on task N compared to task P. By contrast tremor dominant PD patients and controls performed equally across the two tasks. Faster responses on task N correlated with greater risk-taking behaviour on the Iowa Gambling Task for akinetic-rigid patients only. Importantly, there was an interaction between dose of dopaminergic medication and subgroup of PD. In tremor dominant patients higher L-dopa equivalent doses were associated with quicker responses on task P - to perceptually salient, non-novel stimuli. But dopaminergic dose did not correlate with either performance measure in the akinetic-rigid group. Both patient groups were matched in terms of motor impairment and cognitive performance. These results suggest dopaminergic modulation might have differential effects in the two subgroups of PD patients. Moreover, novelty-seeking correlates with risk-taking behaviour but only in akinetic-rigid PD.

F32

AUTISM SPECTRUM TRAITS IN HEALTHY ADULTS PREDICT CHANGES IN STRUCTURE AND BOLD RESPONSE IN SUPERIOR TEMPORAL SULCUS *Elisabeth von dem Hagen[1], Lauri Nummenmaa[1,2], Rongjun Yu[1], Michael Ewbank[1], Andrew Calder[1]; [1]MRC Cognition & Brain Sciences Unit, Cambridge, UK, [2]University of Tampere, Psychology, Finland* – Autism Spectrum Disorders (ASD) are neurodevelopmental disorders characterized by deficits in social interactions and communication, repetitive behaviours, and restricted interests. It has been suggested that autism spectrum traits form a continuum which extends across typically developing individuals and individuals with ASD. Baron-Cohen et al (2001) developed the Autism Quotient (AQ) scale as a measure of the severity of autism spectrum traits in adults with normal intelligence. Using the AQ scale, we wanted to determine whether these traits could predict structural and functional differences in the typical population. Based on Kennedy et al's (2006) finding of abnormal deactivation patterns in resting state network regions in ASD during cognitively demanding tasks, we scanned 19 healthy volunteers using a counting stroop task to determine the effect of autism spectrum traits on resting state deactivation in these individuals. In addition, we performed a VBM analysis of 92 healthy adults to determine whether structural differences were also predicted by individual differences in AQ. Using Kennedy et al's (2006) task, we found significant modulation of deactivation as a function of AQ in posterior STS during task conditions. For the VBM analysis, individuals with higher AQ showed a significant reduction in white matter volume in pSTS. These results suggest that autism spectrum characteristics within the typical population predict differences in structure and BOLD response. Our findings have important implications for group-based analyses of typical and ASD populations. References: Baron-Cohen S., et al. J Aut Dev Dis 2001;31:5-17. Kennedy DP, et al. Proc Natl Acad Sci 2006;103:8275-80.

F33

FUNCTIONAL NEUROIMAGING OF AUDITORY LANGUAGE PROCESSING IN CHILDREN WITH SPECIFIC LANGUAGE IMPAIRMENT *Jens Brauer[1], Beate Sabisch[1], Angela D. Friederici[1]; [1]Max Planck Institute for Human Cognitive and Brain Sciences* – Children affected by specific language impairment (SLI) show problems with language processing in language tasks involving phonological, syntactic, and/or semantic information. Though, they have normal nonverbal intelligence and don't show overt neurological, physical, or emotional deficit. We conducted a functional magnetic resonance imaging (fMRI) experiment on auditory sentence comprehension in children with SLI at the age of 6. Additionally, a group of children, matched for gender, nonverbal IQ, and handedness, served as controls. Short sentences were presented auditorily to the children. These sentences were either correct or carried obvious syntactic or semantic violations. While listening to the material, children were required to evaluate the correctness of the sentences. First

analyses yielded the following results: Even though both groups demonstrate equivalent behavioral results in response correctness and reaction times for the acceptability judgment task, functional activation is deviant in the SLI group in perisylvian language areas. This group shows less activation in inferior frontal and superior temporal cortices. While in control children functional activation of language processing is left-lateralized according to cluster size of activated regions, there is no hemispheric language lateralization in SLI children. These preliminary results indicate a pattern of unusual functional processing of auditory language information at the sentential level in 6-year-old children with SLI. The observed activation pattern in SLI children converges with data reported for adults with SLI. They are also compatible with previous data on structural abnormalities in SLI in perisylvian brain regions.

F34

PATTERNS OF NEURAL ACTIVATION IN SOCIAL ANXIETY DISORDER *Emily Dennis[1], Paul Hamilton[1], Jutta Joormann[2], Michael Chen[1], Ian Gotlib[1]; [1]Stanford University, Mood and Anxiety Disorders Laboratory, Psychology, [2]University of Miami, Psychology* – Social Anxiety Disorder (SAD) is marked by a debilitating fear of social situations that is thought to be subserved, in part, by cognitive biases toward affectively negative information. The neural bases of these cognitive biases in SAD have yet to be systematically explored. Participants in this functional magnetic resonance imaging (fMRI) study were women diagnosed with SAD who had no comorbid Axis-I disorders, and women with no current or past Axis-I disorders. As they were scanned, participants listened to self- or other-directed statements that included positive ("you are attractive"), negative ("she is downcast"), and socially-relevant negative ("he is embarrassed") adjectives. Preliminary results indicate that, in contrast to the never-disordered participants, SAD participants activate the fronto-parietal attention network and the anterior insula in response to negative self-directed statements. Importantly, healthy participants activated this same network in response to positive self- and other-directed statements, whereas SAD individuals showed deactivation in these areas. These results implicate a distributed neural network in affectively biased information processing in SAD and suggest that attentional biases play a key role in the maintenance of SAD.

F35

ELUCIDATION OF SLOWED PROCESSING SPEED IN ADHD *Joshua Ewen[1], Priya Xavier[2], Balaji Lakshmanan[1], Jeffrey Moher[3], Howard Egeth[3], Martha Denckla[2], Mark Mahone[2]; [1]Kennedy Krieger Institute, Neurology and Developmental Medicine, [2], Kennedy Krieger Institute, Developmental Cognitive Neuroscience, [3]Johns Hopkins University, Psychological and Brain Sciences* – Children with ADHD have slowed response latency on most timed tasks, suggesting reduced "processing" speed. Clinical measures of processing speed, however, do not reveal which cognitive sub-process(es) (stimulus perception/evaluation vs. response selection/preparation [RS/P] vs. motor execution) are slowed in ADHD. The psychological refractory period (PRP) is an effect seen in dual task interference paradigms. It depends on a cognitive bottleneck in RS/P and can be used to study slowing specifically in RS/P. The paradigm consists of 2 forced-choice reaction time (RT) tasks presented in quick succession with variable stimulus-onset asynchrony (SOA) (50, 150, and 750msec). Elongation of RT to the second task (T2) with shorter SOAs is thought to represent interference during RS/P. To address our hypothesis that children with ADHD have slowing in RS, we tested 10 children (6 ADHD, 4 controls) ages 9 to 13. Children with ADHD had slower T2 RT at all 3 SOA levels. All conditions had a large effect size (d>0.95), but the effects were not statistically significant, given small N. ADHD participants showed a greater PRP effect (i.e., difference in T2 RT between short and long SOA) (d=0.99). The increased PRP effect in ADHD subjects suggests a delay in RS/P in children with ADHD. This is consistent with neuroimaging evidence of anomalous development of the supplementary motor cortex, thought to be responsible for response control. These data do not exclude additional slowing in other sub-processes. Future research will use event-related potentials in this same paradigm to address the latter question.

F36

NEURAL CORRELATES OF VOLITIONAL SACCADE INITIATION IN SCHIZOPHRENIA *Julia Bender[1], Christian Kaufmann[1], Benedikt Reuter[1], Norbert Kathmann[1]; [1]Humboldt Universität zu Berlin, Psychology, Clinical Psychology* – Action control is known to be impaired in Schizophrenia patients. This is reflected in profound deficits in various volitional saccade tasks, but not in visually-guided saccades. Recent models therefore suggest a deficit in the volitional initiation of action. The present study aimed to identify the neural correlates of a putative saccade initiation deficit by functional magnetic resonance imaging of volitional and visually-guides saccades in 18 Schizophrenia patients and 18 healthy control subjects. The experimental design allowed the isolation of saccadic response selection and wilful saccade initiation. Schizophrenia patients showed altered initiation activity in the frontal eye field, the supplementary eye field and in the intraparietal sulcus, which varied with the type of saccade initiation (volitional vs. visually-guided). The results are discussed in the context of theories of a deficit in willed action in Schizophrenia.

F37

DISSOCIATION OF ERROR MONITORING AND RESPONSE INHIBITION IN COLLEGE STUDENTS WITH ATTENTION-DEFICIT/HYPERACTIVITY DISORDER *Wen-Pin Chang[1], William Gavin[2], Patricia Davies[2]; [1]University of Indianapolis, [2]Colorado State University* – Attention-deficit/hyperactivity disorder (ADHD) has been recognized as a lifelong disorder. Recent studies focused their attention to examine neurological underpinnings in adults with ADHD and found that poor cognitive control in ADHD is associated with deficient error monitoring and response inhibition. However, there remains a paucity of information regarding both error monitoring and response inhibition in college students with ADHD. Therefore, the purpose of this study was to investigate electrophysiological indices of error monitoring and response inhibition in college students with and without ADHD. We examined 17 control (10 males, 7 females; age= 24.02±3.68; IQ= 117.41±6.35) and 17 ADHD (10 males, 7 females; age= 23.88±3.48; IQ= 116.76±7.22) students using a visual flanker task and a simple go/no-go task. The results for the visual flanker task revealed that the ADHD group exhibited a smaller mean error-related negativity (ERN) amplitude as compared to the control group, $t(32) = 2.020$, $p = .027$, but no group difference in the error positivity (Pe) amplitude. Thus, in contrast to control students, ADHD students displayed less error detection (ERN amplitude) but comparable response to evaluating errors (Pe). In the go/no-go task, there were no significant differences between the two groups in the NoGo-N2 and NoGo-P3 amplitudes. Thus, related to inhibitory control, ADHD students displayed brain responses to inhibition of prepotent responses similar to control students even though college students with ADHD displayed deficits in error monitoring. Thus, brain responses in error monitoring and response inhibition were dissociated in college students with ADHD.

F38

DEGREE OF LIMB APRAXIA RECOVERY VARIES IN ACUTE AND CHRONIC STROKE PATIENTS WITHIN PRODUCTION AND CONCEPTUAL DOMAINS *Vessela Stamenova[1,2], Eric A. Roy[3,4,2,1], Debbie Hebert[5], William McIlroy[3,2,1], Sandra E. Black[6,2,1]; [1]Graduate Department of Rehabilitation Science, University of Toronto, [2]Heart and Stroke Foundation of Ontario Centre for Stroke Recovery, [3]University of Waterloo, Kinesiology, [4]University of Waterloo, Psychology, [5], University of Toronto, Occupational Science and Occupational Therapy, [6]University of Toronto, Medicine (Neurology)* – Limb apraxia is a disorder affecting performance of gestures on verbal command (pantomime), on imitation, and/or in tool and action recognition. We aimed to examine recovery on tasks assessing both conceptual and production aspects of limb praxis in left (n=19), right (n=9) and bilateral (n=1) stroke patients. Patients were assessed longitudinally (average 3 times) on 3 conceptual (Action identi-

fication, Action naming and Tool Naming) and 5 production tasks (Pantomime, Pantomime by Picture, Concurrent Imitation, Delayed Imitation and Object Use). They were grouped as presenting with apraxia (Score<2 SDs of the controls' mean (n=27)) or not, and as acute (1st assessment within 3 months post stroke) or chronic (over 3 months post stroke). Hierarchical linear modeling was used to analyze the data because patients were assessed at different intervals and had variable numbers of follow-ups. Average performance of chronic apraxic patients was higher than acute apraxic patients on pantomime, pantomime by picture and concurrent imitation. While all tasks, except Action Identification, showed evidence of recovery in both acute and chronic apraxia patients, a faster rate of recovery among acute patients was observed only in the two pantomime and two imitation tasks. Chronic apraxia patients did not have lower gains in performance than the acute apraxia patients on Object Use and the two naming tasks; tasks that are continuously practiced in everyday life. Thus, patients may continue to improve in these tasks even at chronic stages through the practice they engage in by performing everyday activities.

F39

NORADRENERGIC EFFECTS ON FUNCTIONAL CONNECTIVITY IN AUTISM *Ananth Narayanan[1,2], Catherine White[1], Sanjida Saklayen[1,2], Mary Scatudo[1], Amir Abduljalil[1], Petra Schmalbrock[1], David Beversdorf[1,2]; [1]The Ohio State University, [2]University of Missouri* – Previous experiments have demonstrated decreased functional connectivity in subjects diagnosed with ASD when compared to controls, during language tasks. Therefore, drugs that affect functional connectivity may be beneficial in ASD. The noradrenergic system is upregulated in stress, which causes a decrease in the flexibility of access to semantic networks. This impairment in the network flexibility due to stress is reversed by administration of centrally acting ?-adrenergic antagonists. Propranolol (a central and peripheral ?-blocker) has also shown benefit for language and social behavior in ASD. We hypothesized that administration of propranolol would increase functional connectivity observed during language tasks in ASD as compared to nadolol (peripheral ?-blocker), administered to control for effects on peripheral blood flow. Subjects with ASD and age and IQ-matched controls without neurodevepmental diagnoses were scanned using a Philips 3T scanner, while instructed to respond to the pronunciation (phonological) of a word related to a cue word in a block-design task. Data was preprocessed and analyzed using SPM5 and the correlation of time series was calculated and compared between drug conditions. Administration of propranolol revealed a significant increase in the functional connectivity between activated brain regions as compared to nadolol. Effects on heart rate and blood pressure were identical between the two drugs. These results reveal an increase in functional connectivity upon administration of propranolol in ASD that is not due to peripheral blood flow effects. This may suggest an anatomical substrate for the effects of noradrenergic agents on tasks involving a network search within the brain.

F40

IMPROVING PREFRONTAL CORTEX FUNCTION IN SCHIZOPHRENIA THROUGH FOCUSED TRAINING OF COGNITIVE CONTROL *Bethany Edwards[1], Deanna Barch[1,2,3,4], Todd Braver[1,2,3,4]; [1]Washington University, Psychology, St. Louis, [2]Washington University, Radiology, St. Louis, [3]Washington University, Neuroscience, St. Louis, [4]Washington University, Philosophy, St. Louis* – Previous research has shown that patients with schizophrenia show deficits in cognitive control functions thought to depend on the lateral prefrontal cortex (lPFC), as well as interactions with other regions such as anterior cingulate cortex (ACC), and posterior parietal cortex (PPC). The current study explored the effects of instructed strategy training in improving cognitive control functioning in patients with schizophrenia. Event-related fMRI was used to test whether effects of such training were associated with changes in brain activity dynamics during task performance. Patients with schizophrenia performed the AX-CPT cognitive control task in two-sessions, with the first session occurring pre-training and second immediately following strategy training. The training protocol emphasized direct encoding of contextual cues and updating response selection goals in accordance with cue information. A matched group of healthy controls underwent the same protocol but were only scanned in the pre-training session. Compared to controls, patients exhibited the typical pattern of impaired utilization of contextual information in the pre-training session. However, following training their performance selectively improved in terms of the use of context. Analyses of brain activity indicated changes in dynamics of trial-related activation within lPFC, ACC and PPC. Specifically, the strategy training session appeared to have a "normalizing" effect on patient's brain activity dynamics to bring them in closer alignment to the pattern observed in controls. These results suggest that focused strategy training may facilitate cognitive task performance in patients with schizophrenia by changing the dynamics of activity within critical control-related brain regions.

F41

MODELING LATERALIZATION OF SEMANTIC KNOWLEDGE IN THE ANTERIOR TEMPORAL LOBES *Anna Schapiro[1], James McClelland[1], Stephen Welbourne[2], Matthew Lambon Ralph[2]; [1]Stanford University, [2]University of Manchester* – A connectionist model of semantic knowledge is presented that accounts for the performance on semantic tasks of patients with varying degrees of unilateral damage (due to, for example, tumor resection or stroke) and bilateral damage (due to semantic dementia) to the anterior temporal lobes. Patients with unilateral damage are able to perform at or close to normal levels on naming and word-to-picture matching tests, whereas patients with bilateral damage show a steep decline in accuracy with increasing damage. In addition, patients with bilateral but asymmetrically left-sided damage have more difficulty with verbal tasks, and patients with bilateral but asymmetrically right-sided damage have more difficulty with visual tasks. The model has sparse connectivity between the units representing right and left anterior temporal lobes to encourage independence in the function of the two sides and uses noise and weight decay in training to induce robust and distributed representations. Like the patients, the model performs significantly better with unilateral than bilateral damage, providing a possible explanation for the trends in patient behavior. The model also incorporates decreased connectivity from the left semantic representations to visual output and from the right semantic representations to verbal output, allowing it to exhibit the dissociation seen in patients with asymmetrically right-sided or left-sided damage. The close fit of the model's behavior to the patient data suggests that the representation and processing of semantic information in the brain may be similar to that in the model.

F42

ABSENCE OF CUE INDUCED CROSS-FREQUENCY INTERACTIONS IN CHILDREN DIAGNOSED ATTENTION-DEFICIT/HYPERACTIVITY DISORDER *Ali Mazaheri[1,4], Sharon Coffey-Corina[1,4], Evelijne Hart de Ruijter, Anne Berry, George R. Mangun[1,4], Blythe A. Corbett[1,2,3,4]; [1]Center for Mind and Brain, [2]M.I.N.D. Institute, [3]Psychiatry, [4]University of California (Davis)* – Attention Deficit Hyperactivity Disorder (ADHD) is characterized by symptoms of inattention, impulsivity, and hyperactivity. The current pathophysiologic models of ADHD suggest that symptoms may be related to impaired functional connectivity within brain networks. In this electroencephalogram (EEG) study we analyzed cross-frequency amplitude anti-correlations between distant regions to investigate differences in cue induced functional connectivity in typically developing and ADHD children. EEG was recorded in 19 children (11 ADHD) while they performed a cross-modal attention task in which visual cues signaled the modality of an upcoming target. The power spectra of theta (3-4 Hz) and alpha (7-11 Hz) activity were calculated for the 1 second interval after the cue. Behaviorally, the visual cue appeared to facilitate stimulus processing for both typically developing and children with ADHD (p=0.018), although the reaction times were

slower in the latter (p=0.03). The EEG analysis revealed that a visual cue induced a decrease in occipital alpha activity for typically developing children but not children with ADHD (p<0.01). This decrease in posterior-alpha activity was anti-correlated with midline theta activity on a trial-by-trial basis (p<0.028). This anti-correlation was absent in children with ADHD. We speculate that the presence of this functional connectivity could indicate top-down drive (midline theta) to perceptual areas (occipital alpha) providing a preparatory state for oncoming stimuli. The cue induced theta-alpha connectivity could be necessary for efficient regulation of attentional resources. The lack of connectivity indexed through cross-frequency interactions has the potential to be used as a new locus in studying ADHD.

F43

THE EFFECTS OF NEUROPLASTICITY-BASED COGNITIVE TRAINING IN ULTRA-HIGH RISK, RECENT-ONSET, AND ADULT CHRONIC SCHIZOPHRENIA *Liza Reese[3], Melissa Fisher[2], Rachel Loewy[1], Ashley Lee[1], Sophia Vinogradov[2]; [1]The Wright Institute, San Francisco VA Medical Center, University of California San Francisco, [2]San Francisco VA Medical Center, University of California San Francisco, [3]University of California San Francisco* – We examined the effects of a novel neuroplasticity-based cognitive training program that targets the cognitive deficits in schizophrenia. We compared the response to training, using MATRICS-recommended cognitive measures, of three subject groups (ultra-high risk for psychosis, recent onset of schizophrenia, and adult chronic schizophrenia), to a chronic schizophrenia control group who completed the same number of hours of computer games. The active training condition consists of computerized exercises (developed by Positscience, Inc.) that drive the user to make progressively more accurate distinctions about the spectro-temporal fine-structure of auditory stimuli and speech under conditions of increasing working memory load, and to incorporate and generalize those improvements in auditory signal salience into real-world language comprehension and working memory rehearsal. After 40 hours of this training, and relative to the computer games control group (N=26), ultra-high risk subjects (N=10), recent-onset subjects (N=10), and chronic schizophrenia subjects (N=29), show significant cognitive improvement, as measured by the Global Cognition composite score (p=.003), with gains on measures of Working Memory, Verbal Learning and Memory, and Problem Solving. A larger response to training is observed in younger subjects (age<22) compared to adults with chronic schizophrenia (age>23) (p=.01). These findings suggest that intervening with a restorative cognitive training program at a younger age provides greater benefit to patients and may be a means of preventing the cognitive decline associated with chronic schizophrenia.

F44

NEURAL CIRCUITRY OF SPEECH PERCEPTION AND PRODUCTION: A COMPARISON BETWEEN STUTTERING AND FLUENT SPEAKERS *Helen Chen[1], Einar Mencl[1], Steven Frost[1], Vincent Gracco[1,2]; [1]Haskins Laboratories, [2]McGill University* – The purpose of this study was to investigate the similarities and differences in neural circuitry between stuttering and fluent speakers in visual and auditory perception versus production tasks. A total of 20 subjects, in which 10 were stuttering speakers and 10 were fluent speakers, participated in the study. Words were presented auditorally and visually to examine how presentation modality modulated group differences. In the production trials, participants were requested to say the word that was presented. In-scanner speech responses were recorded. Using functional and diffusion imaging, we examined brain structure and function in language and auditory processing areas. Initial comparison between the two goups revealed fluency-related differences in regions including inferior frontal gyrus (IFG), occipital temporal gyrus, superior temporal gyrus(STG), Angular gyrus(AG) and supramarginal gyrus(SMG) in both perception and production tasks. Further comparisons showed effects of presentation modality on these regions that differed across speaker groups. These results suggest that the two groups differentially activate various language-related processing regions.

F45

ECONOMIC GAMES QUANTIFY DIMINISHED SENSE OF GUILT IN PATIENTS WITH DAMAGE TO THE PREFRONTAL CORTEX *Ian Krajbich[1], Ralph Adolphs[1,2], Daniel Tranel[2], Natalie Denburg[2], Colin Camerer[1]; [1]Division of the Humanities and Social Sciences, California Institute of Technology, [2]Neurology, The University of Iowa* – Damage to the ventromedial prefrontal cortex (VMPFC) impairs concern for other people, as reflected in the dysfunctional real-life social behavior of patients with such damage, as well as their abnormal performances on tasks ranging from moral judgment to economic games. Despite these convergent data, we lack a formal model of how, and to what degree, VMPFC lesions affect an individual's social decision-making. Here we provide a quantification of these effects using a formal economic model of choice that incorporates terms for the disutility of unequal payoffs, with parameters that index behaviors normally evoked by guilt and envy. Six patients with focal VMPFC lesions participated in a battery of economic games that measured concern about payoffs to themselves and to others: dictator, ultimatum, and trust games. We analyzed each task individually, but also derived estimates of the guilt and envy parameters from aggregate behavior across all of the tasks. Compared to control subjects, the patients donated significantly less and were less trustworthy, and overall our model found a significant insensitivity to guilt. Despite these abnormalities, the patients had normal expectations about what other people would do, and they also did not simply generate behavior that was more noisy. Instead, the findings argue for a specific insensitivity to guilt, an abnormality that we suggest characterizes a key contribution made by the VMPFC to social behavior.

F46

THE SAME KIND OF SPATIAL DISTORTION EXPLAINS APPARENTLY DIFFERENT NEGLECT ERRORS IN READING AND BISECTING WORDS *Silvia Savazzi[1], Francesca Mancini[1]; [1]University of Verona* – Neglect patients show rightward errors in bisecting horizontal lines and make errors on the initial letters in reading words. Both these disorders have been found to be ameliorated by the Oppel-Kundt illusion, thought to simulate the way space is represented in neglect1,2,3. However, these two studies found an amelioration of neglect with opposite illusory conditions. Here, we investigate the hypothesis that this difference is due to the specific task used (line bisection and word reading). Four patients with spatial neglect and neglect dyslexia without hemianopia were asked to read words and to bisect words both with letters evenly and unevenly spaced following the Oppel-Kundt illusion. All the neglect patients replicated the results by Ricci et al.1 in bisecting words and the results by Savazzi et al.2,3 in reading words; that is opposite modulations of neglect errors with the same patients. These data indicate that opposite results previously found can be reconciled by taking into account the particular requests of the tasks patients are confronted with: a single object to bisect versus a series of ordered letters within a word. In addition, these results show that even if the behavioural results are different, the theoretical framework is the same, the space anisometry hypothesis3. References 1. Ricci R, Pia L, Gindri P. Exp. Brain Res. 2004; 154: 226-237. 2. Savazzi S, Frigo C, Minuto D. Cogn Brain Res 2004; 19: 209-218. 3. Savazzi S, Posteraro L, Veronesi G, Mancini F. Brain 2007; 130: 2070-2084.

F47

THE SAME KIND OF SPATIAL DISTORTION EXPLAINS APPARENTLY DIFFERENT NEGLECT ERRORS IN BISECTING REAL AND NUMERICAL INTERVALS *Francesca Mancini[1], Silvia Savazzi[1]; [1]University of Verona* – Neglect patients show rightward errors in bisecting lines and numerical intervals (mental number line). For both real and numerical intervals, the bisection error increases as a function of the size of the interval: long lines and large numerical intervals produce large rightward errors, short lines and numerical intervals produce medium rightward errors and very short lines and numerical intervals

produce the crossover effect. The rightward bisection error in bisecting real lines has been found to be ameliorated by the Oppel-Kundt illusion, thought to simulate the way space is represented in neglect1,2,3. Here we tested the hypothesis that physical lines and numerical intervals can be modulated by the same visual illusion. Neglect patients were requested to both physically and numerically bisect intervals of different sizes within evenly or unevenly backgrounds inducing the Oppel-Kundt illusion. We found opposite effects on the real and numerical intervals in terms of both bisection errors and illusory effects. This in line with what found for word reading3 and can be explained by taking into account the particular requests of the tasks: a single object to bisect (a word or a physical interval) versus a series of ordered objects (letters or numbers). These results can be explained within the same theoretical framework, the space anisometry hypothesis2. References 1. Ricci R, Pia L, Gindri P. Exp. Brain Res. 2004; 154: 226-237. 2. Savazzi S, Posteraro L, Veronesi G, Mancini F. Brain 2007; 130: 2070-2084. 3. Savazzi S, Frigo C, Minuto D. Cogn Brain Res 2004; 19: 209-218.

F48

MEMORY MONITORING FAILURES IN CONFABULATION: EVIDENCE FROM THE SEMANTIC ILLUSION PARADIGM *Irene P. Kan[1,2], Karen Fossum[2], Mieke Verfaellie[2]; [1]Psychology, Villanova University, [2]Memory Disorders Research Center, VA Boston Healthcare System, Boston University School of Medicine* – Confabulation ó the tendency to make statements or perform actions that are based on apparent distortions of memory ó is a common symptom in patients with ruptured anterior communicating artery (ACoA) aneurysm. Confabulators are typically unaware of the falseness of these memories and often uphold their memories with the greatest conviction. One prominent model characterizes confabulation as a failure in cognitive control and monitoring. In this study, we used the semantic illusion paradigm to evaluate memory monitoring and to examine whether confabulators are particularly impaired at suppressing semantically-related, yet incorrect, memory traces. The semantic illusion paradigm elicits erroneous endorsement of misleading statements (e.g., "Two animals of each kind were brought onto the Ark by Moses before the great flood") in neurologically intact individuals, even though participants are fully aware of the correct answer (Noah, in the example above). We hypothesized that if confabulators are differentially impaired at suppressing incorrect, but semantically-related, memory traces, they will have particular difficulty in overcoming semantic illusions, even at lower levels of semantic confusability. Confusability was manipulated by using difficult, easy, or extremely easy foils (e.g., Moses, Adam, Malcolm X, respectively). Consistent with our hypothesis, we found that confabulators are more susceptible to semantic illusions than both non- confabulating ACoA patients and healthy controls, but endorsed true statements as often as the other two groups. Reducing semantic confusability had less impact on confabulators than on the other groups, consistent with the notion that confabulators are impaired at evaluating and monitoring the veracity of retrieved memory traces.

F49

SELF-PACED TIMING TASK SHOWS SENSITIVITY TO SUBTLE DYSFUNCTION IN PRE-DIAGNOSED HUNTINGTON'S DISEASE *Kelly Rowe[1,2], David Moser[1,2], Douglas Langbehn[1,2], Chiachi Wang[1,2], Kevin Duff[1,2], Leigh Beglinger[1,2], Sarah Queller[1,5], Julie Stout[1,4], Steven Rao[1,3], Jane S. Paulsen[1,2]; [1]University of Iowa, [2]University of Iowa Roy and Lucille Carver College of Medicine, [3]Medical College of Wisconsin, [4]Monash University, Victoria, Australia, [5]Indiana University* – Cognitive outcome measures remain unknown for pre-diagnosed Huntington's disease (pre-HD), though efforts are underway to conduct clinical trials in these participants. Timing tasks have demonstrated impairment in pre-HD, even before characteristically disease-affected brain regions show volume loss. This study compared performance on self-paced finger-tapping between pre-HD and healthy normal participants. Further, the study evaluated the relationship of task performance with proximity to diagnosis, quantified as the probability of receiving HD diagnosis in the next five years based on trinucelotide expansion in the HD gene and age. Participants in two groups (747 preHD : 188 healthy) listened to tones presented at 550ms intervals, matched that pace by tapping response keys, and continued tapping at that pace for 31 taps after the tone had stopped. There were two conditions: dominant hand index finger tapping and alternating-thumbs tapping. Standardized cross-sectional linear modeling examined the relationships between self-paced tapping precision and age, gender, education, musical experience, typing experience, and proximity to diagnosis. Proximity to diagnosis was related to self-paced tapping precision in both conditions ($t=-11.14, df=920, p<.0001$: $t=-11.32, df=918, p<.0001$), even considering demographic and experience variables. It was possible to identify weaknesses on the alternating thumbs condition in individuals far from HD onset (as low as 4.35% probability of diagnosis over the next five years). In conclusion, the self-paced tapping paradigm has potential for use as a screening tool or outcome measure in preHD trials because it detects impairment in participants with low probabilities of onset, suggesting it could be used to gauge therapeutically-mediated improvement or maintenance in function.

F50

RELATIONSHIP BETWEEN AUDITORY HALLUCINATIONS AND ABNORMAL FMRI ACTIVITY DURING PERFORMANCE OF A WORKING MEMORY TASK: DATA FROM THE FBIRN CONSORTIUM STUDY *Cynthia Wible[1], KangUk Lee[2], Israel Molina[1], Brian Roach[3], Judy Ford[3], Daniel Mathalon[3], Jessica Turner[4], Steven Potkin[4], Daniel OLeary'[5], Greg Brown[6]; [1]Harvard Medical School and Brockton VAMC, Psychiatry, Boston, MA, [2]Kangwon National University School of Medicine, Psychiatry, [3]University of California, San Francisco (UCSF), [4]University of California, Psychiatry and Human Behavior, Irvine, CA , [5]University of Iowa, Psychiatry, Iowa City, IA , [6]University of California, Psychiatry, San Diego, CA* – Auditory hallucinations of voices are a frequent and prominent symptom of schizophrenia. The fBIRN consortium study tested schizophrenic and control subjects in similar FMRI procedures at sites around the country. We analyzed the relationship between levels of FMRI activity and levels of auditory hallucinations during performance of a Sternberg Item Recognition Working Memory Paradigm (SIRP). We hypothesized that measures of auditory hallucinations would be correlated with abnormal activity in the temporal and inferior parietal lobe voice/speech perception and production regions. Subjects were 96 chronic schizophrenics. The functional scans were gradient echo EPI, TR = 2, TE = 30 ms, 90 deg, 64x64, 22 cm FOV, 27 slices, 4 mm thick/1 mm gap, oblique axial. The SIRP task was presented using a block design with four six second runs and subjects encoded numbers and were then tested in a probe phase. Two different analyses were performed (hallucinators vs. non-hallucinators and a correlation analysis between activation and symptom levels). Results of both analyses implicated superior temporal and inferior parietal regions. These regions are part of speech and voice perception and production networks. Voice perception/conversation can also involve the activation of aspects of social cognition and self/other representation. Over-activation of this social communication system could also contribute to other symptoms of schizophrenia. We will present the results in the context of a framework implicating these regions in the generation of most of the symptoms of schizophrenia. Supported by NCRR 1 U24 RR021992.

F51

INVESTIGATING NEUROMYTHS OF SOCIAL BRAIN PATHOLOGIES AND CREATIVITY *Rachael Grazioplene[1], Judith Segall[1], Robert Chavez[1], Ranee Flores[1], Shirley Smith[1,3], Alison Marshall[1], Rex Jung[1,2,3,4]; [1]Mind Research Network, University of New Mexico, [2]University of New Mexico, Neurosurgery, [3]University of New Mexico, Psychology, [4]University of New Mexico, Neurology* – Controversy surrounding the supposed link between creative ability and the abstract cognitive style is often seen in psychotic-spectrum disorders, whereas high mathematical

"creative" ability has been linked to the compartmentalized cognitive style seen in autistic-spectrum disorders. The literature has spoken both for (Dinn et al. 2002; Nettle & Clegg 2006) and against (Tal & Miller 2007) a correlation between positive schizotypal symptoms and measures of creativity; the link between autism and physical/mathematical thinking has been shown more firmly (e.g.Wheelright & Baron-Cohen 2001, Baron-Cohen 2002), with Rawlings & Locarnini going so far as to find support not only for schizotypy-creativity correlation, but also the connection of autism-spectrum traits to scientific creativity (2008). We hypothesize that two general types of creativity, wherein abstract creative thinking reflects more global brain connectivity (schizotypal) while a more mathematical creative ability exists by way of enhanced local network (autism-type) connectivity. Gathering data from a nonclinical sample population of visual artists and high math (>95th %ile on SAT/GRE) engineers, we predict that visual artists will perform better on divergent task measures of creativity, whereas engineers will perform better on convergent reasoning measures. Preliminary data supports a trend towards increased performance of visual artists on divergent reasoning tasks compared to age, gender, and FSIQ matched normal controls (Artists = 105.1; Controls = 97.2, p = .07). Collection of high math Engineering subjects is ongoing. Differences in brain structure (cortical thickness, diffusion tensor imaging) between visual artists and high math engineers will also be presented.

F52

THE EFFECTS OF SMOKING ON NOVELTY PROCESSING: AN ERP STUDY *Sandra Wiebe[1], Dennis McChargue[1], Leigh Blobaum[1], Stephanie Wulff[1], Alex Knezevic[1]; [1]University of Nebraska-Lincoln* – Nicotine addiction is associated with novelty-seeking and impulsivity. We examined smoking-related differences in ERPs to novel stimuli, to shed light on novelty-related neural processes. A sample of 63 participants (38 smokers, 25 non-smokers) completed a visual oddball task that included 20% targets, 70% standards, and 10% novel trials (non-repeating photographs; Suwazano et al., 2000). EEG was recorded from 128 channels, averaged by trial type, and then reduced using spatiotemporal PCA (Spencer et al., 1999). The first spatial component, accounting for 50.8% of variability in the ERP data, primarily reflected central and right leads. In the virtual epoch corresponding in time to a medial frontal negativity, there was a significant main effect of Smoking Status ($p < .02$) and Trial Condition ($p < .0001$) qualified by an interaction between the two ($p < .005$). Overall, this component was maximal to novel trials. A larger negative amplitude was observed in non-smokers than smokers for both novel ($p < .02$) and standard trials ($p < .03$), but not for target trials, when a response was required ($p = .13$). The third spatial component (8.25% of variance) reflected activity at parietal leads. In the virtual epoch corresponding to the P300, there was again an interaction between Smoking Status and Trial Condition ($p < .01$). P300 amplitude was reduced in smokers for the novel condition ($p < .005$) but not other conditions ($p > .65$). Blunted novelty-related responses may reflect specific effects of nicotine or relate to personality differences underlying predisposition to addition.

F53

INCREASED SERUM LEVELS OF THE NMDA RECEPTOR CO-AGONIST D-SERINE CORRELATE WITH COGNITIVE GAINS INDUCED BY NEUROPLASTICITY-BASED AUDITORY TRAINING IN SCHIZOPHRENIA *Rogerio Panizzutti[1,2], Melissa Fisher[3,4], Christine Holland[3,4], Sophia Vinogradov[3,4]; [1]W.M. Keck Foundation Center for Integrative Neurosciences, University of California, San Francisco, CA, [2]Biomedical Sciences Institute, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil, [3]School of Medicine, Psychiatry, University of California, San Francisco, CA. , [4]Veterans Affairs Medical Center, San Francisco, CA* – The cognitive deficits that characterize schizophrenia may be in part related to hypofunction of glutamate-NMDA receptors due to reduced levels of the receptor co-agonist D-serine. Serum D-serine levels are decreased in patients with schizophrenia and increase as their clinical status improves, while administration of oral D-serine appears to ameliorate cognitive symptoms in patients. We previously performed a randomized controlled trial of neuroplasticity-based cognitive training exercises of auditory perceptual and working memory functions in schizophrenia and showed significant improvement in MATRICS-based cognitive outcome measures in active training subjects vs. computer games control subjects. In the present study, we investigated whether the gain in cognitive outcome measures was associated with changes in serum D-serine levels. We measured D-serine and other amino acids in serum from schizophrenia subjects before and after they performed either 50 hours of computerized cognitive training (N= 21) or 50 hours of computer games (N= 20). The active training subjects, but not the control subjects, showed significant positive correlations between changes in D-serine levels and gains in working memory (r= 0.5, p=0.04), verbal learning (r=0.6, p=0.00), and global cognition (r=0.5, p=0.01). The ratio D-serine / L-serine also showed highly significant associations with these same measures. No such associations were observed with glutamate or L-serine levels. Our data suggest that D-serine may serve as a biomarker for a successful response to neuroplasticity-based cognitive training in schizophrenia. These findings may provide some clues as to potential mechanisms of action for this form of cognitive enhancement.

F54

OBSERVATIONAL LEARNING IN THE REMEDIATION OF AN ASSOCIATIVE LEARNING DEFICIT SECONDARY TO PARKINSON'S DISEASE *Winifred Limmer[1], Francesco Fera[2], Antonio Daniele[3], Pietro Spinelli[3], Ahmed Moustafa[1], Catherine Myers[4], Mark Gluck[1]; [1]Center for Molecular and Behavioral Neuroscience, Rutgers University, Newark, NJ, [2]Neuroradiology Unit, University Magna Græcia, Catanzaro, Italy, [3]Institute of Neurology, Catholic University, Rome, Italy, [4]Rutgers University, Psychology, Newark, NJ* – Parkinson's disease (PD) is associated with dopamine depletion in the basal ganglia. Research suggests that disruption of the dopamine signal impairs associative learning via error-correcting feedback. In the present study, a computerized concurrent object discrimination task was administered to PD patients and elderly controls. Pairs of objects, which differed in either color or shape, were presented. Some subjects learned by trial-and-error to find a hidden smiley face beneath one of the two objects; other subjects learned by observation. During a test phase, subjects were tested on the trained pairs, and, during a generalization phase, on novel object pairs that had the same relevant - but different irrelevant - features as the trained pairs. Previously, Shohamy et al. (2006) observed that medicated, but not withdrawn PD patients, were impaired relative to controls during the feedback-based learning phase. In the present study, both medicated and withdrawn PD patients were impaired relative to controls during the feedback-based training phase and the test phase, the medicated patients being more impaired than the withdrawn. Medicated and withdrawn PD patients who learned the discriminations via an observational procedure, however, exhibited no learning deficit, making the same number of errors as controls during the test phase. Interpreted in light of functional neuroimaging studies that suggest that feedback-based and observational learning rely on the integrity of different neural structures, the present results suggest that the learning deficit observed in PD patients may be remediated by training via an observational procedure, which recruits different, putatively intact brain structures.

F55

MECHANISMS OF RECOVERY AFTER STROKE: REORGANIZATION OR REGAINING OF FUNCTION? *Veena Nair[1], Kirk Brown[2], Gregory Kirk[1], Vivek Prabhakaran[1]; [1]University of Wisconsin-Madison, School of Medicine and Public Health, Radiology, [2]University of Wisconsin-Madison, School of Medicine and Public Health, Medical Physics, Medical Scientist Training Program* – Neuroimaging studies of stroke have provided conflicting evidence in terms of mechanisms of recovery after stroke. Prabhakaran et al. (2007) examined the neural substrates underlying word generation in chronic stroke (at least 6

months post-stroke) patients. While normal subjects displayed activations in the left-lateralized fronto-temporo-parietal network, stroke patients showed decreased activation in the cortical regions that were hypoperfused and increased activation in the homologous regions of the normal hemisphere suggesting reorganization of structure-function relationship. Other studies of stroke patients with aphasia have observed reduced activation surrounding the infarct in the left hemisphere language areas at the acute time point (< 2 days post-stroke), and activity in the hypoperfused hemisphere returning back to normal at the chronic stage (Saur et al.,2006) suggesting regaining of function by the affected region. The objective of this study is to investigate mechanisms of recovery after stroke. We will map brain activations in stroke patients who are in the acute (less than 3 days post-stroke) or chronic stage (>4-6 months post stroke) using fMRI while patients perform the verbal fluency task in the scanner. Subjects with left and right strokes, along with normal controls, will be imaged while performing a verbal fluency task. Preliminary results from 2 acute left stroke patients show decreased activity in task-related areas in the affected region, 4 chronic left stroke patients show increased activity in the homologous contralateral hemisphere. These results suggest that reorganization is the mechanism that leads to recovery after stroke.

F56

DEVIATIONS IN ALPHA-BAND FUNCTIONAL CONNECTIVITY BETWEEN BRAIN REGIONS IN PATIENTS WITH SCHIZOPHRENIA DURING MAGNETOENCEPAHLOGRAM (MEG) RECORDINGS AT REST *Srikantan Nagarajan[1], Leighton Hinkley[1], Adrian Guggisberg[1], Anne Findlay[1], Kasra Khatibi[1], Alison Adcock[2], Sophia Vinogradov[3,4]; [1]University of California, San Francisco, Radiology, [2]Duke University, Psychiatry and Behavioral Sciences, [3]University of California, San Francisco, Psychiatry, [4]Veterans Affairs Medical Center, San Francisco* – Evidence from neuroanatomical and imaging studies suggests that schizophrenia is associated with impairments in anatomical cortical connectivity and/or aberrant functional coupling between brain regions. Limited evidence demonstrates aberrant functional connectivity between areas of the brain whose idling frequency exceeds what can be recorded by imaging methodologies such as fMRI. Using magnetoencephalography (MEG), we recorded spontaneous cortical activity during a resting state from 24 patients with schizophrenia and 15 healthy control subjects using a whole-head 275-channel biomagnetometer (CTF Systems, Vancouver BC) with a sampling rate of 600Hz. A single epoch (60s) of artifact-free data was selected and the sources of oscillating neural activity in the alpha range (~8-12Hz) were estimated using an adaptive spatial filtering technique (Vrba and Robinson, 2001). Resting-state functional connectivity in the alpha band between brain voxels was computed using imaginary coherence (IC), a metric that overcomes overestimation biases arising from volume conduction and crosstalk in MEG data (Guggisberg et al., 2007). Tomographic reconstructions of the data were spatially normalized to a canonical MNI template and the mean Z-transformed IC values of alpha activity at each voxel were compared between patients and controls using a non-parametric unpaired t-test. Patients with schizophrenia demonstrated increased alpha band connectivity in the inferior frontal gyrus (IFG) of the right hemisphere, and decreased alpha band connectivity in regions of the right superior temporal gyrus, precuneus and left anterior temporal lobe. These results expand upon the known patterns of aberrant functional connectivity that underlie schizophrenia.

F57

RECOGNITION OF FACIAL AND PROSODIC EMOTIONAL EXPRESSION IN PARKINSON'S DISEASE *Lynette Tippett[1], Sharon Buxton[1], Lorraine Macdonald[2]; [1]University of Auckland, Psychology, [2]Auckland City Hospital, Neurology* – Some research findings suggest Parkinson's disease (PD) affects recognition of emotional facial expressions (especially disgust and anger), and reduces sensitivity to prosodic expressions of anger, disgust and fear, but findings are inconsistent. We investigated recognition of facial and prosodic emotional expressions in 30 medicated-PD participants and 30 age, education and gender-matched controls. The 108 face stimuli were based on Ekman and Friesen (1976) faces. Six faces each displaying 6 emotions (happy, sad, angry, disgust, fear, surprise) were morphed between each emotion and neutral. Three levels of expression were selected: 100% emotion and morph levels with 70% and 40% identification accuracy by young controls. Participants identified each facial expression in a multiple-choice format with emotion labels presented simultaneously. Prosody stimuli comprised 8 trials each of happy, sad, angry, fear and neutral intonations (Ross, Thompson, & Yenkosky, 1997) presented simultaneously with 5 multi-choice labels. Participants listened to a neutral sentence read with different emotional intonations (20 trials) and monosyllabic repetitions with emotional inflections (20 trials). PD participants had no difficulty identifying expressions on 100% emotion faces, but were impaired with morphed emotional expressions with significantly lower scores recognising disgusted, happy, sad and surprised faces but not anger or fear. PD participants were also impaired overall on emotion identification by prosody. These data demonstrate that PD induces subtle dysfunction of emotional processing affecting both facial and prosodic stimuli. Dopaminergic depletion interrupting basal ganglia/frontal-striatal systems is likely to underlie these findings, with orbitofrontal cortex, sensitive to judging vocal and facial emotional expressions, also implicated.

F58

FUNCTIONAL-ANATOMIC ABNORMALITIES IN INHIBITION AND ERROR REGULATION AMONG YOUNG ADULTS WITH CHILDHOOD-ONSET ADHD: AN FMRI STUDY OF OCULOMOTOR CONTROL *Katerina Velanova[1], Beatriz Luna[1,2], Tracey Wilson[1], Kendal Kingsley[1], Elizabeth Gnagy[3], William Pelham[3,4,5], Brooke Molina[1,2]; [1]University of Pittsburgh, Psychiatry, [2]University of Pittsburgh, Psychology, [3]SUNY Buffalo, Psychology, [4]SUNY Buffalo, Psychiatry, [5]SUNY Buffalo, Pediatrics* – Attention deficit hyperactivity disorder (ADHD) is the most common neurodevelopmental disorder of childhood, conservatively affecting 3-5% of school-aged children in the US. The disorder is thought to persist into adulthood in 30-70% of affected children. While extensive research has been conducted to describe the cognitive profile and neural correlates of childhood ADHD, relatively little work has been done with young adults. Here we present data from an ongoing pilot study of young men aged 18-25 years, 9 of whom, run to date, met DSM-III-R or DSM-IV diagnostic criteria for ADHD in childhood. All participants have been followed since childhood as part of the Pittsburgh ADHD Longitudinal Study (AA11873; DA12414). Comprehensive clinical data were available for each participant. For this research, event-related functional magnetic imaging (fMRI) was conducted as participants performed the antisaccade taskóan oculomotor test of inhibitory control. Regions of interest were derived from an independent fMRI study of antisaccade performance in typical young adults. Timecourses of activity for correctly performed antisaccades, and for (corrected) errors were estimated within regions, and effects confirmed in whole-brain voxelwise analyses. Notable findings to date include attenuated activity in supplementary/pre-supplementary motor area and ventromedial prefrontal cortex during correct performance of antisaccades, and atypical signaling in anterior cingulate cortex during error commission. Voxelwise analyses indicate also that ADHD participants recruited additional regions in ventrolateral prefrontal cortex that were minimally active in typical adults. These data provide preliminary evidence of continued functional-anatomic anomalies, even among ADHD adults whose parent-reported daily functioning is relatively unimpaired.

F59

THE STRENGTH OF THE LINKS BETWEEN OBJECTS, ACTIONS, AND NAMES INFLUENCES ACTION PRODUCTION AND VISUAL OBJECT IDENTIFICATION IN PATIENTS WITH LEFT-HEMISPHERE STROKE *Genevieve Desmarais[1], Laurel J. Buxbaum[2]; [1]Mount Allison University, Psychology, [2]Moss Rehabilitation Research Institute* – In healthy participants, similarity of novel objects impacts novel action production, and novel action similarity impacts novel object naming: actions are confused more often when associated with similar as compared to distinct objects, and object names are confused more often when associated with similar as compared to distinct actions. These relationships indicate that neighborhood "distance" may benefit both action and name retrieval. Left hemisphere stroke has been shown to disrupt links between actions, objects, and lexical-semantics (names). We therefore investigated this phenomenon using object identification and action production in 20 left hemisphere stroke patients. Participants were asked to learn the associations between novel objects, novel actions, and nonword names (for example, a curved object is pulled and is called 'FINT'). We manipulated the similarity relationships between objects and actions. On test trials, participants were asked to recall the nonword 'name' of each object, and then produce its associated action. Visually similar objects were mis-named more often than visually distinct objects, a normal pattern. Contrary to previous findings in healthy participants, however, action production did not benefit from object distinctiveness, suggesting that object-shape neighborhood distance may not facilitate action retrieval in these patients. Moreover, 62% of all action errors corresponded with the precise incorrect name given the object, suggesting an effort to rely on object name-action links (rather than on object shape-action links) to guide action. Results are discussed in terms of a cognitive-neuroanatomic model of object-related action production.

F60

SEMANTICS VERSUS GRAMMAR: EVENT-RELATED POTENTIALS DURING AUDITORY LANGUAGE PROCESSING IN WILLIAMS SYNDROME *Inna Fishman[1], Anna Yam[1,2], Mark Grichanik[1], Ursula Bellugi[1], Debra Mills[1,3]; [1]Salk Institute for Biological Studies, La Jolla, CA, [2]University of Florida, Gainesville, FL, [3]Bangor University, United Kingdom* – The present study examined event-related potentials (ERP) patterns linked to the processing of semantic vs. grammatical aspects of language in individuals with Williams Syndrome (WS), autism (ASD) and typically developing controls (TD). ERPs were recorded as participants listened to a series of sentences, half of which ended with an anomalous last word (e.g. I have five fingers on my moon.) and half with a congruent last word (e.g., I have five fingers on my hand). ERPs were averaged according to semantic (i.e., congruous vs. incongruous ending) and grammatical (i.e., open- vs. closed-class first word) categories. Using temporal Principal Component Analysis (PCA), a centroparietal N400 and left anterior negativity (N280) were identified. A significant condition-by-group interaction was found for the N400, whereby WS group had the largest N400 effect in response to incongruent endings, while ASD group exhibited the smallest N400 effect. In contrast, analysis of variance of the N280 component yielded no significant difference between grammatical categories (i.e., open- vs. closed-class words) in the WS group, unlike the TD and ASD groups. These results suggest that while individuals with WS show a large ERP effect to semantic anomaly, their ERP patterns do not show differential processing of the main grammatical classes. These findings (a) support the largely behavioral data indicating atypical semantic organization of language in WS, (b) provide evidence that grammatical processing is also unusually organized in WS, and (c) illustrate qualitatively different processing of language in WS and ASD, potentially mirroring the fundamental differences between the two disorders.

F61

COMPUTERIZED NEUROPLASTICITY-BASED TRAINING OF COGNITIVE CONTROL PROCESSES IN CHRONIC SCHIZOPHRENIA *Maryann Bens[1,2,3], Melissa Fisher[1,2], Alexander Genevsky[1,2], Sophia Vinogradov[1,2]; [1]University of California, Psychiatry, San Francisco, [2]San Francisco Veterans Affairs Medical Center, [3]The Wright Institute* – We previously reported on the effects of a novel neuroplasticity-based cognitive training program that targets auditory perceptual processes and working memory in schizophrenia. In this study we investigated the effects of an additional computerized training module that targets cognitive control processes in schizophrenia (developed by Posit-Science, Inc.). Exercises in the cognitive control module were designed to improve categorization, prediction, novelty detection and task switching. The exercises were continuously adaptive in that they first established the precise parameters within each stimulus set required for an individual subject to maintain 80% correct performance; once that threshold was determined, task difficulty increased systematically and parametrically as performance improved. Thirty adult chronic schizophrenia subjects were stratified by age, education, and symptom severity and randomly assigned to either 20 hours of the targeted cognitive training condition (TCT, N=15), or to 20 hours of a computer games control condition (CG, N=15). Subjects participated in either the TCT or CG condition for one hour per day, five days per week. Repeated Measures ANOVA reveal significant group differences on measures of Stroop Inhibition ($p = .01$), and visual working memory (WMS-III Spatial Span) at trend level significance ($p = .11$). These early findings provide evidence of the specificity of effects and cognitive benefits that individuals with schizophrenia can achieve through a training program that explicitly incorporates core principles of neuroplasticity-based learning.

F62

FRAGILE X MENTAL RETARDATION-1 GENE MRNA AS A PREDICTOR FOR AMYGDALA VOLUME IN FRAGILE X PREMUTATION MEN *John Wang[1], Kami Koldewyn[2,3], David Hessl[2,4], Diana Selmeczy[1], Randi Hagerman[2,5], Paul Hagerman[2,6], Chris Iwahashi[6], Flora Tassone[2,6], Andrea Schneider[2], Susan Rivera[1,2,3]; [1]University of California Davis, Center for Mind and Brain, [2]University of California Davis Medical Center, M.I.N.D. Institute, [3]University of California Davis, Psychology, [4]University of California Davis Medical Center, Psychiatry and Behavioral Sciences , [5]University of California Davis Medical Center, Pediatrics, [6]University of California Davis School of Medicine, Biological Chemistry* – Fragile X Mental Retardation-1 Gene (FMR1) premutation carriers (55-200 CGG repeats) have been shown to have psychological and possible late-life neurodegenerative problems. Evidence of volumetric decreases in limbic structures, increased anxiety, and social cognition deficits suggest possible amygdala dysfunction. Previous studies have shown premutation carriers to have elevated levels of FMR1 mRNA that correlate with CGG repeat size. Carriers with large repeat sizes may also exhibit decreased Fragile X Mental Retardation Protein (FMRP). A previously proposed RNA toxic gain of function model predicts increased cell death and diminished volume in affected brain regions. We investigated amygdala volumes in premutation men compared with well-matched controls and explored the possible molecular correlates of individual volumetric differences. Amygdala volumes were acquired by manual segmentation of participants' structural MRI images. CGG repeat number and mRNA levels were ascertained through standard analysis of peripheral blood. FMR1 mRNA levels were found to be negatively correlated with amygdala volumes in both controls and in premutation carriers with lower CGG repeat size (<120). CGG repeat number and amygdala volumes were also negatively correlated in this lower CGG group. So, mRNA levels may predict amygdala size in controls and premutation carriers with smaller repeat sizes. In premutation carriers with larger CGG repeat sizes (>120), we suspect that decrements in FMRP levels may counteract the effect of high FMR1 mRNA levels. Previous studies have shown full mutation fragile X participants, who lack FMRP, to have

larger amygdalae. We will present these results with hippocampal volumes, neuropsychiatric data, and protein measures.

F63

CONVERGENT EEG AND FMRI EVIDENCE OF REDUCED RESPONSE TO NEGATIVE FEEDBACK IN COCAINE-DEPENDENT INDIVIDUALS *Matthew Shane[1], Carla Harenski[1], Prashanth Nyalakanti[1], Kent Kiehl[1,2]; [1]The Mind Research Network, [2]The University of New Mexico* – Our laboratory has become guided by a model of substance abuse that posits insufficient responsiveness to error-related information as underlying the abuser's chronic, perseverative drug-taking behavior. Indeed, a growing body of work has demonstrated that cocaine abusers show behavioral rigidity (Franken et al., 2007) and attenuated electrophysiology (Hester et al., 2007) after the commission of errors on a variety of laboratory tasks. The underlying nature of these abnormalities remains uncertain, however. One possibility suggests that cocaine abusers' reduced responsiveness underlies an initial failure to detect the commission of their errors; alternately, it may be that their error detection mechanisms remain intact, and that their attenuated response instead indicates a chronic insensitivity to error-related information. To test these alternate hypotheses, we evaluated the amplitude of the cocaine abuser's feedback error-related negativity (fERN) within a time-estimation task that presented participants with explicit positive ('+'), negative ('-') and uninformative ('?') feedback. Participants were simply required to estimate how long they believed a one-second duration took; the explicit performance feedback ensured that any deficit associated with error-detection could not influence participants' electrophysiology. Results indicated that both nonabusing groups evidenced a well-formed fERN on '-' trials, and that this waveform was absent in the cocaine abusing group. In contrast, the cocaine abusers showed the highest negative deflection on '?' trials. These results suggest that cocaine abusers display with an underlying insensitivity to error-related information that may contribute to their chronic and repetitive drug-taking behavior.

F64

CLINICAL EFFECTS IN FMRI ARE INFLUENCED BY ACTIVITY AND VARIANCE: AN EXAMPLE FROM AN ADHD STUDY *Gregory Burgess[1], Marie Banich[1], Erik Willcutt[1], Luka Ruzic[1]; [1]University of Colorado, Psychology, Boulder* – Studies using fMRI have become influential toward understanding the neural bases of clinical disorders. Typically, fMRI statistics are interpreted only with respect to group differences in the magnitude of activity. However, fMRI statistics are also influenced by unexplained variance in the data, and by spatial variability in the localization of activation. These sources of variability could affect fMRI statistics, leading researchers to misinterpret results and miss effects of theoretical interest. We developed simple procedures to identify brain regions where fMRI statistics are affected by spatial variability or unexplained variability. We applied those procedures to fMRI data comparing adults with ADHD to controls during the Color-Word Stroop task. This identified regions involved in executive control and word-reading where statistics were influenced by large amounts of unexplained variance. Importantly, unexplained variance was related to existing behavioral performance measures excluded from the initial model. Considering these correlations increased the significance of the group difference statistic, and also demonstrated group differences in the relationship between brain activity and behavior that would have been missed. Furthermore, our procedures identified brain regions where significant group differences resulted from greater spatial variability in the ADHD group rather than an actual difference in activity. In conclusion, we demonstrate the necessity for researchers to consider unexplained variance and spatial variability before interpreting clinical group differences, and provide simple procedures for accomplishing this.

Perceptual processes: High-level vision

F65

THE EFFECTS OF DISCRIMINABILITY AND SELECTIVE ATTENTION ON EVENT-RELATED POTENTIALS TO GAZING EXPRESSIVE FACES *Janessa Manning[1], Katie Sicking[2], Nicole Wicha[1,3], Reiko Graham[2]; [1]University of Texas Health Sciences Center, San Antonio, [2]Texas State University, [3]University of Texas at San Antonio* – Although it is accepted that gaze and expression information is integrated at some level of visual processing, the exact nature of the interaction is unknown. Behavioral evidence suggests that gaze and expression interactions are maximized when facial expression is difficult to discriminate (Graham & LaBar, 2007). However, it is uncertain whether this occurs because decreasing the discriminability of expression slows down expression processing, allowing for gaze and expression interactions (a speed of processing account), or whether the extra information from gaze helps to resolve expression under conditions of uncertainty (an ambiguity account). Using a blocked design, the current study examined event-related potentials (ERPs) to faces with subtle or intense facial expressions (fear, anger) with direct and averted gaze while subjects (N = 18) made either gaze or expression judgments. Behavioral analyses revealed that subjects were more accurate when the expression discrimination was easy. Furthermore, reaction times were faster for emotion than gaze judgments, but only when emotion was easily discriminable. ERP analyses revealed that both selective attention and expression discriminability had widespread effects on both early and late ERP components. Notably, gaze and expression interactions were observed in components associated with early visual processing, but only when expression discriminations were difficult - e.g., P1 amplitudes were largest to 55% intensity angry faces with direct gaze and 55% intensity fearful faces with averted gaze. These results suggest that information about gaze and expression can be integrated relatively early in visual processing, supporting an ambiguity-based account of gaze and expression interactions.

F66

OBJECT CLASSIFICATION IN THE ABSENCE OF VISUAL AWARENESS AND FIGURE-GROUND SEGREGATION *Johannes J. Fahrenfort[1,2], Klaartje Heinen[2], Simon van Gaal[1], H.Steven Scholte[1], Victor A.F. Lamme[1,3]; [1]University of Amsterdam, Cognitive Neuroscience Group, Psychology, Amsterdam, the Netherlands, [2]Institute of Cognitive Neuroscience, London, UK, [3]Netherlands Institute for Neuroscience, Amsterdam, the Netherlands, part of the Royal Academy of Arts and Sciences (KNAW)* – It is well known that neurons in the temporal lobe classify objects, such as faces, and it is generally assumed that the activity of such neurons is necessary for conscious awareness of these objects. However, object categorization may also occur unconsciously, as has been shown by the selective activation of object selective neurons by masked objects. So what distinguishes conscious from unconscious object recognition? We constructed schematic images containing objects such as faces and houses while keeping local retinal stimulation between conditions identical. Using a dichoptic fusion paradigm, we manipulated stimulus visibility such that objects were either visible or not visible. Confirming earlier results, we found that both consciously perceived and non-perceived objects result in category specific BOLD activation, even if they are task irrelevant and non-attended. Critically however, we show that objects that are consciously seen show a distinct neural signature of figure-ground segregation in early and midlevel visual areas, which is completely absent when objects are not seen. Although counterintuitive, this implies that consciousness is more intimately related to processes of figure-ground segregation and perceptual organization than to object categorization. We propose that figure-ground segregation is a prerequisite for visual awareness, and that both phenomena share part of their neural correlate, which is recurrent processing within visual cortex.

F67

DISTINCT BRAIN ACTIVITY ELICITED BY COLOR MODULATED 'UNNATURAL' VISUAL SCENES *N. Eiji Nawa[1,2], Hiroshi Ando[1,2]; [1]Multimodal Communication Group, NICT Universal Media Research Center, [2]Perceptual and Cognitive Dynamics, ATR Cognitive Information Science Labs., Kyoto, Japan* – Several studies have investigated the brain areas involved in the processing of physical attributes of visual stimuli such as color, luminance and contrast, but relatively little is known about how such attributes affect the perception of complex scenes as 'natural' looking, as opposed to 'unnatural' or 'artificial'. In a previous study, contrast curves were manipulated to generate unnatural stimuli that looked like negative images. BOLD contrasts revealed enhanced activity when viewing contrast modulated unnatural stimuli in a large network encompassing regions in the fusiform gyri, left middle occipital cortex, right inferior temporal cortex, and the inferior frontal cortex (right inferior frontal operculum). In this study, using a block-design fMRI paradigm, we examined whether distinct activity patterns are elicited by natural and unnatural visual stimuli resulting from the manipulation of colors. Stimuli were pictures portraying various natural sceneries, e.g., country fields, beaches, and mountains. Colors in the natural looking stimuli were not altered; however, the stimuli in the unnatural looking set had their colors "reversed", by inverting the parameters in a color-opponent space (L*a*b*). During scanning, participants performed a discrimination task in which they had to judge whether the picture depicted an animal or not. When viewing color modulated unnatural stimuli, BOLD contrasts revealed that activity was greater in the right inferior temporal cortex and the left inferior frontal operculum. The existence of overlapping regions suggests the involvement of a common network in the high-level perception of visual stimuli as natural or unnatural.

F68

FACIAL CONFIGURATIONS AND FEATURES INVOLVE DIFFERENT HEMISPHERES *Dario Bombari[1], Fred W. Mast[1]; [1]Institute of Psychology, University of Bern* – A wealth of knowledge shows that faces can be recognized on the basis of configural or featural information (Leder & Bruce, 1998; Cabeza & Kato, 2000; Lobmaier & Mast, 2007). Features are referred to as detailed information contained in individual facial parts (e.g., the shape of the mouth or the color of the eyes) whereas configurations concern spatial interrelationships between facial parts (e.g., the metric distance between the eyes and the mouth). In the present study, we analyzed whether featural and configural processing involves different hemispheres using a divided visual field methodology. In a same-different matching task, 18 right-handed participants had to match the identity of a cue face containing either featural (scrambled faces) or configural (blurred faces) information with an intact test face presented subsequently in either the left or right visual fields. Unilateral presentation was controlled by monitoring central gaze direction. D prime analysis revealed that the visual field of test face presentation interacted with the information provided by the cue image ($F(1, 17) = 7.43$; $p < .05$), thus suggesting that featural and configural information is differently processed by the two hemispheres. Specifically, our findings show a left hemispheric superiority for featural processing and a right hemispheric superiority for configural processing (Rossion et al., 2000; Maurer et al., 2007). Our findings contribute to the growing body of evidence showing that the two hemispheres differ in the way they process global and local information. This project was funded by the Swiss NSF.

F69

TRAINING FACILITATES OBJECT PERCEPTION IN CUBIST PAINTINGS *Alumit Ishai[1], Martin Wiesmann[1], Robert Pepperell[2]; [1]Institute of Neuroradiology, University of Zurich, Switzerland, [2]Cardiff School of Art and Design, University of Wales Institute Cardiff, UK* – To the naïve observer, cubist paintings contain "cubes" or "boxes" and in the absence of a meaningful title, familiar objects are hardly recognizable. We tested the extent to which a short training session about cubism would facilitate object perception and subsequent memory of cubist paintings by Picasso, Braque and Gris. Subjects, who had no formal art education and were unfamiliar with cubist paintings, performed an object recognition task followed by an aesthetic judgment task. Each painting was preceded by a meaningful title, a false title, or the word "untitled". Three days later, subjects returned for a surprise recognition memory test, in which paintings from the study phase were mixed with new paintings. Half the subjects received a short lecture about cubism and learned how to identify familiar objects in the paintings. Relative to the control group, the trained subjects reported seeing significantly more objects in the paintings, especially in paintings that were preceded by correct titles, and their response latencies were significantly shorter. No differences were found between trained and control subjects in terms of aesthetic rating and memory performance. Our data suggest that meaningful titles are necessary for understanding the content of artwork, and provide empirical evidence for learning-dependent top-down effects on object recognition.

F70

HOW GENDER AND BODY-MASS-INDEX SHAPE FOOD DISCRIMINATION *Ulrike Toepel[1,2], Jean-François Knebel[1], Julie Hudry[3], Johannes Le Coutre[3], Micah M. Murray[1,2,4]; [1]The Functional Electrical Neuroimaging Laboratory, Neuropsychology and Neurorehabilitation Service, Centre Hospitalier Universitaire Vaudois and University of Lausanne, Switzerland, [2]Radiology Service, Centre Hospitalier Universitaire Vaudois and University of Lausanne, Switzerland, [3]Nestle Research Center, Vers-chez-les-Blanc, Lausanne, Switzerland, [4]EEG Brain Mapping Core, Center for Biomedical Imaging of Lausanne and Geneva, Switzerland* – Men and women differ in their susceptibility to eating disorders. Whether perceptual differences in food discrimination are a contributing factor remains unknown. Here, we investigated the spatiotemporal brain mechanisms by which normal-weighted men and women discriminate images of foods from non-foods. Electrical neuroimaging analyses of 160-channel visual evoked potentials (VEPs) independently tested for topographic and strength modulations between object categories for each gender. In women, between-category VEP topographic modulations were observed within the initial 100ms post-stimulus onset, while in men they first occurred at 200ms post-stimulus onset. By contrast, between-category modulations in VEP response strength occurred at ~220ms irrespective of gender. Further, source estimations significantly correlated with Body-Mass-Indices (BMIs) of the participants of either gender. In women, a higher BMI was found to be predictive of increased activations to food images in distributed occipito-temporal cortices during two time periods, i.e. ~100ms and ~220ms. Further, a lower BMI in women was correlated with stronger responses to food images in prefrontal areas over the earlier post-stimulus epoch only. In men, merely a lower BMI was predictive of higher neural source strengths over both the early (~100ms) and late (~220ms) post-stimulus intervals with correlations confined to parieto-occipital areas. Our results indicate that both the speed and locus of food vs. non-food object discrimination is impacted by the gender of the viewer. Moreover, even in normal-weighted populations, activity within neural networks for food perception varies as a function of BMI.

F71

PERCEPTUAL AND SPATIAL MECHANISMS IN NEGLECT DYSLEXIA *Lisa S. Arduino[1], Marialuisa Martelli[2], Roberta Daini[3]; [1]Istituto di Psicologia, Università di Urbino and ISTC-CNR Roma, [2]Dipartimento di Psicologia, Sapienza Università di Roma and IRCCS Santa Lucia Roma, [3]Dipartimento di Psicologia, Università degli studi Milano-Bicocca* – Patients with neglect dyslexia (ND) tend to misread letters occupying the initial left-sided letters of single words and nonwords. The most common errors are substitutions and omissions. The relative proportion of these error types varies across patients and we hypothesized this is because they are due to different mechanisms. In particular, we propose that omissions depend on a spatial mechanism (as unilateral spatial neglect) while substitutions reflect a perceptual one (crowding). Method: Seven right-handed patients were recruited for the study on the basis of the presence of left unilateral spatial neglect and ND. All patients had suffered an

ischemic stroke to the right hemisphere. The severity of neglect was calculated for each patient on the basis of their performance on some visual-spatial tasks. The experimental task included two lists of written verbal stimuli, presented in two conditions: standard font spacing and spaced (center-to-center letter spacing proportional to each letter's eccentricity). Patients were requested to read aloud each stimulus and reading errors were recorded. Results and conclusions: Increasing the distance between letters increased the number of 'omission' errors. By contrast, in the patients who presented more 'substitution' errors an increase in letter separation did not worsen performance but rather improved it, as in the crowding phenomenon. A correlational analysis showed that the severity of unilateral spatial neglect was related to the presence of omissions but not substitutions. The results strongly support the view that these two kind of ND errors depend on different mechanisms, one spatial and the other perceptual.

F72

CONTEXTUAL PLASTICITY OF HUMAN JUDGMENTS: BEYOND STANDARD RANDOMIZATION OF TRIALS *Alexander N. Sokolov[1], Marina Pavlova[2,3]; [1]Centre for Ophthalmology, Low Vision Clinic and Research Laboratory, University of Tuebingen Medical School, Tuebingen, Germany, [2]Cognitive and Social Developmental Neuroscience Unit, Childrens Hospital, University of Tuebingen Medical School, Tuebingen, Germany, [3]Institute of Medical Psychology and Behavioral Neurobiology, University of Tuebingen Medical School, Tuebingen, Germany* – In cognitive neuroscience, studies of stimulus-driven attention, decision making, implicit learning and memory often vary statistical context for a task by employing different-frequent stimuli, such as in repetition-priming, mismatch and oddball paradigms. The overall frequency of occurrence of distinct stimuli is considered the primary modulatory variable for behavioral and brain responses. Using judgments of visual speed, we challenge this view showing that standard randomization of different-frequent stimuli for presentation confounds the effects of overall and outset frequencies of stimulus occurrence. Participants judged sets of visual speeds that comprised either frequent low or frequent high speeds. In four experiments, standard and biased randomization of stimuli for presentation made either frequent or infrequent speeds, respectively, to occur mainly at the series outset. With standard randomization, judgments of speed assumed their levels from the very beginning of the series and did not change across the experiment. By contrast, with biased randomization of stimuli (i.e., with the on-overall infrequent, either low or high speeds presented mainly at the series outset), the judgments exhibited a striking gradual change across the trials. We conclude that biasing the different-frequent stimuli for presentation reveals a novel kind of contextual plasticity of judgments that is contingent on the opposite relationship of the overall and outset frequency of distinct stimuli. The overall- and outset-frequency processing is likely to engage separate neural mechanisms. The findings have significant implications for neurophysiological, electrophysiological and neuroimaging studies that employ distinct stimuli blended in varying proportions.

F73

REGULARITY AND TASK EFFECTS IN THE LEFT FUSIFORM GYRUS DURING CHINESE CHARACTER READING *Yi Guo[1], E.Darcy Burgund[1]; [1]Rice University* – The left fusiform gyrus is hypothesized to be selectively involved in visual word processing. Nevertheless, the particular components of reading to which this area responds is the subject of much controversy. The purpose of Experiment 1 was to examine the role of the left fusiform gyrus in reading, in the context of a dual-route model. Accordingly, activity in the left fusiform gyrus was measured using functional magnetic resonance imaging (fMRI) while subjects performed a phonological task with regular and irregular Chinese characters. Regular characters were those containing elements that provide phonological information for the whole character, and irregular characters were those without such phonological elements. Results exhibited greater activity for irregular than regular characters in the left fusiform gyrus, suggesting that this region is involved in the direct route of the dual-route model. The purpose of Experiment 2 was to determine whether the left fusiform gyrus responds preferentially to lexical phonological access, semantic access, or orthographic processing. Accordingly, activity in the left fusiform gyrus was measured using fMRI while subjects performed phonological, semantic, and orthographic tasks with irregular Chinese characters. A region in the left fusiform gyrus exhibited greater activity during the orthographic task than during the phonological and semantic tasks, which did not differ, suggesting that this region is involved in orthographic processing to a greater extent than phonological or semantic access. In addition, two regions in the right fusiform gyrus exhibited a similar effect. This right fusiform activity may relate to the use of pictorial Chinese characters.

F74

NEURAL CORRELATES OF PRIOR STIMULUS AND PRIOR PERCEPTION DURING VISUAL MOTION SEGREGATION *Joel Snyder[1], Olivia Carter[2], Amanda Pasinski[1]; [1]University of Nevada, Psychology, Las Vegas, [2]University of Melbourne, Psychology* – Two gratings moving in different directions viewed through an aperture are perceived as a coherent plaid moving in one direction or two segregated gratings moving past each other. When the angle formed by the motion directions of the two gratings is larger, observers perceive more segregation. To examine effects of prior angle, we presented an adaptation plaid with a small, intermediate, or large angle, followed by a test plaid with an intermediate angle. Stimuli were flickered on every 200 ms to elicit event-related potentials (ERPs). When the adaptation plaid had a larger angle, the test plaid was more often perceived as coherent, similar to suppressive aftereffects. During adaptation, large angle resulted in ERP modulations in occipital electrodes that peaked 150 ms post-flicker; during tests following large-angle adaptation, ERP modulations in occipital electrodes peaked at 100 and 230 ms post-flicker. To examine effects of perception during adaptation on perception during the subsequent test, we analyzed only those trials in which the adaptation (and test) had an intermediate alpha. Segregated percepts during adaptation were more likely than not to be continued during test, similar to perceptual stabilization. During adaptation, segregated percepts resulted in ERP modulations in occipital electrodes at 85 and 170 ms post-flicker; during tests that followed segregated percepts, ERP modulations occurred with similar timing as segregation-related modulations during adaptation. These results demonstrate that encoding the current and prior stimulus engages brain processes with distinct time courses, whereas encoding the current and prior perception engages brain processes with similar time courses.

F75

EFFECTS OF ORIENTATION AND EXEMPLAR ON OBJECT PRIMING IN THE FUSIFORM CORTEX *Denise Y. Harvey[1], E.Darcy Burgund[1]; [1]Rice University* – Behavioral experiments indicate the critical role of the right hemisphere in specific-orientation and exemplar visual form processing and the left hemisphere in abstract-orientation and exemplar visual form processing. However, findings from neuroimaging studies conflict in their support of these results. While researchers have found that the right fusiform gyrus (RFG) mediates specific-orientation and exemplar visual form processing, it remains unclear to what extent the left fusiform gyrus (LFG) mediates abstract visual form processing. That is, some neuroimaging studies demonstrate exemplar-abstract priming in the LFG, while another implicates orientation- but not exemplar-abstract priming in this region. We investigated this inconsistency by comparing priming in functional magnetic resonance imaging data across four different conditions: same-orientation, same-exemplar; different-orientation, same-exemplar; same-orientation, different-exemplar; and unprimed. In line with previous studies, priming was observed for same-orientation, same-exemplar objects, but not different-orientation, same-exemplar objects or same-orientation, different-exemplar objects, in the RFG. In contrast to some studies, priming was observed for same-orientation, same-exemplar objects and different-orientation, same-exem-

plar objects, but not same-orientation, different-exemplar objects, in the LFG. Thus, we conclude that the RFG stores objects in an orientation- and exemplar-specific manner, and the LFG stores objects in an orientation-abstract and exemplar-specific manner.

F76

RECURRENT ACTIVITY IN THE VENTRAL STREAM SUPPORTS RECOGNITION OF VISUAL OBJECTS *Alexander Clarke[1], Kirsten Taylor[1,2], Lorraine K Tyler[1]; [1]Centre for Speech, Language and the Brain, Experimental Psychology, University of Cambridge, UK, [2]Memory Clinic - Neuropsychology Center, University Hospital Basel, Switzerland* – Visual object recognition takes place within a hierarchically-organised processing stream in ventral temporal cortex, with feature complexity increasing from posterior to anterior regions. Activity along the stream is modulated as a function of the information required to complete different processing tasks, with anterior regions involved when more fine-grained analyses are required (Tyler et al, 2004). In the present study we asked how meaningful object representations evolve over time and how the time-course of activity along the ventral stream is modulated under different processing conditions, by comparing basic-level naming (e.g. tiger) which requires more detailed object information than domain-level naming (i.e. living). We included a baseline of meaningless objects. Visual object processing involves an initial feedforward sweep along the ventral stream within 100-150ms, which may be sufficient for broad categorical decisions, with subsequent recurrent processing necessary for finer-grained decisions. This predicts (a) increases in recurrent activity which (b) includes anterior regions for basic-level compared to domain-level naming or meaningless objects. We recorded MEG signals while subjects named objects at a basic or domain-level. Sources of cortical activation were estimated using MNE for a priori ROIs from posterior to anterior sites along the ventral stream. All conditions displayed early bilateral responses propagating from posterior to anterior sites within 150ms, consistent with rapid feedforward processing, followed by stronger recurrent activity between posterior and anterior ROIs during basic-level compared to domain-level naming. This dynamic pattern suggests that recurrent activity along the stream may be necessary to form detailed representations of meaningful objects.

F77

ACTION RECOGNITION FROM BODY FORM ANALYSIS *Markus Lappe[1], Simone Kuhlmann[1], Marc de Lussanet[1]; [1]Psychological Institute II and Otto Creutzfeldt Center for Cognitive and Behavioral Neuroscience, Westf. Wilhelms University, Münster, Germany* – In point-light biological motion the combination of the form of the human body and its motion is easily perceived from very limited visual input. It is debated whether this percept results from the analysis of motion vectors via the dorsal pathway or from the analysis of the form of the body and its changing over time via the ventral pathway. We have proposed to use the method of lifetime limitation of the point-lights to eliminate local motion signals in the stimulus and prohibit the motion vector route. Good performance in walking discrimination tasks has supported a predominant role of from analysis. Walking discrimination is a standard procedure for biological motion studies but arguably limited in scope. In the current study we investigated the perception of limited lifetime point-light stimuli with a broader set of stimuli, and for the more natural task of action recognition. Participants viewed a set of 33 different action stimuli (e.g. dancing, hopping, jumping, etc.) that were recorded from human actors. The actions were presented as point-light stimuli in which each point was shown only for a single video frame, thereby eliminating local motion signals. Participants had to name or describe the actions. The results showed that participants were very good at recognizing these actions (about 90% correct) even though they could not use motion signals for the recognition. Our findings corroborate the view that action recognition is primarily based on the analysis of the changes of body form over time.

F78

INVESTIGATION OF BISTABLE BIOLOGICAL MOTION WITH "SILHOUETTE SPINNER": THE POWER OF HUMAN INTENTION AND THE BIOLOGICAL CONSTRAINT *Chao-Hsuan Liu[1,2], Chi-Hung Juan[1,3], Daisy L. Hung[1,3], Ovid J.L. Tzeng[1,3,4]; [1]Institute of Cognitive Neuroscience, College of Science, National Central University, Jhongli, Taiwan, [2] College of Science, National Central University, Life Sciences, Jhongli, Taiwan, [3]Laboratories for Cognitive Neuroscience, National Yang-Ming University, Taipei, Taiwan, [4]Institute of Linguistics, Academia Sinica, Taipei, Taiwan* – Visual competition has been investigated with binocular rivalry paradigm and other multistable phenomena such as ambiguous figure reversal and bistable apparent motion (BAM). In this study, we employed "silhouette spinner" as a biological BAM stimulus, which was first created by Nobuyuki Kayahara. The silhouette spinner can be perceived either as a clockwise or an anti-clockwise spinner in spite of the identical physical movement. We examined how subjects' intention can alternate their subjective percepts and how it interacts with bottom-up factors (e.g. fixation positions, frame durations). Our preliminary results showed that the changing rate of the percepts was lower in the passive viewing condition than in the active viewing condition (intentional effects). Furthermore, the intentional effects were significantly stronger when subjects fixed at the spinner's foot than at the body. This pattern of results indicates that human intention can effectively change their percepts of the bistable stimulus but this intentional effect is possibly constrained by the principle of the biological motion.

F79

TOP-DOWN ACTIVATION OF FUSIFORM CORTEX WITHOUT SEEING FACES *Ruthger Righart[1,2], Frédéric Andersson[1], Sophie Schwartz[1,3], Eugène Mayer[4], Patrik Vuilleumier[1,2,3]; [1]Neurology and Imaging of Cognition Laboratory, University of Geneva, [2]Swiss Center for Affective Sciences, University of Geneva, [3]Geneva Neuroscience Center, University of Geneva, [4]Neuropsychology Unit, Neurology, Geneva University Hospital* – Face processing can be modified by bottom-up and top-down processes, but it is unknown how these processes interact in patients with prosopagnosia. We investigated a well-documented prosopagnosia patient (P.S.) who has lesions in the right occipital and left fusiform gyrus, whereas the right fusiform gyrus is intact and still activated during face processing. P.S. was instructed to detect the presence of faces or houses in pictures with different amounts of noise. P.S. showed a normal activation in the FFA (Fusiform Face Area) to faces with low-noise. However, her FFA activated to the same degree to images containing noise-only when she was instructed to detect faces (not when instructed to detect houses). These results reveal that the fusiform cortex is still sensitive to task-demands and selectively modulated by top-down processes, despite severe face recognition deficits.

F80

DOES MENTAL ROTATION RECRUIT HUMAN MOTION AREA MT? A MULTI-VOXEL PATTERN ANALYSIS *Giorgio Ganis[1,2,3], Haline Schendan[2,4]; [1]Harvard Medical School, Radiology, Boston, MA, [2]MGH/Athinoula Martinos Center, Charlestown, MA, [3]Harvard University, Psychology, Cambridge, MA, [4]Tufts University, Psychology, Medford, MA* – Mental rotation is a process thought to take place when performing spatial transformation tasks that require bringing misoriented (static) visual images into spatial congruence with one another. The present fMRI study tested the hypothesis that mental rotation utilizes neural operations also recruited during motion perception. First, a localizer for human motion area MT was used in the same subjects performing a mental rotation task in order to determine whether mental rotation actually recruits human motion area MT. Second, a multi-voxel pattern analysis was conducted at the single subject level, in the common region activated by motion perception and by the mental rotation task, to determine whether the pattern of activation was the same for the two conditions. Mental rotation activated portions of area MT in common with motion perception, both at the group level and in the majority of individual subjects. However,

multi-voxel analyses showed distinct patterns of spatial activation in the two conditions in area MT. These results suggest that both mental rotation and motion perception recruit neural populations that carry out motion computations in area MT but that the specific operations differ in the two cases. To explain the different spatial pattern of activation, we hypothesize that area MT activation elicited by motion stimuli reflects predominantly bottom-up influences, whereas area MT activation elicited by mental rotation (when actual motion is not present but instead visualized) reflects primarily top-down influences.

F81

THE RADICAL IS A UNIT IN CHINESE CHARACTER PERCEPTION: EVIDENCE FROM BEHAVIORAL AND PSYCHOPHYSIOLOGICAL COSTS DUE TO STIMULUS INVERSION *Man-Ying Wang[1], Yi-Jhong Han[1], Bo-Chen Guo[2]; [1]Soochow University, Psychology, Taipei, Taiwan, [2]National Taiwan University, Psychology, Taipei, Taiwan* – The recognition of Chinese characters is considered to be a process mediated by radicals. Evidence is not as clear on whether the radical actually constitutes a unit in character perception. This study examines recognition costs for the inversion of a two-radical character versus a single-radial character, with faces and objects as control stimuli. The tasks are lexical, face and object decision. RT inversion cost for two-radical characters is about twice as much as single-radical characters and faces. Inversion costs are exhibited in the reduction of P3 positivity as in the study of mental rotation (Heil, 2002). The magnitude of P3 reduction over parietal/temporal electrodes parallels behavioral effects so that two-radical characters resulted in greater P3 reduction by inversion than single-radical characters and faces. These findings suggest that the radial serves as a unit in the perceptual processing of inverted and, most likely, upright Chinese characters.

F82

DIRECTION-SPECIFIC AFTEREFFECTS ARISE FROM CELLS TUNED TO DIFFERENT SOCIAL CUE TYPES *Rebecca P. Lawson[1], Andrew J. Calder[1]; [1]MRC Cognition and Brain Sciences Unit, Cambridge, United Kingdom* – Electrophysiological recording in the anterior superior temporal sulcus (aSTS) of macaques has demonstrated separate cell populations responsive to different gaze directions, head directions and body orientations (Perrett et al. 1992). A proportion of these cells responded to different cues (e.g. heads or bodies) oriented in the same direction (e.g. facing left). Recent psychophysical studies have found direction-specific aftereffects in humans following adaptation to a single gaze direction (Jenkins et al, 2006; Calder et al. 2008); similar effects have also been found for heads and bodies (Fang & He, 2007; Lawson et al, in press). However, it is unclear if these effects occur at the level of direction-selective cells tuned to specific classes of social cue (i.e., gaze, head, and body representations) or putative social attention cells tuned to the same direction irrespective of cue type. We address this by measuring participants' discrimination of head direction following adaptation to 20° left and right oriented heads and bodies. A third "non-social" adaptor, directionally oriented chairs, was included to rule out the possibility that any aftereffects simply reflect recruitment of general 3D object representations. Aftereffects were found for the head adaptor condition only. These effects transferred across changes in the size and identity of the heads, indicating that these effects were not the result of adaptation to low-level properties. Our study provides the first evidence that direction-specific aftereffects in humans occur as a result of adapting direction-selective cells tuned to specific classes of social cue.

F84

IS 30 THE NEW 20? BEHAVIORAL EVIDENCE FOR PROTRACTED DEVELOPMENT OF FACE RECOGNITION *Laura Germine[1], Bradley Duchaine[2], Ken Nakayama[1]; [1]Harvard University, [2]University College London* – Face perception and recognition is important over the entire life span, from early infancy to old age. There is an implicit assumption in the literature, however, that perceptual abilities reach their peak at or before the end of adolescence and so no study has investigated face learning competence beyond early adolescence. We investigated face recognition development using a variant of the Cambridge Face Memory Test (CFMT), where subjects learn six new faces, followed by stringent tests of recognition under conditions of varied lighting, pose and image degradation (Duchaine and Nakayama, 2006). From the results of over 47,000 subjects on the web, we found that performance rises steeply post-puberty, and does not peak until just after age 30. In a second experiment, we replicated this pattern of performance for recognition of unfamiliar adult and children's faces, but found no evidence of a late performance peak for inverted faces. This indicates that this peak is specific to recognition of upright faces. Finally, in a third experiment, we found a similar late performance peak for faces, but not for names, with an intermediate but somewhat late peak for recognition of eyeglasses. Our data provide the first behavioral evidence for late or delayed maturation of face processing, in particular the learning of new faces. This is consistent with recent studies showing slower maturation of face-specific areas in the brain (Golarai et al., 2007). It remains to be determined whether this late peak arises from increased experience with faces.

F85

SELECTIVITY OF VISUAL WORD FORM AREA IS DEPENDENT ON ATTENTION AND READING SKILL *Li-Wei King[1], Dafna Palti[1], Manuel Perea[2], Jessica Kim[1], Caroline Huang[1], John Gabrieli[1]; [1]Massachusetts Institute of Technology, [2]Universitat de València* – An area of left fusiform cortex, commonly referred to as the visual word form area (VWFA), has consistently been shown to activate during the processing of written language. However, the question of whether the VWFA differentiates between strings of differing lexicality and legality is still open. In this study, we tested whether attention modulates the selectivity of the VWFA, and whether this selectivity could be influenced by reading skill. We localized the VWFA in a group of normal reading young adults by selecting left fusiform clusters for each individual that activated more for words than for photographs of faces and houses. We then extracted the activation of these ROIs while participants performed a spatial cueing task that directed their attention either towards or away from three different types of letter strings (words, pseudowords, and consonant strings). Participants were divided into two groups based on standardized reading measures. The lower-reading group showed no significant differences in VWFA response to different stimulus types, regardless of attentional manipulation. The higher-reading group showed an interaction between attention and string type. Specifically, the better readers showed higher VWFA activation for words than for consonants strings in the unattended condition, but not in the attended condition. Thus, selective response of the VWFA toward orthographic regularity is not uniform across contexts, but varies according to individual reading skill and attention.

F86

A DISTANCE PRINCIPLE OF ORGANIZATION OF THE VENTRAL VISUAL STREAM *Elinor Amit[1], Yaacov Trope[1], Galit Yovel[2]; [1]NYU, [2]Tel-Aviv University* – Perceiving the distance of an object from the self is a fundamental feature of the visual system. Here we used fMRI to test the hypothesis that the ventral visual stream represents distance-related information in discrete cortical regions. In particular, object-related regions (Lateral Occipital Complex - LOC) are biased towards proximal stimuli, whereas scene-related regions (Parahipocampal Place Area - PPA) are biased towards distant stimuli. Participants were presented with Ponzo lines, which create an illusion of depth. In one condition, the stimuli (pictures of objects or houses) appeared in the perceived proximal position. In the second condition, the stimuli appeared in the perceived distal position. In addition, we ran a localizer, which included scenes, objects and scrambled images of objects. We defined for each subject the PPA (Scenes > Objects, p < 10-4, uncorrected) and the LOC (Objects > Scrambled Objects, p < 10-4, uncorrected). Consistent with our hypothesis, we found a double dissociation such that object areas showed a higher response to perceived proximal stimuli than perceived distal stim-

uli, whereas scene-related regions showed a higher response to perceived distal objects than perceived proximal objects. Importantly, this effect was found for both objects and houses. This outcome suggests the plausibility of a distance principle of organization of the ventral visual stream.

F87

NEURAL RESPONSE TO PHYSICAL SIMILARITY TO THE SELF DIFFERS DEPENDING ON THE TRUSTWORTHINESS OF THE OTHER FACE *Sara Verosky[1], Alexander Todorov[1]; [1]Princeton University* – People have been found to self-enhance across a number of domains, including self-face recognition. In order to investigate how this positivity affects the processing of the self-face, we conducted a functional magnetic resonance imaging (fMRI) study examining whether neural response to physical similarity to the self would differ depending on the valence of the face the self was morphed with. We morphed models of participants' faces with novel faces that were either trustworthy or untrustworthy in appearance and we asked them to decide whether each morph looked more like them or more like the other person. Behaviorally, participants were more likely to say the trustworthy as compared to untrustworthy morphs looked like the self. Bilateral inferotemporal cortex, right middle temporal cortex, and right prefrontal cortex all showed an interaction between the linear effect of physical similarity to the self and trustworthiness, responding more strongly as the trustworthy morphs looked more like the self and less strongly as the untrustworthy morphs looked like the self. Increased behavioral discrimination between the trustworthy and untrustworthy morphs of the self was correlated with increased activity to the trustworthy as compared to untrustworthy morphs in the right inferior frontal gyrus (IFG). These findings indicate that trustworthy as compared to untrustworthy faces are seen as more similar to the self and they suggest that the IFG plays a special role in self-representation.

F88

YOU NEED BOTH SIDES OF THE BRAIN TO PROCESS MY BODY *Boris Suchan[1], Denise Minnebusch[1], Martin Busch[2], Dietmar Schulte[3], Dietrich Grönemeyer[2], Silja Vocks[3]; [1]Institute of Cognitive Neuroscience, Neuropsychology, Ruhr-University, Bochum, Germany, [2]University of Witten-Herdecke, Radiology, Germany, [3]Ruhr-University, Clinical Psychology and Psychotherapy, Bochum, Germany* – The extrastriate body area (EBA), a specialised area for body processing is in the focus of research over the last years. By contrasting human bodies and objects, reliable activation can be elicited in a bilateral distributed network covering the lateral EBA and also the medial fusiform body areas (FBA). This organisation is similar to that involved in face processing. We used dynamic causal modelling to get further insight in the organisation and interaction of this network. Different models were estimated and compared using Bayesian statistics. The most likely model suggests bilateral effective connectivity of the EBAs but not FBAs. Detailed results yield evidence for a hemispheric balanced network without any hemispheric lateralisation. Each EBA is effectively connected to its associated FBA unidirectional. Both EBAs show strong effective connectivity with a more pronounced effect of the right onto the left EBA. These results yield strong evidence for balanced effective connectivity within the network involved in body processing. They further suggest parallel networks like used in face processing.

F89

A RUSH TO JUDGMENT *Jonathan Page[1], Laura Aldrich[1], Brandy Baczwaski[1], Laurie Colson[1], Kaley Radermacher[1]; [1]Minnesota State University-Mankato* – Discrimination under time constraints leads to errors in judgment. We looked at this using standard behavioral measures of correct/incorrect responses and reaction times, and using electrophysiological measures of P300 and late positive potential (LPP) waveform components of the event-related potential (ERP). Participants viewed a series of achromatic and colored circles with either vertical (target) or horizontal (standard) stripes in two timing conditions: fast (ITI 800 ms) and slow (ITI 1.6 s). We were specifically interested in error processing and focused our analyses on misses and false alarms. Differences in behavioral responses (RTs) and cortical recordings (P300 and LPP) were found in these conditions and compared. Our results suggest that 'snap' judgments lead to more visual errors, with correlates in neural processing that are evident in both P300 and LPP components of ERP waveforms.

F90

PATTERN ANALYSIS OF CATEGORY-SELECTIVE EXTRASTRIATE CORTICAL ACTIVITY DURING PERCEPTION AND IMAGERY OF SCENES *Matthew Johnson[1], Marcia Johnson[1,2]; [1]Yale University, Interdepartmental Neuroscience Program, [2]Yale University, Psychology* – Reflective processes such as visual mental imagery and visual working memory maintenance can modulate activity in category-selective extrastriate areas of cortex such as the fusiform face area (FFA) and parahippocampal place area (PPA). While it is thought that this activity likely represents a re-instantiation of activity patterns experienced during perception and thus carries information relevant to the identity of the representation in question, relatively few studies have attempted to decode the information represented by reflectively induced activity in such areas. In the present study, participants either viewed (Perceive conditions) or were instructed to form vivid mental images (Image conditions) of four well-learned scene stimuli while being scanned with functional magnetic resonance imaging (fMRI) at a relatively high resolution (2mm x 2mm x 2.5mm voxels). Scene-selective areas of posterior visual association cortex were identified with a separate localizer task, and scene-selective voxels were subjected to several types of pattern analysis to determine whether the spatial pattern of activity in those areas conveyed information about the task being performed (perception versus imagery) and/or the identity of the specific stimulus being perceived or imagined. Preliminary analyses indicate that, even after accounting for overall differences in activation magnitude between the Perceive and Image conditions, activity patterns in PPA and other scene-selective regions still differ depending on the task being performed. Thus far, we have not found patterns that distinguish specific stimuli, but future work will continue to explore the possibility of stimulus-specific activity patterns in category-selective extrastriate cortex during reflective processing.

F91

REORGANIZATION OF ATTENTIONAL NETWORKS WITH CORTICAL DEAFFERENTATION *Keith Main[1], Temilade Adelore[1], Erin Kinzel[1], Leanne Metcalfe[1], Kevin Moloney[1], Vijay Palvia[1], Zane Blanton[1], Susan Primo[2], Julie Jacko[3], Eric Schumacher[1]; [1]Georgia Institute of Technology, [2]Emory University, [3]University of Minnesota* – The visual cortex of the mammalian brain has a topographic relationship with the retina. This relationship can be altered through changes in retinal input (i.e. cortical reorganization). Recent research shows that cortical reorganization occurs in adult humans with macular degeneration (MD), an eye disease that results in the loss of central vision. Baker et al. (2005) reported that activation in the lesion projection zone occurs for MD patients' when visual stimuli are presented to their preferred retinal locations (PRL) (i.e., the intact retinal area used to fixate in place of the diseased macula) (c.f., Schumacher et al., 2008). However, Masuda et al. (2008) showed this finding may be primarily due to attentional feedback, not feed-forward reorganization. Whatever the mechanism, if reorganization does occur, it may not only affect the primary visual cortex but also areas involved in the allocation of spatial attention. MD patients often dramatically alter their oculomotor behavior to accommodate the location of PRLs. Is this change accompanied by a concomitant alteration in attention networks? Using fMRI tasks that have reliably demonstrated activation of attentional networks (Corbetta & Shulman, 2002; Mangun et al. 1998), we show a MD patient with aberrant activity in areas involved in exogenous but not endogenous allocation of attention. This finding suggests a reorganization of attention networks in MD patients, a change that could in-turn influence V1 through top-down feedback.

F92

PREDICTING DISTRIBUTED PATTERNS OF BRAIN ACTIVITY DURING COLOR PERCEPTION *Steven M. Frankland[1], Sharon L. Thompson-Schill[1]; [1]University of Pennsylvania, Center for Cognitive Neuroscience* – Following recent advances in multi-voxel pattern analyses of fmri data (e.g., Mitchell et al. 2008; Kay et al. 2008), we attempted to develop a general predictive model of cortical activity during a color perception task. A computational model learned the relationship between stimulus variance along the axes of different three-dimensional color spaces and variance in BOLD signal in bi-lateral ventral temporal and occipital cortices. Once trained, the model successfully predicted a distributed pattern of activity for previously unseen color categories, not just unseen instances thereof. Moreover, using a spherical searchlight technique (Kriegeskorte et al. 2006), we were able to compare the predictive accuracies of multi-voxel models trained on different color spaces in local brain regions previously implicated in color perception. Along with other recent work, this constitutes an improvement in the attempt to leverage pattern classification analyses of fmri data to understand neural representation. For unlike previous approaches in which binary categories are associated with patterns of brain activity (e.g, Haxby et al., 2001), we can (1) predict a neural signature for entire color categories (e.g., red) that were not included in the training of the model and (2) compare the performance of models trained on different stimulus spaces to evaluate which space descriptions co-vary with neural activity across brain regions.

F93

VIEW INVARIANCE IN MASKED REPETITION PRIMING EFFECTS IS A FUNCTION OF PRIME EXPOSURE *Marianna Eddy[1], Phillip Holcomb[2]; [1]Massachusetts Institute of Technology, [2]Tufts University* – How objects are represented in the brain has been debated for decades. The current experiment provides evidence that achieving viewpoint invariance in priming can depend on the amount of feed-forward processing of the prime. We previously examined event-related potential (ERP) effects of masked repetition priming when the prime object was rotated 30°, 60°, or 150° from the conventional target view. Early perceptual processing, as indicated by the N190/P190 effect, showed invariance to target objects regardless of how much the prime was rotated. However, invariance in a later, higher level component (N400) was only achieved for the 30° rotation condition. One explanation for the lack of invariance on the N400 is not enough time for feed-forward processing to activate a higher level, presumably viewpoint independent representation with a 50 ms prime exposure. The current experiment used the same masked priming paradigm as the previous study, but increased the prime duration to 90 ms. Intact perceptual priming effects (N190/P190) were found for all of the rotation conditions. In addition, N400 effects or trends towards effects were found for all degrees of rotation with increased prime exposure. These results suggest that perceptual information activated during brief (50 ms) prime exposure is not sufficient to produce higher level benefits in target processing when the prime is rotated in depth. However, with increased exposure to the prime, presumably a higher level representation of this object is activated that allows for a benefit in target processing even when the viewpoint of the prime and target differ.

F94

CATEGORIZATION OF ACCUMULATED SENSORY EVIDENCE: A FLEXIBLE LINK BETWEEN DECISION AND ACTION *Marios Philiastides[1], Paul Sajda[2], Hauke Heekeren[1]; [1]Max Planck Institute for Human Development, Neurocognition of Decision Making Group, [2]Columbia University, Biomedical Engineering* – Animal models of perceptual decision-making often include three main processing stages: sensory evidence representation, temporal integration of sensory evidence and evidence categorization, which is often expressed through a motor response. Though this hierarchical model is appealing, the boundaries between the latter two stages, if in fact such discrete stages exist, remain unclear. The problem arises because in monkeys the areas implicated in integrating the sensory evidence are also the ones that select, and execute motor responses. In contrast, recent human neuroimaging studies identified decision-related activity independent of the response modality used, suggesting that humans might have evolved an abstract decision-making network that allows a flexible link between decision and action. To test whether there is a separate categorization stage, we designed an object categorization task using a novel dynamic stimulus to provide accumulating evidence while simultaneously recording EEG data from thirteen subjects. Using single-trial analysis techniques we identified a late, response-locked component, which not only correlated with psychophysical performance but was also a good predictor of the content of a subject's choice. Time-course analysis of the period preceding this component revealed ramp-like activity consistent with evidence accumulation. Source localization places this component in left medial parietal cortex, a region that was shown to communicate with both areas exhibiting accumulator activity as well as premotor and motor cortices. Taken together these results suggest that human perceptual decision-making entails a separate categorization stage, which converts the accumulated evidence into a categorical decision and provides a flexible link between decision and action.

F95

SENSITIVITY TO EMOTIONAL VARIANCE IN A TEXTURE OF FACES *Jason Haberman[1,2], Pegan Lee[1,2], David Whitney[1,2]; [1]UC Davis Center for Mind and Brain, [2]UC Davis, Psychology* – Humans are sensitive to the statistical characteristics of a scene. The visual system efficiently derives a mean representation across multiple dimensions, including low-level features such as dot size (Ariely, 2001; Chong & Treisman, 2003), motion (Alvarez & Oliva, 2008), and oriented gratings (Parkes et al., 2001), as well as high-level features such as faces (Haberman & Whitney, 2007, 2008). We explored whether the visual system represents another kind of high-level summary statistic - variance. After viewing a set of 16 emotionally distinct faces for 2 seconds, observers adjusted a group of test faces to match the variance of the set just displayed. Observers were surprisingly precise in their ability to report emotional variance; they showed a nonlinear dependence on the degree of set variance that resembled a dipper function. Specifically, variance sensitivity improved slightly with increased set variance relative to a homogeneous set of faces, followed by parametrically decreasing sensitivity as variance continued to increase. Dipper functions have been described for many other visual domains, including blur (Watt & Morgan, 1983), contrast discrimination (Nachmias & Sansbury, 1974), and even orientation variance detection in textures (Morgan, Chubb, & Solomon, 2008). To our knowledge, this work is the first of its kind to demonstrate sensitivity to variance in complex objects, and it is interesting to note that the data resemble the dipper pattern found for low-level visual features. This supports the notion that a specialized mechanism for variance detection exists that is adapted to assess crowds of faces.

F96

THE PERCEPTION OF IMPOSSIBLE GESTURES: MEG EVIDENCE *Diogo Almeida[1], David Corina[2], David Poeppel[1]; [1]University of Maryland, College Park, [2]University of California, Davis* – Visual objects and scenes elicit a cascade of responses, the peaks of which have been argued to index different stages in visual processing and differing neuronal selectivity. Here we test, using MEG, the response properties of a novel stimulus crafted to test gesture and sign (possible versus anatomically impossible arm/hand configurations) and compare the evoked field to the well-known cortical signals driven by faces (e.g. M130, M170). American Sign Language signs were edited to become physically impossible gestures. Participants (n=17, ASL naïve) were asked to judge whether each stimulus (static presentation) was a physically possible gesture while undergoing MEG. Passive viewing of upright or inverted emotionally neutral faces was used as a control task. MEG data from the same posterior sources that best capture the M170 for faces show that no effect

of gesture anomaly was observed in the M170. However, anomalous gestures elicited higher amplitudes 600-1200ms post stimulus onset in the left hemisphere and 400-1000ms post stimulus onset in the right hemisphere. Compared to the control (faces), (i) at 130ms (M130), gestures elicited higher amplitudes (ii) at 190ms (M170), gestures elicited later and more attenuated amplitudes and (iii) from 250ms onwards, gestures elicited higher amplitudes (bilaterally, in all cases). We conclude that detection of specific kinds of visual information is structured in early perceptual processes, but detection of configural anomaly involves both early (more transient) and later (more extended) perceptual processes. We are currently collecting data from ASL users to investigate how lexical knowledge interacts with gesture anomaly detection.

F97

NEURAL CONNECTIVITY OF EXPERIENCED VISUAL INFORMATION *Anthony Herdman[1], John Gaspar[1]; [1]Simon Fraser University, Psychology* – We will present our findings on the neural connectivity within a network used for orthographic perception. We applied phase-coherence analysis methods to magnetoencephalographic data collected during a letter/nonletter judgement task. Phase-locking values between source waveforms for predefined frequency bands identified the connectivity amongst brain regions responsible for detecting experienced (letters) from inexperienced (nonletters) stimuli. Significantly larger phase-locking to letter than nonletter stimuli occurred in the theta band (3-8 Hz) amongst visual areas at about 140 ms. However, there was a stronger theta phase-coherence between right occipital and left inferior frontal sources around this time for nonletter than letter stimuli. In the alpha band (8-13 Hz) larger phase coherences occurred in visual cortices similar to the theta band and likely reflect differences in synchronous activity of the evoked visual responses. There was generally a greater alpha desynchronization in visual cortices that occurred around 250 ms and persisted longer for nonletter than letter stimuli. These results might indicate that more processing is required for nonletter stimuli in order to rule out all possible perceptual hypotheses that the nonletter could be a letter. Our results will be presented in the context that functional connectivity of the visual network is altered by experience with visual stimuli in order to allow for rapid identification as compared to novel/inexperienced stimuli, such as nonletters.

F98

EVENT-RELATED FMRI OF INTEGRAL AND SEPARABLE DIMENSIONS IN SIMPLE VISUAL OBJECTS *Anthony Cate[1], Xiaojiang Kang[1,2], Timothy Herron[1], David Woods[1,2,3,4]; [1]Veterans Administration Northern California Health Care System, [2]UC Davis, Neurology, [3]UC Davis, Center for Neuroscience, [4]UC Davis, Center for Mind and Brain* – This study tested the hypothesis that different regions in both ventral and dorsal extrastriate visual cortex encode information about the size and shape of simple visual objects. Event-related fMRI responses were measured to pairs of briefly-presented shapes taken from a set of 5 simple rectangles that varied parametrically in width and height. Stimuli were presented in a counterbalanced sequence that included baseline fixation trials. Trials were binned according to the pattern of dimensional change in the stimulus pair. After participants' cerebral hemispheres were inflated and normalized to a cortical surface curvature template using FreeSurfer, analyses distinguished voxels sensitive to changes in the integral object dimensions of aspect ratio and surface area, as well as to changes in width and height. Contrasts were performed to identify visual regions that showed greater BOLD responses to changes in aspect ratio (shape) than to changes in area and vice versa, and regions were characterized in terms of the degree to which they responded to changes in width and height as integral or separable dimensions. Voxels sensitive to aspect ratio changes were identified in the medial fusiform gyrus, and voxels sensitive to surface area changes were found in the posterior parahippocampal gyrus. Subregions of the posterior parietal cortex were also found to be sensitive to both criteria as well. This study shows that the functional specificity of extrastriate visual areas, including regions that are typically selective for images of complex objects, can be characterized in terms of basic modes information-processing using simple shapes.

F99

HIGHER-LEVEL VISUAL AREAS ENCODE PERCEIVED OBJECT POSITION *Jason Fischer[1], David Whitney[1]; [1]University of California, Davis; Center for Mind and Brain, Psychology* – Beyond early retinotopic cortex, the human visual system contains a host of higher-level, specialized regions, selectively tuned to stimuli such as motion and optic flow (MT+), faces (FFA), objects (LOC), and scenes (PPA). While these areas can be reliably parceled on the basis of stimulus preference, their other functional properties such as the precision and nature of position coding are not well understood. Specifically, while retinotopy and center-periphery biases have been reported in some of these areas, it is possible that additional sources of information such as head and eye position also influence position coding at higher stages in the visual processing hierarchy. In the present study, we tested the degree to which activity in higher-level visual areas reflects perceived versus retinal stimulus position. In an fMRI experiment, subjects performed a 5AFC position discrimination task; we dissociated retinal and perceived stimulus position by analyzing the trials in which subjects misreported the positions of the stimuli. Using a multivariate pattern analysis to track the coupling of the BOLD response with parametric stimulus changes, we found that activity in areas MT+, FFA, PPA, LO, and pFs reflects perceived object position significantly more precisely than it reflects retinal position. Early visual areas, on the other hand, preferentially coded the physical positions of the stimuli. Our results demonstrate that position coding in higher-level visual areas incorporates extra-retinal information, and more closely reflects the position in which we perceive an object than the position in which it falls on the retina.

F100

TEMPORAL-NASAL ASYMMETRY OF THE N170 RESPONSES TO FACE-LIKE PATTERNS IN THE VISUAL PERIPHERY *Przemyslaw Tomalski[1], Gergely Csibra[1,2], Mark H. Johnson[1]; [1]Centre for Brain and Cognitive Development, Birkbeck, University of London, UK, [2]Central European University, Philosophy, Budapest, Hungary* – Newborns and adults alike show preferential orienting towards upright schematic face (Config stimulus - white oval with three black dots), an effect suggested to be mediated by the superior colliculus and the retinotectal visual pathway. We investigated whether the N170, a face-sensitive ERP component indexing face detection, is modulated by the contrast polarity and orientation of Config stimuli and whether it shows the temporal-nasal hemifield asymmetry. In two experiments participants passively observed upright or inverted Config stimuli with normal or reversed contrast polarity, while monitoring the central fixation stimulus. In Experiment 1, the contrast polarity and orientation of face-like patterns presented in the fovea were found to interact, modulating the N170 in a face-typical manner. It peaked earlier and was less negative to upright positive polarity than to inverted or/and negative polarity stimuli. In Experiment 2, the influences of the retinotectal pathway on this effect were tested by presenting the stimuli monocularly to either the temporal or the nasal visual field. The temporal/nasal hemifield factor influenced the modulation of the N170 amplitude by both contrast polarity and orientation. The N170 peaked earlier in response to stimuli presented in the temporal than in the nasal visual field. Our results are consistent with the existence of a low-level, subcortical, face-biasing mechanism that facilitates rapid detection of faces and face-like stimuli. The visual input to the superior colliculus appears to modulate the activity of cortical face processing areas, which generate the N170 component.

F101

RELATING NEURAL OBJECT REPRESENTATIONS TO PERCEPTUAL JUDGMENTS WITH REPRESENTATIONAL SIMILARITY ANALYSIS *Marieke Mur[1,2], Mirjam Meys[1,2], Jerzy Bodurka[1,3], Peter Bandettini[1,3], Nikolaus Kriegeskorte[1]; [1]Section on Functional*

Imaging Methods, Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, Bethesda, MD, [2]Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University, Maastricht, The Netherlands, [3]Functional Magnetic Resonance Imaging Facility, National Institute of Mental Health, National Institutes of Health, Bethesda, MD – Human inferior temporal cortex (hIT) has been shown to be involved in the representation of visual objects. Recent studies have begun to investigate the relationship between perceived object similarity and similarity of response patterns in hIT. These studies often used a small set of (novel) stimuli from a few a priori defined categories. Here, we use a stimulus set consisting of 96 object images from a wide range of object categories including faces, body parts, animals, places, and artificial objects. We compare the neural and perceptual similarity structure of these 96 object images using representational similarity analysis. We performed BOLD fMRI measurements at high resolution (voxel size 1.95x1.95x2 mm3). Activity in response to 96 different object photos was measured in four subjects. hIT was defined at a range of sizes by selecting the most visually responsive voxels, based on independent data. The neural similarity structure of hIT response patterns was constructed by computing the dissimilarity (1-correlation distance) between each pair of object activity patterns. Subjects were asked to arrange the 96 object images in 2D to report perceptual similarity. The neural and perceptual similarity structures were significantly correlated ($r = 0.46$, $p < 0.0001$). This indicates that objects that are perceived as similar tend to elicit similar response patterns in hIT. In addition, both structures showed a categorical organization, with the main clusters being animate and inanimate objects. These findings suggest that, for a wide range of real-world objects, similarity of neural object representations in hIT reflects perceived object similarity.

F102

VISUAL TRAFFIC JAMS: CROWDING OF TWO-TONE CARS

Amrita Puri[1], Faraz Farzin[1,2], David Whitney[1,2]; [1]Center for Mind and Brain, University of California, Davis, [2]University of California, Psychology, Davis – Crowding refers to the increased difficulty in perceiving non-foveal objects when they are flanked by other objects. This phenomenon is typically explored using stimuli that can be readily segmented into parts or features; it is thought that when too closely spaced, interference between these low-level features contributes to crowding. Recent work using Mooney faces, two-tone images lacking discernable features, demonstrates that crowding can also occur selectively between higher-level, holistic representations (Farzin et al., under review). Here, we tested whether crowding occurs for non-face objects containing little or no low-level information that would support part-based recognition. Participants fixated a small square while a two-tone, Mooney-like car photograph briefly flashed at varying eccentricities either with (crowded) or without (uncrowded) flanker cars, and reported whether the orientation of the target car was to the right or left. Discrimination accuracy decreased with increasing eccentricity and with flanker presence, but was unaffected by flankers at the fovea, consistent with a between-object crowding account. However, when participants were separately shown an uncrowded two-tone car of varying size, performance increased with image size at all non-foveal eccentricities, with the magnitude of the required scaling factors suggesting an additional contribution of within-object crowding. The results suggest that crowding occurs both within and between objects.

F103

VISUAL AGNOSIA, A DEFICIT IN TEMPORAL VISUAL INFORMATION PROCESSING?

Maarten van der Smagt[1], Susan te Pas[1], Tanja Nijboer[1]; [1]Experimental Psychology, Helmholtz Institute & Utrecht University – Visual agnosia is generally defined as the loss of ability to identify, name and/or recognize objects, faces shapes, colors or even brightness (i.e. an impairment of detailed visual knowledge), despite intact (low-level) visual perception and memory functions. Here we tested two patients, one with color agnosia and one with brightness agnosia, on a task that required the detection of gradual changes in color and brightness of a 5 degree disc, presented on a CRT. The colored disc changed every 33 ms in chromaticity along one of three different MacAdam ellipses in color space (200 equal steps per revolution), while keeping the luminance constant. The achromatic disc increased and decreased every 33 ms linearly in luminance between 10 and 55 cd/m2 (in 100 steps). Results for these patients, who showed average or above average performance on several tasks designed to test low-level color and luminance (contrast) perception, yielded a double dissociation. The brightness agnosic patient was within normal range for the colored disc but much slower to detect brightness differences, whereas the color agnosic patient was within normal range for the achromatic disc, but much slower for the colored disc (often needing multiple revolutions around the ellipses before detecting a change). Interestingly, a control patient with achromatopsia was also within normal range on the colored disc. Despite the general agreement that low-level visual functions must be intact in agnosia, these results suggest that a modality specific impairment in the detection of gradual changes might underlie the phenomenon of visual agnosia.

Poster Session G

Emotion

G1

UNIVERSAL AND CULTURALLY-SPECIFIC NEURAL BASIS OF INGROUP BIAS IN EMPATHY *Bobby K. Cheon[1], Dong-Mi Im[2], Tokiko Harada[1], Vani A. Mathur[1], Jason Scimeca[1], Hyun-Wook Park[2], Joan Y. Chiao[1,3]; [1]Northwestern University, Psychology, [2]Korea Advanced Institute of Science and Technology, [3]Northwestern Interdepartmental Neuroscience Program* – Empathy, the capacity to understand and share the emotional states of others, is associated with neural response primarily within bilateral insula and anterior cingulate cortex. Both individuals and culture groups vary in the degree to which they show greater empathy for the suffering of their own group members. Here we examined the universal and culturally-specific neural bases of ingroup biases in empathy. Using cross-cultural neuroimaging at 3T, we measured neural activity in native Korean and Cauasian-American participants while they viewed images of either ingroup or outgroup members in either painful or neutral situations. All participants showed greater neural activity in cortical midline structures, such as the medial prefrontal cortex (MPFC) and posterior cingulate cortex (PCC), to ingroup relative to outgroup pain. Additionally, Caucasian-American participants compared to native Korean participants showed greater right parahippocampal and bilateral fusiform activity in response to ingroup pain. By contrast, Korean participants relative to Caucasian-American participants showed greater MPFC, PCC and left insula response to ingroup pain relative to outgroup pain. Taken together, these findings indicate that ingroup biases in empathic reactions share similar neural substrates across cultures, yet the distress of ingroup members may elicit distinct cognitive and affective responses between cultures.

G2

NEURAL AND BEHAVIORAL CORRELATES UNDERLYING EMOTION REGULATION OF RISKY DECISION-MAKING *Laura N. Martin[1], Mauricio R. Delgado[1]; [1]Rutgers University* – Decisions are often influenced by one's emotional state, at times leading to maladaptive behaviors. The positive emotional state induced by the expectation of winning the lottery, for example, may tempt an individual to spend excessively for a chance at the jackpot. Thus, it is important to understand how to better control emotional responses to affective stimuli present in society. It is plausible that effective cognitive control, achieved by antecedent focused emotion regulation strategies, can diminish the impact of positive emotions and promote goal-directed behavior. The current study tested whether the benefits of emotion regulation would extend beyond emotional experience to subsequent decision-making. Participants in the scanner were presented with a picture representing a choice between potential monetary rewards. While viewing the picture, participants were cued to respond naturally (Look condition), increase (Excite regulation condition) or decrease their excitement (Relax regulation condition). In the Excite and Relax regulation conditions, participants altered their emotions by imagining exciting (e.g., riding roller coasters) or relaxing (e.g., napping on the beach) scenes, respectively. After the picture presentation, participants faced a choice between a gamble (e.g., 50% chance of winning $12) and a sure thing (e.g., 100% chance of winning $6). Participants gambled less during the Relax condition (compared to Look or Excite) consistent with the hypothesis that decreases in positive emotion can promote better decision-making. Moreover, this effect was stronger in female subjects. Future analysis will focus on the neural basis underlying the successful regulation of positive emotions probing the role of cortico-basal ganglia circuits.

G4

NEURAL CORRELATES FOR PROCESSING BIOLOGICAL AND SOCIAL EMOTIONAL STIMULI *Michiko Sakaki[1,2,3], Kazuhisa Niki[1]; [1]National Institute of Advanced Industrial Science and Technology, [2]Japan Society for the Promotion of Science, [3]University of Southern California* – Emotions often promote individual survival or reproduction by directing behaviors to biologically significant stimuli (e.g., food; dead animals), while they also contribute to social adaptation by directing behaviors to socially significant stimuli (e.g., emotional faces) (Britton, et al. 2006). The present study aimed to examine the neural substrates associated with processing biological and social emotional stimuli. By using photographs and words, we also addressed whether emotional pictorial materials and verbal materials recruit similar neural substrates or not. In the scanning session, sixteen participants were presented with either a photograph or a word, both of which were manipulated in terms of stimulus type (biological, social, neutral, and nonsense), and they rated each item for whether they liked it or not. The results revealed that social emotional pictures and social emotional words produced activity in similar brain regions, such as the posterior cingulate, the left superior frontal gyrus, and the bilateral occipitotemporal gyri. In contrast, biological emotional words produced activity in different brain regions from biological emotional pictures. In other words, biological emotional pictures induced activity in the bilateral thalamus, the midbrain, and the left amygdala, whereas biological emotional words did not produce activity in any of these regions. These results suggest (a) the involvement of the subcortical regions in processing biological emotional pictures, (b) the involvement of cortical regions in processing social emotional materials, and (c) the larger stimulus type effects (verbal vs. pictorial) for biological emotional stimuli than for social ones.

G5

ATTENTION ORIENTATION IN ADULTS AND CHILDREN EXPOSED TO TRAUMA *Kara Lindstrom[1,2,3], Jennifer Britton[1], Karin Mogg[4], Brendan Bradley[4], Monique Ernst[1], Christina Hoven[5], Yair Bar-Haim[6], Daniel Pine[1]; [1]SDAN/NIMH/NIH, [2]Clinical Neuroscience/Karolinska Institutet, [3]Stockholm Brain Institute, [4]Southampton University, Psychology, [5]Child Psychiatric Epidemiology Group, Columbia University, [6]Tel Aviv University, Psychology* – After witnessing a traumatic event, people may have a higher risk of developing an anxiety disorder. Some individuals with anxiety disorders show an abnormal attention orientation to threat; thus, attention biases towards threat may be present in individuals exposed to a traumatic event. The dot-probe task, an attention orientation paradigm, was administered to assess attention bias towards or away from an emotional cue (happy or angry face) in parents and children (age 9-15) exposed to the World Trade Center (WTC) attack on September 11th, 2001 and control subjects. Compared to parents with low exposure to events of September 11th, highly exposed parents show greater attention bias towards angry faces. When the parent was evacuated from WTC, the evacuated parents have an increased threat bias compared with non-evacuated parents. The children of evacuated parents show a lack of a happy bias when compared with children of non-evacuated parents. These findings explore the effect of witnessing a traumatic event on psychiatric assessment and attention orientation.

G6

AFFECTIVE CONSEQUENCES OF PRODUCING SEQUENCED MOTOR RESPONSES *Amy Hayes[1], Ian Glasscock[1]; [1]Bangor University, Wales, UK* – Past research has shown that when items are more fluently perceived or acted upon, they are liked more (e.g. Hayes, Paul, Beuger &

Tipper, 2008; Reber, Winkielman & Schwarz, 1998). Winkielman & Cacioppo's (2001) hedonic fluency model proposes that sensitivity to processing fluency influences positive (but not negative) affect, and that the affect provides information about the environment and may serve as a reward mechanism for facilitating performance. Here we used a serial response time task to investigate whether producing sequenced motor responses evokes positive affect. In each trial a tone or visual target called for a speeded response from the subject (pressing a button to the tone; "tagging" the location of the visual target.) In some blocks of trials, the sequence of responses to the tones and visual targets followed a fixed sequence; in other blocks the sequence of responses was pseudorandom. Subjects were not informed about the sequence manipulation. After each block of trials, subjects rated on a visual scale their positive and negative affect, and their sense of how effortful the previous block had been. Sequenced blocks were rated as less effortful, and consistent with the hedonic fluency model positive affect was elevated following sequenced blocks but negative affect was not influenced by the sequence manipulation. These results did not interact with a grouping factor that classified subjects as aware or not aware of the sequence, based on post-experiment interview. However, additional research is needed to determine how awareness and affect interact when learning sequenced behaviour.

G7

MEG MEASUREMENT OF FACIAL EMOTION RECOGNITION ABILITIES IN TEMPORAL LOBE EPILEPSY *Maria I. Ventura[1], Adeeti Ullal[2], Srikantan S. Nagarajan[1], Heidi E. Kirsch[3]; [1]University of California, San Francisco, Radiology, [2]Harvard-MIT Health Sciences and Technology, [3]University of California, San Francisco, Neurology* – Because temporal lobe epilepsy (TLE) may affect the function of structures involved in social cognition, there is an increasing need to understand social cognitive deficits, such as impaired facial emotion recognition, in TLE. We investigated this phenomenon using magnetoencephalography (MEG). Subjects with TLE and controls performed a facial emotion discrimination task (happy vs. sad faces) and a non-emotional discrimination task (face vs. non-face). We examined the M170 response, suspected to be a face-selective component of the neural response. Root mean square (RMS) analysis of the M170 revealed significant intergroup differences: subjects with left TLE had smaller amplitudes and delayed latencies compared to those with right TLE and to controls in the emotional discrimination task. Subjects with TLE also performed poorly on a validated test of facial emotion recognition (CATS) compared to normal controls, with left TLE subjects performing worse than those with right TLE. Exploratory time frequency source localization of brain activity during both emotion and non-emotion face tasks reveals that the activation pattern extrastriate visual cortex, including the fusiform face area, does not differ from that of controls. Neurophysiological and behavioral data show deficits in facial emotion recognition in subjects with TLE which may depend on laterality of seizure focus. Exploratory analysis of cortical activation, as indexed by task-evoked frequency changes in MEG data, suggest that this deficit is not apparent at the level of extrastriate visual cortex and might instead be due to disruption of downstream processing, e.g. in temporal structures affected by the subjects' epilepsy.

G8

BEHAVIORALLY MODIFYING FEAR MEMORY: EXTINCTION LEARNING DURING RECONSOLIDATION BLOCKS RECOVERY OF FEAR IN HUMANS *Candace M. Raio[1], David C. Johnson[1], Marie-H. Monfils[2], Daniela Schiller[1,2], Joseph E. LeDoux[2], Elizabeth A. Phelps[1,2]; [1]New York University, Psychology, New York, NY, [2]Center for Neural Science, New York University, New York, NY* – Evidence suggests that consolidated memories, once retrieved, enter a time dependent lability period before re-stabilizing (i.e., reconsolidation). Although non-human animal studies have successfully altered memories by pharmacologically targeting the neurobiological mechanisms underlying reconsolidation, these results are problematic to replicate in humans, due to the invasive nature and side effects of drug manipulations. A novel drug-free behavioral protocol in rats demonstrated that fear memories were attenuated when extinction training occurred during reconsolidation. Our aim was to extend these findings to humans and further examine the specificity of this effect. In Experiment 1, fear conditioned subjects underwent either standard extinction or extinction preceded by reactivation of the fear-eliciting cue 10 minutes or 6 hours beforehand. There was no spontaneous recovery when extinction training occurred within the reconsolidation window (10 minutes post-retrieval). However, extinction outside this window (6 hours post-retrieval), or extinction without retrieval, allowed for spontaneous recovery of fear. In Experiment 2, we aimed to selectively target one fear memory while leaving another intact. Subjects were fear conditioned to two cues and underwent extinction whereby only one cue was reminded 10 minutes before extinction. A day later, subjects showed reinstatement of fear only to the cue that was not reminded before extinction. These data suggest that specific fear memories can be persistently modified when extinction training occurs within the reconsolidation window of a retrieved fear memory. These findings have significant clinical implications for the treatment of anxiety disorders such as Post Traumatic Stress Disorder, by targeting the intrusive memories that afflict patients.

G9

EFFECT OF DOPAMINE REGULATING GENES (DAT1 & COMT) ON LOGICAL REASONING WITH EMOTIONAL CONTENT *Melanie Stollstorff[1], Stephanie Bean[1], Lindsay Anderson[1], Chandan Vaidya[1,2]; [1]Georgetown University, [2]Children's National Medical Center* – Variation in dopamine (DA) regulating genes influences performance on cognitive tasks, such as working memory, and have also been shown to influence affective processing. Both working memory and affective processing are important during logical reasoning in real life under emotionally charged circumstances. How variation in DA modulation influences logical reasoning with emotional and non-emotional content is unknown. We investigated the effect of the catechol-o-methyltransferase gene (COMT) and the dopamine transporter gene (DAT1) on emotional and non-emotional reasoning in healthy adults. Participants were grouped according to DAT1 (9/10 or 10/10) and COMT (Met/Met, Met/Val, Val/Val) genotypes. The reasoning task included syllogisms with emotional and non-emotional content. Results indicated that regardless of genotype, accuracy was lower on emotional than non-emotional syllogisms. A task by DAT1 interaction showed that accuracy was lower in DAT1 9/10 than 10/10 subjects on emotional reasoning but did not differ for non-emotional reasoning. A task by COMT interaction showed that accuracy was lower in the COMT Met/Met than Val subjects on emotional reasoning but did not differ for non-emotional reasoning. Thus, inheritance of DAT1 10-repeat allele and COMT Val allele was beneficial for emotional reasoning.

G10

ELECTROPHYSIOLOGICAL CORRELATES OF MORAL PROCESSING: AN EVENT RELATED POTENTIAL STUDY *Carla L. Harenski[1], Alek G. Chakroff[1], Matthew S. Shane[1], Kent A. Kiehl[1,2]; [1]The MIND Research Network, Albuquerque, NM, [2]University of New Mexico, Psychology and Neuroscience, Albuquerque, NM* – Several theories regarding moral decision making have emphasized the role of fast, automatic responses to moral stimuli in the decision making process (e.g., Haidt, 2001; Pizarro & Bloom, 2003). Although most studies examining the neural mechanisms of moral processing to date have utilized functional magnetic resonance imaging (fMRI), the superior temporal resolution of other imaging techniques, such as event-related potentials (ERPs), may help identify neural markers underlying the early detection of morally salient information. The goal of the current study was to investigate whether neural responses to moral stimuli could be differentiated from those to non-moral stimuli within the first 1000 ms of processing. ERPs were recorded while fourteen healthy participants viewed 100 unpleasant social scenes, 50 of which contained moral violations (e.g. an abusive situation), and 50 which did not (e.g. an argument), and 50 neutral pictures (e.g. a conversation). The task was to identify whether each picture

occurred indoors or outdoors. Moral and non-moral pictures were matched on emotional arousal. ERPs elicited by moral pictures showed an increased frontal positivity relative to non-moral and neutral pictures, peaking within the 220-300 ms time window. The larger frontal positivity may reflect automatic selective attention to intrinsically-relevant objects within images (Schupp et al., 2004). This suggests that the differentiation between moral and non-moral conditions may represent the fast, automatic detection of morally salient information within a social context.

G11

MULTIMODAL INTEGRATION OF EMOTIONAL SIGNALS *Raliza Stoyanova[1], Anthony Cox[1], Andy Calder[1]; [1]MRC Cognition and Brain Sciences Unit, Cambridge, UK* – Although multiple sensory inputs are involved in the assessment of emotional context, little is known about the nature of these multimodal interactions. Most research in this area has addressed the effect of congruency between concurrently presented faces and voices on emotional categorization of either of these channels. However, it remains unclear whether these congruency effects are confined to naturalistic pairings of human emotional signals (i.e., faces/voices, bodies/voices) or extend to other semantically related, emotional pairings. To address this question, in one experiment, we examined the effect of unattended fear, disgust and neutral vocalizations on the speeded categorization of simultaneously presented fear and disgust-evoking scenes. In another experiment, we examined the opposite effect. The data revealed that when participants had to categorize emotional voices, congruent images facilitated response latency while incongruent images led to response slowing and poorer accuracy, relative to neutral. By contrast, fear voices facilitated the speed of categorizing both types of negative emotional images, with a similar trend for disgust voices. Considered together, these data indicate that the interaction between semantically related emotional images and voices is consistent with a categorical account of emotion such that fear images specifically facilitate the recognition of fear voices and slow the recognition of disgust voices and vice-versa for disgust images. However, unlike with more naturalistic, spatially congruent pairs of stimuli such as faces and voices, this effect is not bi-directional.

G12

BEAUTY IS IN THE EAR OF THE REMEMBERER: THE EFFECTS OF MEMORY ON MUSIC PREFERENCES *Daniel Meegan[1], Christopher Warren[2]; [1]University of Guelph, [2]University of Victoria* – As with many stimuli, melodies tend to be judged more favorably following previous exposure. Fluency explanations for this 'mere exposure effect' suggest that it occurs because 'old' (i.e., perceptually-identical or conceptually-similar to previous stimuli) stimuli are processed with more fluency, and the experience that accompanies this fluency leads to a positive bias on tasks requiring an affective judgment about the stimuli. Evidence supporting a causal relationship between fluency and judgment bias is indirect, however. We report an experiment designed to directly test this hypothesis by manipulating the degree to which previously exposed stimuli could be processed fluently. The high fluency condition presented melodies composed in a familiar key and the low fluency condition presented melodies composed in an unfamiliar key. As predicted by the fluency hypothesis, likability judgments were affected by previous exposure only for the high fluency condition. At CNS 2008, we reported a parallel finding in which attractiveness judgments of inverted faces (the low fluency condition) were not affected by exposure. That presentation was received with questions about whether sufficient experience processing such disfluent stimuli (e.g., inverted faces or unfamiliar key melodies) would enable fluent processing and hence normal exposure effects. To address this question, we provided preliminary listening experience with music composed in an unfamiliar key. Later, we found that melodies constructed in this no-longer-unfamiliar key were responded to more positively following exposure.

G13

NEURAL CORRELATES OF REAPPRAISAL SUCCESS DEPEND ON INTENSITY OF EMOTIONAL RESPONSE *Jennifer A. Silvers[1], Jochen Weber[1], Tor D. Wager[1], Brent L. Hughes[1], Matthew L. Davidson[1], Kevin N. Ochsner[1]; [1]Columbia University* – The ability to regulate one's emotions is critical to physical and emotional well-being. One of the most effective strategies for modulating emotional responses is cognitive reappraisal. While some studies have examined what reappraisal-related neural activity predicts successful regulation of negative emotion, none have investigated whether this activity varies according to the intensity of one's emotional response. In the present study, we investigated how the intensity of emotional response may impact what brain regions are associated with reappraisal success. Twenty-six healthy adults participated in an event-related fMRI paradigm. On each trial, participants were presented with a negative or neutral picture and were instructed either to reappraise ("reappraise" trials) or respond naturally ("look" trials) to the stimulus. At the end of each trial, participants rated their current level of negative affect. These ratings were used to categorize negative pictures as eliciting responses with "high" or "low" affective intensity. Reappraise > look contrasts for high and low negative stimuli were created and correlated with their respective reappraisal success scores, calculated as the drop in negative affect due to reappraisal (i.e., look-reappraise affect rating difference). For both high and low negative stimuli, reappraisal success was positively correlated with enhanced activity during reappraisal in the ventromedial prefrontal cortex and the perigenual anterior cingulate cortex. However, successful reappraisal of highly negative stimuli was uniquely correlated with enhanced reappraisal-related activity in the ventrolateral prefrontal cortex. These findings suggest that reappraisal of high and low intensity negative stimuli may rely on both overlapping and distinct regions.

G14

EMOTIONAL PROCESSES IN BORDERLINE PERSONALITY TRAITS: AN FMRI STUDY *Chia-Hsin Chuang[1], June Hung[1], Rou-Shayn Chen[1], Ying-Zu Huang[1], Chin-Song Lu[1], Yau-Yau Wai[2], Jiun-Jie Wang[2]; [1]Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Neurology, Taiwan, [2]Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Radiology, Taiwan* – Previous neuroimaging studies showed that the emotional gateway in the brain, the amygdala, is overly active in patients with BPD. However, it remains unclear whether such dysfunctional emotional processes in the brain occur exclusively in BPD or not. Specifically, if cerebral emotional processes foster the development of BPD, one may expect to see similar dysregulation in emotional processes even in individuals who have borderline personality traits (i.e. those meeting less than five out of nine diagnosis criteria of BPD). To test this hypothesis, we used fMRI to examine the neural correlates of emotional processes in 6 females with borderline personality traits and 6 controls. Participants were scanned while viewing the same set of emotional pictures from the International Affective Picture System (IAPS) and, in different blocks, making a forced-choice response regarding arousal (aroused or unaroused) or pleasure (pleasant or unpleasant). The responses were collected to create an individualized mixed blocked/event-related design. Our results showed that, for individual with borderline personality traits, appraisal on emotional arousal is associated with lateralized medial frontal activation, whereas appraisal on pleasure is associated with lateralized amygdala activation. Our study supports the idea that emotional dysregulation should be regarded as a fundamental cerebral process underlying both BPD and borderline personality traits.

G15

NEURAL CORRELATES OF MUSIC-EVOKED NOSTALGIA *Frederick Barrett[2], Petr Janata[2]; [1]University of California, Psychology, Davis, [2]Center for Mind and Brain, University of California, Davis* – Nostalgia is an emotionally rich experience, characterized by experience of both positive and negative emotions, and socially-themed autobiographical memories.

Music is a common and powerful evocateur of both nostalgic and non-nostalgic autobiographical memories. Investigation of music-evoked nostalgia may provide unique insight into the neural basis of emotional experience during memory recall. In this study, we used popular music to evoke nostalgic and non-nostalgic autobiographical experiences, and differentiated activation related to increased nostalgia and activation related to more general autobiographical memory recall. Thirty 20s samples of popular music were randomly selected and presented to 12 participants (4 M), while blood oxygen level dependent (BOLD) signal was recorded. Orthogonal parametric regressors, constructed from nostalgia, happiness, sadness, arousal, song familiarity and autobiographical salience ratings obtained immediately after each song, were entered into a general linear model predicting BOLD signal. Individual and group-level T-contrasts were calculated for each parametric regressor. Contrasts at the individual level showed wide variation in the focus and extent of activations correlated with each parametric regressor. Group-level contrasts showed both increased activation of medial prefrontal cortex (MPFC) and increased activation of left-lateralized dorsolateral prefrontal cortex (LDLPFC) to be positively correlated with increased strength of nostalgia. Group-level contrasts also showed increased activation in LDLPFC to be positively correlated with increased autobiographical salience. These findings are consistent with literature showing LDLPFC activation during autobiographical memory recall, and suggest that MPFC activation is involved in the recall of emotionally rich nostalgic memories.

G16

EMOTIONAL RESPONSES TO MUSIC AND THE REWARD SYSTEM: AN INVESTIGATION WITH [11C]RACLOPRIDE PET, FMRI, AND PSYCHOPHYSIOLOGICAL METHODS *Valorie N. Salimpoor[1,2], Mitchel Benovoy[1], Gregory Longo[1], Alain Dagher[1,2], Jeremy Cooperstock[1], Robert J. Zatorre[1,2]; [1]McGill University, [2]Montreal Neurological Institute* – The ability of music to incite intensely positive affective states has led to the speculation that it may involve the dopamine reward system. Previous neuroimaging studies have been limited to showing only correlations in blood flow or oxygenation to striatal regions of the brain during music listening, but a direct connection has not been demonstrated. This study involved an innovative combination of techniques to assess the direct links between music and the dopamine reward system: (1) psychophysiological measurements of biosignals (including heart rate, respiration, skin conductance, blood volume, and body temperature) to characterize intense autonomic nervous system responses, (2) fMRI to assess blood oxygenation to striatal regions, and (3) PET scanning using [C11]raclopride as a radioligand to measure dopamine binding activity in striatal regions. Self-selected music was used as stimuli to ensure subjectively pleasurable responses, and the chills phenomenon was used to characterize intense affective states. Baseline control stimuli were individually selected for each participant from other participants' musical selections based on low ratings on pleasure and intensity of affective states. Thus, each piece of music was used once as control and once as experimental stimuli. Results demonstrated both blood oxygenation and dopaminergic activity in the striatal regions (nucleus accumbens, caudate, and putamen) of the brain, allowing for conclusive evidence of dopamine reward system involvement. This study has important implications for understanding the role of the dopamine reward system as music is not a biological reward with survival value (c.f. food) nor does it have an exogenous basis (c.f. drugs).

G17

WHY REGULATION FAILS: ANTICIPATORY PREFRONTAL CORTEX ACTIVITY PREDICTS INCREASED AMYGDALA ACTIVITY AND REDUCED REAPPRAISAL SUCCESS *Bryan Denny[1], Kevin Ochsner[1], Jochen Weber[1], Matthew Davidson[1], Brent Hughes[1], Tor Wager[1]; [1]Columbia University* – We examined how one prepares to engage in reappraisal, which is an emotion regulation strategy that involves the cognitive reinterpretation of an emotion-inducing stimulus. In this study, participants completed 3 within-subject conditions: Reappraise a negative image (Reapp Neg), respond naturally to a negative image (Look Neg), and respond naturally to a neutral image (Look Neutral). Each trial contained a cue period (signifying the condition), an anticipation period, a stimulus period, and a negative affect rating period. Participants reported significantly less negative affect in the Reapp Neg condition relative to the Look Neg condition, and the magnitude of this drop served as our measure of reappraisal success. Amygdala activity during a contrast of Reapp Neg-Look Neg trials during the stimulus period was shown to be negatively correlated with reappraisal success. We used novel mediation analyses to determine whether anticipatory activity predicted reappraisal success via changes in amygdala activity during stimulus presentation. We found that activity in the medial prefrontal cortex (MPFC) during cue and anticipation was positively correlated with amygdala activity during stimulus presentation. Further, amygdala activity during stimulus presentation mediated a negative correlation between anticipatory MPFC activity and reappraisal success. This positive relationship between anticipatory MPFC activity and stimulus-related amygdala activity was itself mediated by stimulus-related precuneus and brainstem activation. These results suggest that more MPFC activity during reappraisal anticipation is associated with less reappraisal success, in contrast to MPFC activity during reappraisal itself, which has been associated with greater reappraisal success.

G18

EFFECTS FO FOCAL BRAIN DAMAGE ON SEXUAL BEHAVIOR *Timothy Koscik[1], Daniel Tranel[1]; [1]University of Iowa* – Sex is a fundamental aspect of real-world behavior. Sexual behavior can be disrupted by focal brain injury resulting in serious consequences (e.g., contracting STDs, unintended offspring). Cases of sexual dysfunction following damage to ventromedial prefrontal cortex (VMPC) or the insula have been reported (e.g. Anderson et al., 1999). The present study aims to extend these case reports by examining a broad range of sexual behaviors in a large sample of brain-damaged patients. In particular, awareness of sexual feelings and sex-related, physical violence were assessed. Participants consisted of men and women with lesions to either of two target regions (VMPC or insula), and brain-damaged comparisons (BDCs) with damage outside of these areas. Participants completed a self-report questionnaire designed to assess prevalence of risky sexual behaviors and sex-related cognition and attitudes. Questionnaire items included statements using 5-point Likert-scale format, and a series of standard questions developed by Reitmeijer, et al. (2001). The results so far indicate differential influence of VMPC or insula damage on sexual behavior and cognition. Participants with insula damage displayed decreased sexual awareness compared to BDCs ($p=0.01$). Compared to BDCs, participants with VMPC damage displayed a trend toward increased frequency of sex-related, physical violence, e.g., giving physical pain for pleasure ($p=0.05$). The present study, based on a lesion approach, suggests that the insula and ventromedial prefrontal cortex are important for normal sexual behavior and cognition.

G19

BELIEFS, GUILT, AND THE BRAIN: NEURAL MECHANISMS UNDERLYING SOCIAL COOPERATIVE BEHAVIOR *Luke Chang[1], Alec Smith[2], Martin Dufwenberg[2], Alan Sanfey[1]; [1]University of Arizona, Psychology, [2]University of Arizona, Economics* – Researchers across many disciplines have been intrigued by why people cooperate with a partner when they can better serve their own interests by acting selfishly. One possible mechanism underlying this phenomenon may be the influence of guilt on decision-making. Guilt has been formally defined as the extent to which a person believes they have let a partner down, modulated by an individual sensitivity parameter. Understanding the neural systems underlying this phenomenon has important implications for elucidating the broader impact of the interaction between cognition and emotion on decision-making. We employed a model of guilt aversion

developed within the context of Psychological Game Theory to predict the amount of guilt experienced by the participants within a social interaction. Seventeen participants were scanned using fMRI while they played a modified single-shot Trust Game. Participants' decisions and beliefs were entered into the model to produce a quantitative measure of guilt on a trial-by-trial basis. These values were then used as parametric regressors in a full-brain-analysis to predict regions of the brain associated with the experience of guilt. Consistent with our predictions, we observed a network of regions associated with processing negative emotions that included the amygdala, insula, and hippocampus. These results suggest that belief dependent states are processed by neural regions that have been previously associated with more basic emotions. More importantly, this study demonstrates that high-level questions about the role of emotions in decision-making can be addressed using the interdisciplinary Neuroeconomic framework by integrating psychological game theory and model-based fMRI.

G20

MOOD-DRIVEN DECISION BIASES IN THE ULTIMATUM GAME *Katia Harle[1], Alan Sanfey[1]; [1]University of Arizona, Psychology* – This study investigated the neural processes associated with emotional biasing of economic decision-making, specifically the effect of induced negative emotions. We used fMRI to monitor brain function in people engaged in a classic social economic task, the Ultimatum Game, which involves accepting or rejecting monetary offers from human and non-human (computer) partners. This research expands on a previous behavioral study, which showed that priming participants with negative emotions with underlying withdrawal motivational tendencies (i.e. sadness and disgust) result in higher rejection rates. Thus, negative avoidant emotions may play a particularly important role in modulating economic decisions of a social nature. To explore the neural basis of decision biases following such mood induction, we first used short video clips to induce either sadness or a neutral emotional state. The impact of additional modulating factors such as the degree of unfairness of the offer and type of interaction (i.e. human vs. computer partner) was also analyzed. Behaviorally, participants who first experienced sadness rejected more unfair offers than those in the neutral condition, replicating our previous findings. Preliminary fMRI analyses revealed that receiving unfair offers while in a sad mood elicited activity in brain areas related to negative emotions (insula) and cognitive conflict (anterior cingulate cortex). In contrast, receiving unfair offers while in a neutral mood elicited activity in brain areas related to reward anticipation (nucleus accumbens). These findings suggest a potential priming of neural regions involved in decision-related affective processing (e.g. insula) by more complex and socially-relevant emotions, such as sadness.

G21

MEASURING SOCIAL COGNITION AND THEORY OF MIND ACROSS DISEASED POPULATIONS USING FMRI *Nyaz Didehbani[1], Tandra Toon[1], Michelle McClelland[1], Michelle Kandalaft[1,2], Cassandra Adams[1,2], Sandra Chapman[1], Daniel Krawczyk[1,2]; [1]University of Texas at Dallas Center for BrainHealth, [2]University of Texas Southwestern Medical Center* – Social cognition is the ability to regulate your own emotions, recognize others' thoughts, and anticipate other's feelings. It also includes knowing social rules and responding appropriately. One key aspect of social cognition is theory of mind which includes a person's ability to associate mental states and feelings to oneself and others. Preliminary data suggests differing regions of brain activity among those with social deficits compared to healthy controls. Research has shown that participants with Schizophrenia and Asperger's syndrome are prone to difficulties with social cognition. In our study, we recruited healthy controls, participants with Schizophrenia, and Asperger's Syndrome. We used a theory of mind task in fMRI, whereby participants watched a series of short animations of moving shapes and were asked to make judgments about whether the shapes were friendly or not (theory of mind condition) or the same weight (control condition). The imaging results showed three areas of activation particularly the superior medial prefrontal cortex. These areas of activation differed between our healthy controls and our participants with Schizophrenia and Asperger's Syndrome, suggesting differences in social processing. Neurocognitive tests in addition to behavioral intervention data will also be discussed in relation to the imaging results.

G22

DISCRIMINATING FLEETING FACIAL EXPRESSIONS USING FEATURAL AND CONFIGURAL INFORMATION *Timothy Sweeny[1], Marcia Grabowecky[1,2], Ken A. Paller[1,2], Satoru Suzuki[1,2]; [1]Northwestern University, Psychology, [2]Interdepartmental Neuroscience Program* – Humans are impressively adept at discriminating fleeting emotional expressions. We investigated how the type and duration of expression influenced discrimination accuracy. Observers viewed two facial expressions, one neutral and the other emotional (fearful, angry, or happy), in a two-interval forced-choice task with stimulus duration varied across trials (10, 20, 30, 40, or 50 ms). All faces were masked by a face with a surprised expression. On each trial, observers attempted to select the face with the emotional expression, and to report the expression. Discrimination against neutral was above chance at all durations, and more accurate for happy than for angry or fearful expressions. Emotional expressions that displayed teeth yielded the highest accuracy. To evaluate discrimination among emotional expressions, we calculated d' using 'hits' and 'false alarms' specific to each expression pair. Discrimination between angry and happy expressions was better than discrimination between fearful and happy expressions, and both pairs were discriminated well above chance even when presented for only 20 ms. In contrast, discrimination between fearful and angry expressions was near chance at all durations. With inverted faces, only discrimination between angry and happy expressions was impaired, which suggests a contribution of configural processing in this discrimination. Together, these results demonstrate that surprisingly brief presentations are sufficient for discriminating emotional expressions from neutral expressions. However, discriminating emotional expressions is difficult and depends on information from individual features and from their configurations.

G23

MENTALIZING OR MAXIMIZING: AN FMRI STUDY ON PROPOSER BEHAVIOR IN THE ULTIMATUM AND DICTATOR GAMES *Mascha van 't Wout[1], Alan Sanfey[1]; [1]Neural Decision Sciences Laboratory, Psychology, University of Arizona, Tucson AZ* – Examining behavior in interactive scenarios such as the Ultimatum Game (UG) and Dictator Game (DG) can provide useful insights into the nature of social decision-making. In this study, we examined brain activity in proposers as they made offers to both non-anonymous and anonymous partners in both of these games. In the UG, generous proposer decisions can be based on either social utility motives (wanting fairness) or from the anticipation that low offers could be rejected, leaving both players with nothing. In contrast, generous decisions made in the DG are usually thought to reflect only social utility motives. Using fMRI we tested whether generous UG proposers who exhibit brain activity patterns related to reward maximization, as opposed to social motivations, would in turn be less generous in the DG. Sixteen participants played the UG and DG while dividing either $10 or $40 with both non-anonymous and anonymous partners. Behaviorally, participants gave more money to partners in a UG as compared to a DG and more money to non-anonymous rather than anonymous partners. fMRI analyses showed activation of social network areas (amygdala, orbitofrontal and medioprefrontal cortex) in response to non-anonymous partners as compared to anonymous ones. We further observed activity in the rostral cingulate and dorsomedial prefrontal cortex (BA 8/9) for the interaction between task (UG/DG) and amount of money offered. This confirms our hypothesis that participants in the UG with brain activity patterns indicating "mentalizing" (medial prefrontal cortex) are also more generous in the DG.

G24

TEMPORAL UNPREDICTABILITY INCREASES AMYGDALA ACTIVATION AND DECREASES TRUST *Andrew S Fox[1,2], Romana Snozzi[4], Frédéric Schneider[4,5], Richard J Davidson[1,2,3], Tania Singer[4], Ernst Fehr[4,5]; [1]University of Wisconsin-Madison, Psychology, [2]University of Wisconsin-Madison - Waisman Laborotory for Brain Imaging and Behavior, [3]University of Wisconsin-Madison, Psychiatry, [4]University of Zürich, Center for the Study of Social and Neural Systems, [5]University of Zürich, Institute for Empirical Research in Economics* – Trust is ubiquitous in human society and is critical for interpersonal interaction. Recent work investigating the biological bases of trust has implicated evolutionarily old brain structures, such as the amygdala, in judgments of trustworthiness and the decision to trust an anonymous individual. In our study we examined the effect of experimentally induced amygdala activation on trust behavior in a simple economic game, called the Trust Game. In the Trust Game, we gave participants 10 Monetary Units (MU's; paid in Swiss Franc's) and offered them the opportunity to invest any number of MU's in an anonymous individual designated as the trustee. For each MU invested by the participant, the trustee received 3 MU's that they could distribute between themselves and the participant as they saw fit. If the participant believes the trustee to be trustworthy they will maximize their gains by investing all of their MU's, whereas if the participant believes the trustee to be untrustworthy they retain the most MU's by investing nothing. In our experiment, while participants (n=55) were making this decision we exposed them to unpredictably spaced auditory stimuli, which are known to activate the amygdala. Additionally, approximately half the subjects (n=28) underwent fMRI while making these decisions. Results demonstrated that altering the temporal predictability of an auditory stimulus both increased amygdala activation and decreased investment amounts in the Trust Game, as predicted. These data suggest that task-irrelevant manipulation of amygdala activity influences the decision to trust.

G25

LETTING GO OF SADNESS: MINDFUL DETACHMENT IN EMOTION REGULATION *Norman Farb[1], Adam Anderson[1], Zindel Segal[2]; [1]University of Toronto, Psychology, [2]Centre for Addiction and Mental Health, Psychiatry, University of Toronto* – Effectively regulating negative emotion is important for mental health. Indeed, extant research suggests that emotional reactivity to stressors predicts negative health outcomes. Mindfulness training (MT) has been shown to reduce the risk of depressive relapse and improve chronic mood, but little is known about its mechanisms of action. Using fMRI, the authors have developed a model of mindful emotion regulation linking: i) neural and subjective changes in emotional reactivity associated with MT, ii) neural evidence of attentional processes subserving MT-related changes in reactivity, and iii) how such changes promote positive mental health outcomes. Evidence from three fMRI studies will be presented to support a model of MT promoting reduced emotional reactivity to dysphoric challenge. Study 1 presents the association between mindfulness training (MT) and neural markers of emotion reactivity, in which MT was not associated with altered subjective experience of sadness following dysphoric challenge, but was associated with reduced neural reactivity. Study 2 links MT-related changes in interoceptive processing with altered neural recruitment in attentional suppression and maintenance tasks, implicating enhanced connectivity of suppression networks with interoceptive cortical networks following MT. The idea of reduced reactivity will be further explored in Study 3, which investigates neural indices of emotional reactivity that predict relapse into depression. Taken together, the studies suggest that neural changes associated with mindfulness training may facilitate a reduction in emotional reactivity through enhanced attentional control. A comparison of the neural signatures predicting depressive relapse and areas associated with mindfulness training will be discussed.

G26

DIFFERENTIAL EFFECTS OF FEARFUL AND ANGRY FACIAL EXPRESSIONS ON LEARNING *F. Caroline Davis[1], Leah Somerville[1], Lisa Shin[2], Paul Whalen[1]; [1]Dartmouth College, [2]Tufts University* – Research suggests that the amygdala is sensitive to both the valence and information value conveyed by facial expressions. For example, the human amygdala is more responsive to facial expressions of fear than anger, even though both expressions communicate negative valence. In non-human animals, amygdala responses to stimuli predicting negative events are enhanced when those stimuli have uncertain predictive value. We have proposed that the human amygdala is more responsive to fearful faces because of their inherently uncertain nature: angry faces embody a direct threat and call for focused attention, whereas fearful faces offer less information about the source of threat and therefore call for diffuse attention. This hypothesis predicts that angry faces should lead the viewer to learn more about the faces themselves, while fearful faces should lead the viewer to learn more about the context. We tested this hypothesis by measuring the effects of fearful and angry facial expressions on memory. In study 1, participants viewed fearful, angry, or neutral faces alternating with neutral words. Results show that when compared to neutral face blocks, fearful faces augmented memory for words, whereas angry faces impaired memory for words. In study 2, participants viewed blocks of fearful or angry faces alternating with neutral words. Results show that subjects remembered more words from the fearful face condition and more faces from the angry face condition. These data support the idea that although they communicate a similar message in terms of negativity, fearful and angry facial expressions call for different kinds of learning.

G27

AMYGDALA-CINGULATE CONNECTIVITY DURING REGULATION OF EMOTION PREDICT TREATMENT RESPONSE IN MAJOR DEPRESSIVE DISORDER *Aaron S. Heller[1], Tom Johnstone[2], Ned H. Kalin[1], Richard J. Davidson[1]; [1]University of Wisconsin, Madison, [2]University of Reading* – Theoretical work in Major Depressive Disorder (MDD) suggests that the inability to adaptively regulate negative emotion is a core etiological process underlying the development of MDD. However, few studies to date have investigated the neural substrates of emotion regulation (ER) in depression, and none to our knowledge have assessed group differences in within-subject connectivity. Studies investigating the neural substrates of ER in healthy control participants implicate the amygdala and pre-frontal cortex (PFC) as nodes in a healthy ER network, and this network has been shown to be abnormal when depressed patients attempt to regulate emotion. Other neuroimaging studies comparing controls to depressed patients at rest have further suggested abnormalities in the Anterior Cingulate Cortex (ACC) in depression, with pretreatment activity in this region predicting improvement in depressive symptoms when given antidepressant medication. Accordingly, we performed a functional connectivity analysis of Functional Magnetic Resonance Imaging (fMRI) data when subjects performed an ER task to investigate whether amygdalar-PFC interaction is abnormal in depression and whether those regions showing abnormal functional connectivity are also predictive of antidepressant treatment response. Indeed, when reappraising negative affect elicited by emotional slides, depressed patients showed a decrease in amygdala-perigenual ACC (periACC) connectivity. Within the depressed group, degree of amygdala-periACC connectivity during reappraisal further predicted treatment response to Venlafaxine eight weeks post-scan as assessed by the Hamilton-Depression Inventory. These results point to a disordered amygdala-periACC network underlying the ER deficits in depression, and further suggest that the integrity of this network is critical to support symptom remission.

G28

THE AFTERMATH OF AFFECTIVE STIMULI: EVIDENCE FROM FMRI RECORDED INSULA AND AMYGDALA ACTIVITY IN GENERALIZED ANXIETY DISORDER *Desmond J. Oathes[1], Daniel M. McFarlin[1], Tammi R.A. Kral[1], Michael J. Jenson[1], Issidoros Sarinopoulos[2], Jack B. Nitschke[1]; [1]Waisman Laboratory for Brain Imaging and Research, University of Wisconsin-Madison, Psychiatry and Psychology, [2]Michigan State University, Psychology* – Problematic cognitions in affective disorders are thought to result from the combination of aversive events and an internal focus of attention. Behavioral evidence and a prominent theoretical model of generalized anxiety disorder (GAD; Borkovec et al., 2004) suggest that individuals with GAD engage in avoidance strategies to mitigate the emotional impact of aversive events. In the present study, we examined blood oxygen level dependent signal changes in an event-related functional MRI paradigm during which participants viewed emotional pictures and provided affective ratings after each picture. Half of the ratings required participants to rate the emotional impact of the pictures on themselves (self-ratings). The other half asked participants to rate the valence (pleasantness or unpleasantness) of the picture (picture-ratings). GAD subjects showed less amygdala and insula activity than controls while rating their emotional responses to affective pictures. Self-ratings and negative ratings were especially likely to evince a pattern of hypoactivity in the amygdala and insula for GAD subjects. These data support Borkovec's avoidance model of GAD. Implications for understanding the neurobiology, environmental triggers, and subjective experience of emotional distress in clinical anxiety will be discussed.

G29

INDIVIDUAL DIFFERENCES IN EMOTIONAL AWARENESS MODERATE THE EFFECTS OF AFFECTIVE STIMULI ON WORKING MEMORY PERFORMANCE *Joseph U. Kim[1], Michael S. Cohen[1], Colin G. DeYoung[2], Adam E. Green[1], Todd S. Braver[3], Jeremy R. Gray[1]; [1]Yale University, [2]University of Minnesota, [3]Washington University* – Previous work has shown that inducing particular emotional states can facilitate performance on verbal and visuospatial working memory tasks by selectively influencing lateral PFC activity (Gray, Braver, and Raichle, 2002). We examined whether individual differences in trait emotional awareness moderate these emotion-cognition interactions. The 20-item Toronto Alexithymia scale (TAS-20; Bagby et al., 1994), designed to measure difficulty identifying and describing one's own emotional states, was administered to college students and community members. 99 participants were scanned while performing a 3-back task using blocks of words and faces; prior to each 3-back run, subjects watched short videos intended to induce mild emotional states (pleasant/approach related, unpleasant/withdrawal related, or neutral). Those who scored high on facets of alexithymia (low emotional awareness) showed emotion-related enhancement of working memory (WM) performance, such that approach states led to improved verbal WM performance and withdrawal states led to improved face WM performance. This was not observed in subjects with lower alexithymia scores. In addition, lower levels of emotional awareness (higher alexithymia scores) correlated with lower brain volume in the right temporoparietal junction/ superior temporal sulcus (TPJ/STS) region (uncorrected $p < .0005$) when controlling for gender, age, and gender by alexithymia interaction. Activity in TPJ has been associated with identifying emotional states in oneself and others, among other functions. This region may be involved in emotion-cognition interactions.

G30

RECALL OF EMOTIONAL STIMULI IS PRECEDED BY NEURAL REACTIVATION OF EMOTIONAL CONTEXT: AN FMRI STUDY *Katherine Vytal[1], Jennifer Wilson[1], Stephen LaConte[2], Stephan Hamann[1]; [1]Emory University, Psychology, [2]Baylor College of Medicine* – Tulving and other theorists have proposed that recalling events critically involves reactivating neural representations that were originally active during the event. Recent FMRI and human single-unit electrode recording studies have supported this view, demonstrating medial temporal activity that precedes individual freely recalled items and reinstates neural patterns characteristic of recalled stimulus categories such as face, object, or location. Because emotion is a highly salient stimulus attribute, we reasoned that reinstatement of emotional activity would immediately precede spontaneous free recall of emotional stimuli, reflecting reinstatement of emotional attributes and context, and further, that this activity would predict whether the subsequently recalled item would be emotionally arousing or neutral. Eleven subjects were scanned at 3 Tesla, first while they encoded negative emotional (phone-KILLER), positive emotional (trumpet-ECSTASY) and neutral paired associates (table-ACTOR), and later while they freely recalled items by speaking into a pneumatic microphone. Analysis of the two-TR period before the onset of each recalled item indicated significantly increased memory and emotion-related medial temporal activity, including the hippocampus and amygdala, prior to recall of positive and negative emotional words, compared to neutral words. Activity in another emotion-related region, the insula, also preceded emotional but not neutral recall. These results are consistent with reactivation views of free recall, suggesting that emotion-related brain activity is reinstated prior to spontaneous free recall of emotional but not neutral stimuli. This reinstated information likely guides further retrieval processes as a specific item is ultimately selected for recall. Further multivariate analyses will examine reinstatement of distributed patterns of emotion-related activity and activity during overt cued-recall.

G31

COMPASSION FOR PHYSICAL AND SOCIAL PAIN ARE ASSOCIATED WITH OPPOSITE HEART RATE RESPONSES *Xiao-Fei Yang[1,2], Mary Helen Immordino-Yang[1,3], Savio W. H. Wong[1]; [1]Brain and Creativity Institute, University of Southern California, [2]Neuroscience Graduate Program, University of Southern California, [3]Rossier School of Education, University of Southern California* – Do compassion for physical and social pain share similar physiological response patterns? Here, we report the results of heart rate analyses from a psychophysiological study. Eight Chinese participants were exposed to a series of narratives based on episodes from real people's lives, designed to induce either compassion for physical pain (CPP), compassion for social/psychological pain (CSP), or engagement without strong emotion (Control). Participants learned the content of the narratives and discussed their feelings about each stimulus individually with an experimenter before psychophysiological recording, to ensure that each participant's response to each stimulus corresponded to the established emotional category. During psychophysiological recording, participants saw 5-second reminder videos about each narrative, followed by 13 seconds of dark screen and 2 seconds of fixation. Participants were asked to become as emotional as possible about each narrative, and to rate the intensity of their emotion on a scale from 1 to 4. Instantaneous heart rate was derived from ECG recording; heart rate during fixation served as baseline. CPP elicited acceleration in heart rate, while CSP elicited deceleration in heart rate relative to baseline. Heart rate during control stories stayed constant. Further, degree of acceleration/ deceleration correlated positively with participants' subjective rating of emotion intensity. Overall, our results show opposite heart rate responses to compassion for physical and social pain, suggesting differential modulation of the autonomic system for these social emotions.

G32

EMOTIONS COME AND GO: NEURAL ACTIVITY TO ONSETS AND OFFSETS OF HAPPY AND ANGRY FACIAL EXPRESSIONS *Andreas Mühlberger[1], Matthias Wieser[1], Monika Frey[1], Antje Gerdes[1], Paul Pauli[1], Felix Breuer[2], Peter Weyers[1]; [1]University of Würzburg, Psychology, [2]Magnetic Resonance Bavaria (MRB)* – Pictures of facial expressions of emotion have been shown to elicit emotional reactions and neural activation in different neural structures related to emotional processing (e.g., amygdala). However, in daily live emotional expressions are in constant

dynamical change, and first results show enhanced processing of dynamically presented emotional expressions. Additionally, the development of a facial emotional expression (onset) might be processed differentially from the offset of the same expression. For example, an offset of a happy expression might be a sign of danger, while an offset of an anger expression might be a sign to relax. Therefore, we presented short video clips of the onset or offset of happy and angry facial expressions while measuring brain activity by fMRI in a block design. Emotional facial expressions were generated using Poser 5 software. Twenty-two participants (12 men and 10 women) were investigated. In line with our assumptions first analyses indicated enhanced neural activity in the Amgydala during the presentation of angry onset as well as happy offset, whereas other structures like hippocampus and fusiform face area were more sensitive to angry offset and happy onset. These results show that the emotional significance of dynamical changes is analyzed in its temporal context. Further research is necessary to elude the emotional processing of dynamical facial expressions in detail.

G33

EMPATHY AND SIMULATION OF THE PHYSIOLOGICAL RESPONSE TO PLEASANT AND UNPLEASANT THERMAL SENSATIONS *Adrienne Moore[1], Mary Wright[2], Megan Luetje[1], Martin Paulus[3]; [1]U C San Diego, Cognitive Science, [2]U C San Diego, Division of Biological Sciences, [3]U C San Diego, Psychiatry* – The goal of this study was to test the hypothesis that empathy for the physical discomfort of others involves a simulation of the other's autonomic response to the discomfort. Pairs of female participants were recruited to observe one another inserting the left hand into ice water (a cold pressor task), tepid water, and warm water for short intervals. VAS ratings of pleasantness, unpleasantness and pain resulting from the hand immersion were collected from all participants, with reference to their own sensations, and with reference to how they imagine the other person to feel. Heart rates were collected from one participant per pair, both during experience of and observation of the hand immersion in water baths of comfortable and uncomfortable temperatures. We found that trait empathy measured by the Interpersonal Reactivity Index (IRI) was significantly correlated with VAS rating of the unpleasantness of the other's ice water immersion ($r=.45$, $p < .05$). Further, the IRI subscale Empathic Concern was significantly correlated with a bradycardic heart rate response to observing another's cold discomfort ($r=.766$, $p < .01$), while a bradycardic response to observing both pleasant and unpleasant temperature sensations was significantly correlated with the Perspective Taking subscale of the IRI ($r=.623$, $p=.03$). This study links specific ANS mediated physiological changes in response to observed pleasant and unpleasant sensation with aspects of empathy, and motivates future work to identify the neural substrates involved.

G34

MINDFULNESS-INDUCED CHANGES IN THE EXPERIENCES OF PAIN AND NEGATIVE EMOTION: AN FMRI STUDY *Peter Mende-Siedlecki[1], Hedy Kober[1], Jason Buhle[1], Brent Hughes[2], Ethan Kross[3], Tor Wager[1], Kevin Ochsner[1]; [1]Columbia University, [2]University of Texas, Austin, [3]University of Michigan, Ann Arbor* – In recent years, emotion regulation has become a burgeoning area of research. Concurrently, acceptance-based meditation practices have sparked both lay and scientific interest. Though the two disciplines may share functional goals, understanding of the behavioral efficacy and neural substrates of acceptance as an emotion-regulation strategy is lacking. This study used fMRI to examine the use of acceptance-based mindfulness strategies to regulate responses to both physically and emotionally aversive stimuli. Sixteen healthy subjects were scanned while viewing neutral and aversive images and while experiencing warm or painful heat. While experiencing these stimuli, participants were instructed to either (a) react emotionally to the stimuli and to allow themselves to feel angry or hurt (react) or (b) accept the sensations they experienced and to recognize that these feelings would pass (accept). Subjective ratings indicated that participants displayed statistically significant drops in negative affect when maintaining an accepting mindset rather than a reactive mindset. Compared to warm heat, painful heat activated a widespread network known as the pain matrix (encompassing the insula, the anterior cingulate cortex, the thalamus, and the brainstem), while aversive images (compared to neutral images) activated the dorsal amygdala, the anterior cingulate, and regions within the brainstem. Critically, the cognitive strategy of acceptance modulated activations in the insula and dorsal amygdala during the presentation of aversive heat and aversive images, respectively.

G35

AN EEG STUDY OF REAPPRAISAL AND SUPPRESSION STRATEGIES FOR EMOTION REGULATION *Aliya Tolegenova[1], Gerald Matthews[2], Satybaldy M. Jakupov[1], Almira Kustubayeva[1]; [1]Kazakh National University, Almaty, Kazakhstan, [2]University of Cincinnati, Cincinnati* – Objective: Gross (1998) has developed experimental techniques for investigating different emotion regulation strategies. However, the neuropsychological bases for regulation remain unclear. In addition, there may be gender differences in emotion regulation. Hence, the aim of the present study was to investigate EEG rhythm differences during emotion regulation tasks in males and females. Subjects and methods: Subjects were 150 students (75 female, 75 male). Subjects were randomly allocated to one of three groups: control (C: no instructions), reappraisal instruction (R) or suppression instruction (S). A film was used to induce fear according to instructions of Gross and Levenson (1995). EEG was recorded by using an electroencephalograph "Neuron-Spectrum-1" monopolarly from symmetrical frontal, central, parietal, and occipital lobes with the indifferent joint ears electrodes. Spectral Power Density of EEG rhythms in 10 bands (2-45 Hz) was analyzed. Results: Gender differences were found in several bands, including alpha-4 (females showed higher power), theta-2 (males showed higher power) and gamma (females showed higher power in F2 and F4). The strongest effect of emotion regulation was found in the theta-1 band. At the majority of sites, reappraisal increased theta-1 power. In addition, effects of emotion regulation on alpha-1 and alpha-2 differed in males and females. Conclusion: Data add to understanding of emotion-regulation by demonstrating that experimental manipulations of regulation strategy influence EEG. However, there were gender differences in EEG during viewing of the fear-inducing film, and some evidence was found for differential effects of emotion regulation on alpha in males and females.

Linguistic processes: Other

G36

THE UNDERLYING NEURAL SUBSTRATES OF PROSODY COMPREHENSION: EVIDENCE FROM A FUNCTIONAL MAGNETIC RESONANCE IMAGING STUDY *Isabelle Deschamps[1,2], Inbal Itzhak[1,2], Shari Baum[1,2], Vincent Gracco[1,2,3]; [1]McGill University, Faculty of Medicine, School of Communication Sciences and Disorders, Montreal, Canada, [2]Centre for Research on Language, Mind and Brain, McGill University, Montreal, Canada, [3]Haskins Laboratories, New Haven, CT* – The present study examined the cortical networks involved in the comprehension of prosody using functional magnetic resonance imaging. Judgments about the illocutionary force (intent) of a sentence were dissociated from purely acoustic judgments associated with the changes in fundamental frequency (Fo) distinguishing a statement from a question. The same sentence with different word-final intonation contours was used in two different judgment tasks. Two endpoint stimuli and two ambiguous stimuli were presented in a slow event-related paradigm. Twelve subjects identified either the direction of the contour (rising/falling) or made a declarative/interrogative (question/statement) judgment. The results from the whole brain analyses as well as the ROI analyses demonstrate that while similar networks were engaged in both tasks, greater activation accompanied question/statement judgements compared to rising/

falling judgments. The common cortical areas of activation for the two tasks included the medial frontal gyrus, the middle frontal gyrus on the right hemisphere, bilateral regions on the superior temporal and anterior cingulate gyri, the superior parietal lobe on the right hemisphere, and a bilateral area on the anterior insula. Common subcortical activation included the bilateral thalamus, putamen, and the cerebellum. A number of right hemisphere cortical and left hemisphere subcortical areas differentiated the two conditions. In general, ambiguous stimuli yielded increased activation mainly in frontal regions. The results address current theories of the neural bases of prosodic processing, and suggest that the attribution of illocutionary force invokes a broader, but largely overlapping, network relative to F0 contour judgments.

G37

THE INTERACTION BETWEEN PROSODY AND SYNTAX IN THE PROCESSING OF SUBJECT- AND OBJECT-CONTROL VERBS *Sara Bögels[1], Herbert Schriefers[1], Wietske Vonk[2,3], Dorothee J. Chwilla[1], Roel Kerkhofs[3]; [1]Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behaviour, [2]Max Planck Institute for Psycholinguistics, Nijmegen, [3]Center for Language Studies, Radboud University Nijmegen* – We investigated processing differences between subject- and object-control verbs in locally ambiguous Dutch sentences, which are disambiguated by an intransitive or transitive verb, e.g., The man promised(subject-control) / advised(object-control) the woman to sleep(intransitive) / support(transitive) (Dutch word-order). Linguistic literature shows that control verbs determine the understood subject of the later infinitive verb in the sentence, but their processing has not been studied before. We investigated whether a prosodic break (PB) after the control-verb leads to a preference for a transitive disambiguation. An off-line auditory fragment-completion experiment revealed predominantly intransitive completions after object-control verbs, but more transitive completions after subject-control verbs. A PB indeed shifted the preference to more transitive completions in both cases. An on-line ERP-study showed that after subject-control verbs, the intransitive as compared to the transitive disambiguating verb elicited an N400 effect, both with and without a PB. This result suggests, as the off-line results, that the default preference for subject-control verbs goes in the same direction as the effect of the PB. After object-control verbs, however, this 'intransitive N400 effect' only appeared when a PB was present. This shows that no clear default syntactic analysis of the sentence exists for object-control verbs, in contrast with the off-line results. Moreover, a PB can affect and change the syntactic analysis listeners pursue. Thus, this study reveals a dissociation between processing ofsubject- and object-control verbs. Furthermore, a different pattern of results was found for on- and off-line experiments: care is warranted in generalizing from off-line to on-line results.

G38

ARE TABOO ERRORS DETECTED BEFORE THEY ARE PRONOUNCED? AN ERP STUDY *Els Severens[1], Ine Janssens[1], Robert Hartsuiker[1]; [1]Ghent University, Experimental Psychology* – It has been thought that we monitor speech internally for errors and filter errors out before they are pronounced. There is only one study that provides direct evidence for covertly correcting speech errors. Motley, Camden, and Baars (1982) used the SLIP-task to elicit speech errors that differed in social acceptability. In this task some target word pairs are overtly named (e.g., tool kits), while the phonological make up of preceding bias word pairs (e.g., could tin) promotes speech errors. Either taboo errors (e.g., cool tits) or neutral errors (e.g., cool tarts) were elicited. There were fewer taboo than neutral errors. Additionally, the Galvanic Skin Response (GSR) was measured. The GSR was larger in the taboo condition; this was interpreted as demonstrating that taboo words were generated but corrected internally. However, the GSR is not a reliable measure of cognitive processes. In the present study we therefore wanted to replicate these results with a more reliable measure. The electro-encephalogram was measured while participants carried out a SLIP-task, which elicited taboo or neutral errors in Dutch. In the taboo condition there was a more negative going wave around 600 ms after the target word pairs. Previously, a similar negativity has been described to conflict. We suggest that in our study, this conflict results from the taboo error that is detected and corrected internally. In the control condition this conflict is smaller because the error is socially acceptable. These findings provide support for an internal monitor that checks internal speech for errors.

G39

HOW CHILDREN HANDLE DIALOG INFORMATION: AN ERP INVESTIGATION OF FOCUS PROCESSING *Ann Pannekamp[1], Ulrike Toepel[2], Elke van der Meer[1]; [1]Humboldt University of Berlin, Cognitive Psychology, Germany, [2]Neuropsychology and Neurorehabilitation Service, University Hospital and University of Lausanne, Switzerland* – Language acquisition is a complex task that involves not only the comprehension of single words and sentences but also the identification and integration of context information. An important step during this process is learning to interpret pragmatic information foci and their prosodic realization in discourse. So far, little is known about the time course in which children acquire these abilities. However, previous studies report that the development continues into adolescence. Using event related potentials (ERPs) we investigated the perception of spoken dialogs in the presence vs. absence of adequate prosodic cues for focus identification in three age groups (5, 8 and 12 years) and an adult control group. In adults, the processing of information foci was accompanied by focus-related positive-going shifts (FPS) irrespective of prosodic adequacy. However, missing prosodic markings on information foci additionally elicited N400 patterns. In the 12-year-olds, brain responses appeared to be similar as in adults. The 8-year-olds revealed an FPS only when the information focus was adequately prosodically realized. When the accent was missing the 8-year-olds simply showed an N400-like mismatch reaction. In the 5-year-olds, no FPS responses due to focus perception were evoked. Yet, the missing accentuation resulted in a mismatch reaction at single electrodes. The findings indicate late developmental changes in dialog interpretation, that is, the abilities to identify and understand relevant discourse information increase with age and become more and more independent of prosodic accentuation.

G40

BEFORE AND AFTER: AN ERP STUDY OF THE NEURO-COGNITIVE CHANGES ASSOCIATED WITH LATE SECOND LANGUAGE LEARNING *Erin White[1,2], Fred Genesee[1,2], Karsten Steinhauer[2,3]; [1]McGill University, Psychology, [2]Centre for Research on Language, Mind, and Brain, [3]School of Communication Sciences & Disorders, McGill University* – Currently, very little is known about the neuro-cognitive changes that accompany second language (L2) learning. Longitudinal work with English-speaking adults learning French suggests that foreign language learning can lead to functional changes in brain activity even in late L2 learners who have received limited classroom-based instruction (Osterhout et al., 2006). However, it is unclear whether such changes are possible for all aspects of learning, such as L2 morphology that cannot be directly transferred from one's first language. We present pre-post ERP data of Korean- and Chinese- speaking adults both at the beginning and end of a 9-week intensive intermediate level English course. Participants read correct sentences and those containing a violation of English grammar (i.e. verb-subject agreement or tense). Learning led to changes in the ERP signal at both orthographic and morpho-syntactic levels of sentence processing. By the end of the course the students exhibited a P600 effect that was not present in the first testing session, suggesting they were beginning to develop morpho-syntactic processing resembling that of native-speakers. Moreover, this P600 development reflected changes in participants' accuracy during the experiment across the two testing sessions. Additionally, in the Korean speakers, the P200 amplitude elicited in response to content words decreased, suggesting that for these participants orthographic processing had became less effortful. These results suggest that L2 learning at the behavioural level is associated with processing changes at the neuro-cognitive level and that even among late L2 learners, as proficiency improves brain processing begins to resemble that of native speakers.

G41

ADAPTATION TO PHONOLOGICALLY SIMILAR WORDS IN BILATERAL SUPERIOR TEMPORAL SULCI *Kenneth Vaden[1], Gregory Hickok[1]; [1]University of California at Irvine, Cognitive Sciences* – The goal of the present study was to functionally identify cortical regions supporting phonological-level processes in speech recognition. Most neuroimaging speech experiments use subtraction methodologies, often contrasting speech listening against non-speech baselines. Such contrasts may weaken activity in regions that respond non-selectively to speech, and typically ignore significant linguistic distinctions, making it unclear how to linguistically characterize observed activity. A better alternative is to manipulate specific linguistic representations to highlight specific speech processes. We used an fMRI-adaptation experiment to detect repetition-inhibition of response to repetitive phonological content in spoken wordlists, measured by phonological similarity among words. Speech performance is degraded in perception, production, and memory when words share phonemes with other words in close temporal proximity. A related phenomenon is neural adaptation, which occurs when a neural substrate is inhibited by repeated exposure to stimulus dimensions that it processes. Seventeen participants listened to recordings of CVC wordlists: phonologically dissimilar words, phonologically similar words, or a single word repeating. Short lag priming between list items was sufficient to reveal activity differences consistent with our prediction of repetition-inhibition. Words sharing greater numbers of phonemes had significantly reduced activity relative to words with no phonemes in common, bilaterally in middle Superior Temporal Sulci (STS). The activity pattern observed in STS demonstrated sensitivity to phonemic content in speech, further neuroimaging evidence for STS in phonological processing that corroborates observations of pure word deafness resulting in cases of bilateral STS damage.

G42

SIGN MEMORY AND LEXICAL ACCESS: EVIDENCE FROM AMERICAN SIGN LANGUAGE *Michael Grosvald[1,2], Christian Lachaud[1], David Corina[1,2,3]; [1]Center for Mind and Brain, University of California at Davis, [2]University of California, Linguistics, Davis, [3]University of California, Psychology, Davis* – In our efforts to develop a theory of sign language recognition, we explore how the processing of sign language forms diverges from that of non-linguistic actions. This study used a 1-back paradigm to investigate memory and lexical access in 31 deaf signers and 18 hearing non-signers. Participants watched a series of video clips, each showing an American Sign Language sign or a non-linguistic grooming gesture, and needed to decide during each clip whether the action shown was the same action seen in the preceding clip. We manipulated sequential co-occurrences of particular image pairs to examine effects of prior exposure on memory judgments across stimulus class (signs versus gestures) and viewpoint (Upright, Side, or Inverted). We hypothesized that memory would be aided, and response times shortened, in contexts where lexical representations of the shown actions were available to subjects (i.e. for signers responding to signs). As expected, deaf subjects were faster and more accurate than hearing subjects. However, a surprising group difference emerged when comparing response times to Upright-view signs and gestures preceded by the same actions in various orientations: deaf subjects' responses to Upright-view actions were significantly slower when preceded by Side-views than by Upright-views; hearing subjects showed no such effect. These effects were more pronounced for gestures than signs. Our interpretation of this outcome is that lexical access was performed automatically by deaf subjects although not required for this task. We explore the implications of these findings in relation to theories of expertise in visual perceptual processing and memory.

G43

ERP EVIDENCE FOR 'STRESS DEAFNESS' IN LATE PROFICIENT FRENCH-GERMAN BILINGUALS *Maren Schmidt-Kassow[1], Sonja A. Kotz[1]; [1]MPI CBS, Leipzig, Germany* – French and German ERP data have shown that metric violations (i.e., incorrectly stressed words) in a sentence elicit a P600 component that is comparable to the P600 evoked by syntactic violations (Magne et al., 2007; Schmidt-Kassow & Kotz, in press). There is also recent evidence that French speakers are impaired in discriminating between two stimuli that vary in stress position (Dupoux et al., 2008). Therefore, French speakers have been labelled as 'stress deaf'. In the current study, we investigated whether late proficient French-German bilinguals can perceive metric violations in metrically regular German sentences. All of the participants were highly proficient learners of German, i.e., they were able to stress all words in sentence on the intended syllable in a production task. In contrast to German native speakers, French-German bilinguals failed to show a P600 component in response to the metric violations although attention had been directed to the metric pattern of the sentences. Thus, the current data corroborate the hypothesis that French speakers are stress deaf even if they reached a highly proficient level of German.

G44

NEURAL SUBSTRATES OF IRONY COMPREHENSION: A FUNCTIONAL MRI STUDY *Midori Shibata[1], Akira Toyomura[1], Hiroaki Itoh[1], Jun-ichi Abe[1]; [1]Hokkaido University, Psychology* – Irony is one of the pragmatic statements that conveys the opposite meaning to its literal meaning. Comprehension of irony may be required to infer the intentions, beliefs, and feelings of the speaker who expresses the opposite meaning. In this study, we investigated the neural substrate involved in the comprehension of irony using event-related functional magnetic resonance imaging (fMRI). Twelve participants read the short scenario which consisted of five sentences. The first four sentences explained the situation of protagonists. The fifth one had a connotation of either ironical, literal, or unconnected meanings. The participants had to press a button for "yes" or "no" regarding to whether the final sentence expressed the ironical meanings or not. In the ironical sentence condition, the bilateral inferior frontal gyrus (IFG), inferior parietal lobule (IPL), superior frontal gyrus (SFG), medial prefrontal cortex (MPFC), the left superior temporal gyrus (STG) and parahippocampal gyrus were activated. In the literal sentence condition, the bilateral IFG, SFG, MPFC, middle frontal gyrus, IPL, and the left STG were activated. We analyzed differential contrast in the ironical sentence condition versus the literal sentence condition. This contrast revealed higher activation in the MPFC, the left STG, and the left parahippocampal gyrus. The involvement of MPFC in mentalizing processes has been reported (Frith and Frith, 2003). Our results suggest that the comprehension of irony is strongly related to mentalizing processes.

G45

LEXICAL PROCESSING IN DIGLOSSIC CODE SWITCHING BETWEEN MODERN STANDARD ARABIC AND PALESTINIAN COLLOQUIAL ARABIC: AN EVENT-RELATED BRAIN POTENTIAL STUDY OF ARABIC NATIVE SPEAKERS *Reem Khamis-Dakwar[1], Karen Froud[2], Sami Boudelaa[3]; [1]Adelphi University, [2]Teachers College, Columbia University, [3]Cambridge University, UK* – Diglossia is a phenomenon whereby social functions are distributed between formal and colloquial language varieties. We used EEG to to investigate MMN responses of native speakers of colloquial and standard Arabic (a diglossic language) to switching between language varieties, while controlling for semantic, acoustic-phonetic, and phonological variables. 16 participants were presented with four real-word conditions: 1) PCA words with different meanings (PCA ?a? (right) - ?ad (border); 2) PCA and MSA words with the same meanings (PCA ?a?, MSA ?aq (right); 3) switching between dialects and between meanings (PCA ?a?-MSA ?a? (prompt)); and 4) switching across languages (PCA fi:l (elephant): English feel). Real-word conditions were matched by pseudoword conditions utilizing identical phonetic contrasts. High-den-

sity EEG recordings were simultaneously acquired. MMN was derived from EEG recordings by averaging and montaging to a subset of fronto-central sensors, and subtracting averaged responses to standard stimuli from averaged deviant responses within each condition. MMN amplitude revealed a lexicality effect. Increased MMN amplitude was associated with colloquial-standard switches, compared to within-dialect conditions, even when the lexical semantics were held constant. This result indicates that the switch between dialects has neurophsysiological consquences over and above those related to a simple phonemic category change. Our results show that appropriately constrained use of single words in pre-attentional auditory processing paradigms can provide evidence of graded neurophysiological responses reflecting linguistic distinctions between diglossic langauge varieties. Such studies can elucidate questions about the neural representation of diglossia.

G46

CONTRIBUTIONS OF LEFT INFERIOR FRONTAL GYRUS SUB-REGIONS IN READING DIFFERENTIATED BY REGION-OF-INTEREST ANALYSIS *Priya Kalra[1], Taeko Wydell[2]; [1]Harvard Graduate School of Education, [2]Brunel University* – The Dual-Route Cascade model of reading (Coltheart et al. 2001) postulates a grapheme-phoneme conversion route for pseudowords and infrequent words of regular orthography, and a lexical search route for frequent and irregular words. Two areas within the left inferior frontal gyrus (LIFG-pars opercularis and LIFG-pars triangularis) analogous to Brodmann's areas 44 and 45 respectively have been put forward as candidates for the neural correlates of each route . However, whole-brain analyses have not demonstrated reliable double dissociations in activation between the two areas, in contrast to the predictions of the DRC model. Although both areas are predicted to be recruited in a variety of reading conditions, their contributions are predicted to differ. Our aim was to demonstrate this difference using region-of-interest (rather than whole-brain) analysis. Six healthy right-handed native English speaking volunteers aged 21-28 (3 female, 3 male) were scanned in a Siemens 3T scanner while performing a Homophone Decision Task (judging whether two stimuli would be pronounced the same way) across four conditions (regular word, irregular word, pseudoword and pseudohomophone). Data was analysed using SPM5 and MARSBAR. Although both regions-of-interest were recruited in all conditions, their percent BOLD signal change across conditions suggested complementary contributions within the DRC model. We interpret these results as support for the DRC model and as support for construing Brodmann's areas 44 and 45 as possible neural correlates of different routes within the model.

G47

READING THE MINDS OF OTHERS: DISENTANGLING THE GENDER-SPECIFIC MECHANISMS *Heather J. Ferguson[1], Richard Breheny[1], Anthony J. Sanford[2], Christoph Scheepers[2]; [1]Research Department of Linguistics, University College London, UK, [2]University of Glasgow, Psychology and CCNi, UK* – The ability to understand and predict other peoples' behaviour by attributing independent mental states to them is commonly referred to as theory of mind (ToM). Over the past 50 years a great deal of work has investigated ToM, focusing largely on developmental issues, impairments of this ability (e.g. autism and schizophrenia) and also on locating a neurological basis for ToM reasoning. However, this research has traditionally relied on response-based measures and thus very little is known about the on-line processes that are activated when comprehenders use ToM. Moreover, investigations using ToM tasks have initiated theories of a gender bias in cognition, based on evidence that females are superior to males on off-line tests of social judgment and measures of empathy, while males excel in practical 'systemising' skills, such as mathematical reasoning and spatial tasks. In three experiments, we used the visual-world paradigm to disentangle the on-line predictions that males and females generate during false belief (Exp. 1) and deception (Exps. 2 & 3) story comprehension tasks. Overall, our results demonstrate that comprehenders can immediately modify expectations based on their own knowledge about reality to direct their visual attention to appropriate referents according that character's perspective. However, the direct comparison of males and females suggests the existence of gender-specific cognitive strategies, where females consistently make 'person-relevant' predictions from the earliest opportunity, but males show delayed or no equivalent anticipation. We compare these findings across the specific language tasks involved and initiate discussions of possible explanations for the processing bias.

G48

THE EFFECT OF MOOD ON ANTICIPATION IN LANGUAGE COMPREHENSION: AN ERP STUDY *Dieuwke de Goede[1], Petra van Alphen[1], Emma Mulder[2], Yvonne Blokland[3], José Kerstholt[4], Jos van Berkum[1,5]; [1]Max Planck Institue for Psycholinguistics, [2]University of Amsterdam, [3]Utrecht University, [4]TNO Soesterberg, [5]Donders Institute, Centre for Cognitive Neuroimaging* – Several aspects of cognition, such as memory retrieval, problem-solving and decision-making, have been found to be sensitive to a person's mood. The evidence suggests that people in a happy mood are more inclined to use heuristic, top-down processing strategies than people in a sad mood. Here we investigate whether mood also affects the use of heuristics to anticipate upcoming language. In constructions like David praised Linda because..., verbs like praise bias readers to expect more information about the person who is praised (in this case, Linda). The bias is so strong that pronouns disconfirming the expectation (he in David praised Linda because he...), actually elicit a morphosyntactic P600 effect, indicating that such pronouns are briefly taken to be structurally problematic. We reasoned that if people process information more heuristically when being in a happy mood than when being in a sad mood, this should modulate the size of this expectation-based P600 effect. In a two-session EEG experiment, we used short film clips to manipulate the mood of participants who read short stories in which verb-based expectations were confirmed or disconfirmed with a gender-marked pronoun. When readers were in a happy mood, bias-inconsistent pronouns elicited a clear P600 effect, but when the same readers were in a sad mood, no such effect was observed. This supports the idea that a happy mood increases the use of heuristics. Moreover, it reveals that language-relevant ERP effects can come and go as a function of general mood state.

G49

EXPLORING LANGUAGE SWITCHING WITH LEXICAL DECISION AND EVENT RELATED POTENTIALS *Kaitlyn Litcofsky[1], Katherine J. Midgley[1,2], Phillip J. Holcomb[1], Jonathan Grainger[2]; [1]Tufts University, Medford, MA, [2]LPC-CNRS, Université de Provence, Marseille, France* – Whether in production or comprehension, bilinguals can freely switch between their two languages. What are the underlying neural mechanisms and processing costs associated with these language switches? We investigated this by presenting common, single-word non-cognates in English and French to 26 native English speakers proficient in French in a lexical decision task. Items were either "switch" items, for which the language differed from the previously presented language (POMME - BEACH) or they were "non-switch" items, in which case the language remained the same (FIGHT - DRINK). Event-related potentials were recorded from 32 scalp electrodes to each item. Our most salient result was a clear, widespread language effect showing larger negativities in L1 relative to L2 in the N400 epoch, an effect previously reported by this lab. Additionally, the N400 component showed a tendency to index language switching in both L1 and L2, each having a different scalp distribution. Interestingly, we found effects on the late positive component reflecting switch effects that were robust in L1, but nonexistent in L2. Finally, the RT data showed an asymmetric switch effect such that L1 items incurred greater switch costs than did L2 items, replicating the findings found in the literature and prior work from this lab. These results appear to be consistent with theories postulating a greater inhibition of the dominant L1 during L2 processing followed by a need for greater reactivation of L1 after a switch. Our findings will be discussed within the framework of current models of bilingual language control.

G50

THE ROLE OF PHONOLOGICAL COMPLEXITY IN THE PAST TENSE DEBATE *Tomasina Oh[1], Keith Tan[1], Philina Ng[1], Berne Yeh[2], Steven Graham[3]; [1]National University of Singapore, English Language & Literature, [2]National University Hospital, Singapore, [3]National University of Singapore, Psychology* – For decades the English past tense has been the battleground for proponents of a dual (rules-and-memory) system versus those of a single (associative) system. For the former, the regular-irregular verb distinction reflects the rule-based nature of language (walk-walked) and its memorized aspects (run-ran) respectively. Previous imaging studies show differential activation for each type of verb, taken by some as further evidence for a dual model. Others believe that activation associated with regular past tense is actually due to higher phonological processing rather than rule application. Indeed, by matching regular and irregular verbs for phonological complexity, Desai et al. (2006) showed activation related to regular verbs (specifically left superior temporal gyrus/STG) disappeared. The current study extended this idea by also manipulating levels of complexity. Using a 2x3 design (regular vs. irregular x high, mid, low phonological complexity) twenty participants generated past tense verbs during fMRI. Two main findings emerged: (i) matching for phonological complexity did not remove all activation for regular verbs, suggesting a genuine difference between regular and irregular verbs over and above differences in complexity. Areas associated with irregular generation were similar to those found by Desai et al. We propose that our areas (including left middle frontal gyrus, right caudate, left thalamus and right cingulate) reflected a greater effort to suppress the automatic "-ed" rule. (ii) Relative to low complexity, high complexity verbs did not activate left STG, nor any traditional phonological processing areas. Together these results suggest that evidence is insufficient to reject a dual model.

G51

ELECTROPHYSIOLOGICAL INVESTIGATION OF INTERACTIONS OF PROSODY AND SEMANTICS IN CROSS-MODAL PHRASAL INTERPRETATIONS *Shani H. Abada[1,2], Shari R. Baum[1,2], John E. Drury[1,2], Karsten Steinhauer[1,2]; [1]School of Communication Sciences & Disorders, McGill University, [2]Centre for Research on Language, Mind and Brain, McGill University* – Previous electrophysiological research shows that the processing of prosodic boundaries in sentences elicits a Closure Positive Shift (CPS) in young adults. It is unclear whether boundaries in simple phrases elicit this component, and to what extent prosodic processing is influenced by concurrent visual input. To probe the interactions of the brain systems subserving the processing of prosodic and semantic information in simple phrases, subjects performed a cross-modal picture/phrase matching task while listening to phrases of conjoined nouns, (e.g., "[bike and dog] and [cup]", "[bike] and [dog and cup]") whose groupings were signaled by prosodic breaks. These spoken phrases either did or did not match concurrently presented pictures of three objects, presented in a horizontal row with a vertical bar marking the relevant (mis)matching groupings. Two further conditions included pure semantic word/picture mismatches (always on the 2nd word/object pair), and a double violation involving both a semantic and a prosodic mismatch. Behavioral and ERP results revealed that incongruous visual contexts modified responses, supporting an influence of visual context on prosodic processing not previously known. A positive component is elicited time-locked to pauses. Its amplitude is larger in prosodic mismatches and its morphology is modulated by the boundary location. Behavioral data revealed increased accuracy in semantic compared to prosodic mismatches, although ERP data revealed that both aspects are crucial, as evidenced by an N400 sensitive to prosody as well as semantics. Results address the electrophysiological correlates of prosody, as well as the interaction between, and relative weighting of, semantic and prosodic information.

G52

TITRATION OF STIMULUS DURATION: A METHOD FOR ACQUIRING DYNAMIC INFORMATION WITH FMRI *W. Einar Mencl[1], Stephen Frost[1], Shin-Yi Fang[2], Nicole Landi[3], Helen Chen[1], Kenneth Pugh[1,2,4], Jay Rueckl[1,2]; [1]Haskins Laboratories, [2]University of Connecticut, [3]University of Minnesota, [4]Yale University* – While fMRI is renowned for its spatial precision, interpreting temporal differences in activation is problematic due to the nature and variability of the hemodynamic response. We have explored an experimental technique for inferring the temporal sequence of activations along the cortical pathway for printed single-word identification. In Experiment 1 (N = 15), we presented word and nonword stimuli for varied durations prior to backward masking (33, 66, or 200 msec). Under the simplest assumptions, brief stimuli should only activate early nonlinguistic visual areas, whereas stimuli available for longer durations should be able to progress into successive stages of the reading network. Results were relatively consistent with this assumption: for words, 33 msec presentations produced restricted activations primarily in left striate/extrastriate areas; 66 msec durations elicited activation in these areas, plus the superior parietal cortex and BA 44/45; 200 msec durations produced activations at these areas, and enhanced activations in the posterior extrastriate and occipitotemporal zones. In Experiment 2 (N = 16), we presented words only, but at a more thorough set of presentation durations (17 to 200 msec). Initial analyses suggest that the response in many areas is not strictly linear across presentation duration. Ongoing analyses are targeted to clarify the nature of these nonlinear responses. We accept that the direct interpretation of these results as indicating simple stage-by-stage processing depends upon the unrealistic assumption that the reading network is a sequential, non-reentrant system. However, the technique and these data provide a starting point for investigating its nonlinear properties.

G53

THE ROLE OF THE DORSAL PATHWAY IN CHINESE WORD READING *Danling Peng[1], Ruifang Guo[1], Yuan Deng[2], Yanhui Yang[3], Guosheng Ding[1]; [1]State Key Lab of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China, [2]Institute of Psychology, Chinese Academy of Science, Beijing, China, [3]MRI Center of Xuan Wu Hospital, Beijing, China* – Previous studies on word reading demonstrate that word reading is related to two systems: the anterior reading system and the posterior reading system. The latter include the ventral pathway and the dorsal pathway. Many studies have proved that the ventral stream is responsible for visual word recognition, while for the dorsal pathway, some researchers consider that it is involved in the analysis of the phonology or the integration of morpheme and phoneme. However, there are less known about the relationship between the dorsal pathway and orthography. In our study, we investigated the role of the dorsal pathway in orthographic processing of Chinese characters. We presented to undergraduate students two types of characters with normal characters and shifted characters (i.e. positions of radicals in character were counterchanged). Participants were asked to judge whether stimulus presented was a real Chinese character regardless of position of radicals. We found that both of these two types of characters activated the dorsal pathway. ROI analysis indicated that there was significant main effect of type in the precuneus gyrus (BA7) of the left hemisphere. The shifted characters had stronger activation than the normal characters. According to these results, we propose that the dorsal pathway maybe involved in radical position encoding in orthographic processing of Chinese characters.

G54

PATHWAY FOR SCRIPTS SPATIAL ANALYSIS-THE COMPARISON OF DIFFERENT SCRIPTS *Yafeng Sun[1], Danling Peng[1], Guosheng Ding[1], Yuan Deng[2], Yanhui Yang[3]; [1]State Key Lab of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, China, [2]Institute of Psychology, Chinese Academy of Science, Beijing, China, [3]MRI Center of Xuan Wu Hospital, Beijing, China* – Nowadays researchers have paid more attention to how the dorsal pathway functions while peo-

ple read scripts. They have found that role of the Parietal Lobe (PL) or the Superior Temporal Gyrus (STG) differs for different scripts. However, most previous studies only focused on one script but did not make a direct comparison between different scripts. The aim of this research was to compare the role of the dorsal pathway in processing very different scripts such as Chinese and English. Fourteen undergraduate students participated in this study and all of them have passed the CET-6. We presented to participants both Chinese characters and polysyllabic English words with three formats. One was normal and the other two were degraded (i.e., the number of blank spaces between radicals or syllables was changed: 0, 0.75 & 1.5 spaces). It was found that the STG was activated by only English while the PL activated by both. The activation patterns were also inferenced by the formats of the scripts. The results demonstrate that the activations of the dorsal pathway are modulated by both the characteristics of scripts and the requirement of space analyses.

G55

OLDER ADULTS' PROCESSING OF PROSODY IN SPOKEN ENGLISH GARDEN-PATH SENTENCES: A DISSOCIATION BETWEEN ONLINE ERP DATA AND OFFLINE BEHAVIORAL DATA *Efrat Pauker[1,2], Shani Abada[1,2], Inbal Itzhak[1,2], Shari Baum[1,2], Karsten Steinhauer[1,2]; [1]School of Communication Sciences and Disorders, McGill University, Montreal, Canada, [2]Centre for Research on Language, Mind and Brain, Montreal, Canada* – Previous ERP investigations provided evidence for the immediate use of prosodic information in the comprehension of temporary syntactic ambiguities in garden path sentences (Pauker et al., 2006; Steinhauer et al., 1999). However, few ERP studies to date have examined the ability of older adults to process syntax-related prosody online. The present auditory study used ERPs to determine whether older adults (65-80 years) make use of prosody in resolving early and late closure (EC/LC) ambiguities, and directly compares the data to those of young adults (18-30 years). Participants made offline acceptability judgments on two types of sentences (EC/LC) which were either well-formed or contained prosody-syntax mismatches that varied in severity. Behaviorally, both groups identified prosody-syntax mismatches to some extent, but older subjects accepted mismatches significantly more often (70%) than younger participants (40%). Older adults also failed to discriminate between the two types of prosodic mismatches, while younger adults showed significantly lower acceptance of the more severe mismatch. ERP results demonstrate CPS components and garden-path effects (P600 and N400/P600) in both groups; however, older adults displayed a more posteriorly distributed CPS and more anterior P600 components than young subjects. The ERP data suggest that older adults processed and integrated prosodic information in real-time. However, behavioral offline data did not capture these online effects. Age-related differences (a) in neurocognitive processing mechanisms as reflected by distinct ERP scalp distributions, and/or (b) in the subsequent offline evaluation of initial processing difficulties, may contribute to this dissociation between online and offline data.

G56

THE EFFECT OF WORD REGULARITY AND FREQUENCY ON NAMING BEHAVIOUR AND FMRI BOLD ACTIVATION *Jacqueline Cummine[1], Carrie Esopenko[1], Gordon Sarty[1], Ron Borowsky[1]; [1]University of Saskatchewan, Psychology* – Background: It has been suggested that the Frequency (high frequency, HF and low frequency, LF) X Regularity (regular words, REGs and exception words, EXCs) interaction on naming RT occurs because the whole-word and sub-word reading systems produce a competing phonological code for LF-EXCs (i.e., increased phonemic processing and preparation of motor response). It has also been shown that tasks involving phonemic processing activate regions in the right middle temporal gyri (rMTG; Glasser & Rilling, 2008), and tasks involving preparation of motor responses activate regions in the supplementary motor association cortex (SMA; Richter et al., 1997). Purpose: We explored the effect of regularity and frequency, both behaviourally (i.e., naming RT), and functionally (i.e., fMRI) and the extent to which activation is found in these regions. Method: Participants (N=63 in the behavioural experiment and N=10 in the functional experiment) named words blocked by regularity and frequency. Naming RTs were collected and fMRI activation maps that separate unique versus shared regions of activation were created. Results: Behaviourally, the standard regularity x frequency interaction was significant. That is, EXCs were named significantly slower than REGs, and LF-EXCs were named significant slower than all other stimuli. Functionally, we found more activation for EXCs in the SMA (i.e., increased preparatory response), and exclusive activation for LF-EXCs in the rMTG (i.e., increased phonemic processing). Conclusion: Using a blocked design, we replicate the standard Regularity X Frequency interaction in naming, and provide evidence for the role of rMTG in phonemic processing and SMA in preparing a motor response.

G57

THE INITIAL LANGUAGE EXPERIENCE SHAPES BOTH HUMAN BRAIN FUNCTION AND ANATOMY: EVIDENCES FROM THE CONGENITALLY PROFOUNDLY DEAF *Yanyan Li[1], Guosheng Ding[1], Danling Peng[1], Liping Wu[2], Ping Hu[2], Yating Lv[1], Yufeng Zang[1], Chunyun Guo[3]; [1]State Key Lab of Cognitive Neuroscience and Learning, Beijing Normal University, Beijing, P. R. China, [2]Special Education College of Beijing Union University, Beijing, P. R. China, [3]Special Education School of Dagang District, Tianjin, P. R. China* – Language experience plays an important role in shaping both the function and the anatomy of human brain. The current study explored how the initial language experience impacts the development of brain function and anatomy with comparing two groups of congenitally profoundly deaf and one group of hearing people. One deaf group born of deaf parents (deaf native signers) acquired language experience (Chinese sign language) earlier than the other deaf group born of hearing parents (deaf nonnative signers). The BOLD fMRI activation were examined when the participants tried to understand Chinese Sign Language or spoken language in 3T-fMRI scanner. The effect of the initial language experience was revealed by the comparison between two deaf groups, while the effect of language modality revealed by the deaf group (sign language) and hear group (spoken language). The results showed that the left classical language areas were active in both sign language and spoken language comprehension. The recruitment of different parts of this network is modulated by both the age of acquisition and language modality. In addition, we also found that the gray matter density is modulated by age of first language acquisition. These essential findings provide strong evidence that the initial language experience contributes to the development of both brain function and anatomy.

G58

EARLY AUDITORY CORTICAL REGIONS DISCRIMINATE INTELLIGIBLE FROM UNINTELLIGIBLE SPEECH *Kayoko Okada[1], Jon Venezia[1], William Matchin[1], Kourosh Saberi[1], John T. Serences[2], Gregory Hickok[1]; [1]University of California, Irvine, Cognitive Sciences, [2]University of California, San Diego, Psychology* – Previous neuroimaging work that uses standard subtraction methodologies has shown that selective responses to intelligible versus unintelligible speech are found in regions of the superior temporal sulcus whereas early auditory areas in Heschl's gyrus and immediately surrounding regions in the supratemporal plane do not discriminate between intelligible and unintelligible acoustic control stimuli. The present study investigated this issue using multivariate pattern classification analyses. In a block-design fMRI experiment, we presented subjects with two intelligible speech conditions, clear speech (sentences) and noise-vocoded speech, as well as two unintelligible speech conditions, spectrally rotated speech and spectrally rotated noise-vocoded speech. Standard subtractive analyses replicated previous results showing bilateral anterior and posterior STS activity for intelligible compared to unintelligible conditions whereas early auditory areas in the supratemporal plane showed no difference. Using pattern classification analysis, however, we found that despite the lack of amplitude differences, early auditory regions nonetheless yielded reliably different spatial activation patterns to intelligible versus unintelligible speech in

both hemispheres. This result calls into question previous conclusions based on typical subtraction methodologies and suggests that regions that are not speech selective in terms of the voxel cluster-level amplitude of the physiological response may contain a finer-grained organization that processes speech differently from non-speech acoustic signals.

Linguistic Processes: Other

G59

ELECTROPHYSIOLOGICAL INVESTIGATION OF NULL ARGUMENTS: OMITTED STIMULUS POTENTIALS *Sophie G. Tate[1], Hiroko Nakano[1]; [1]Saint Mary's College of California, Psychology* – The current study investigated electrophysiological processes of null arguments in English speakers. A null argument refers to a dropped subject or object argument in a sentence. A null argument structure is not grammatical in English, but it is in some languages such as Spanish (subject drop) or Japanese (subject and/or object drop). In this study, English monolinguals listened to paired sentences: a context sentence, e.g., "Oh, the bottom of the door is dented"; a follow-up test sentence, which contained an overt object argument (Pronoun or Lexical) or null argument (Null), e.g., "Did you kick it?", "Did you kick the door?", or "Did you kick ø?, respectively. ERPs measured at the onset of the null argument showed early positive deflection, which prolonged for several hundred milliseconds (Omitted Stimulus Potentials). The amplitude of the positivity for the Null condition was larger than those for the both Pronoun and Lexical conditions. The OSP observed with this linguistic material shares some similarities and dissimilarities (e.g., latency and prolongation) with the OSPs elicited by randomly omitted flashes of light or tones in series of presentation as well as with the general P300 and the P600. The OSP observed in this study may eflect a detection of perceptual deviation as well as syntactic processes of an argument structure. The nature of the OSP component is discussed.

Linguistic processes: Other

G60

PATHS, MANNERS, AND OBJECTS *Alexander Kranjec[1,2], Eileen Cardillo[1,2], Anjan Chatterjee[1,2]; [1]Hospital of the University of Pennsylvania, Neurology, [2]The Center for Cognitive Neuroscience, the University of Pennsylvania* – Languages segregate information about an object's trajectory (PATH) and an object's intrinsic motion (MANNER) into different parts of speech (e.g. prepositional phrases and verbs in English). Previous work using fMRI (Wu, Morganti & Chatterjee, 2007) found dissociable neural networks mediating the representation of an object's path versus its manner of motion, suggesting a further parsing of the where motion processing streamóinto dorsal areas for path and ventral areas for manner. These results support the hypothesis that neural segregation of motion processing parallels the structuring of events by language. There are reasons for thinking that these two kinds of motion processing rely on distinct reference frames. For example, compared to path, manner entails motion intrinsic to an object's general form, generating the further hypothesis that processing manner attributes is more closely linked to object processing. To test this, we extended the one-back task from Wu et al. to include multiple agents. In a blocked design, participants attended to changes in either the form of the agent, its path, or its manner. Participants found path changes equally salient regardless of whether they co-occurred with manner or agent changes. In contrast, participants had greater difficulty detecting a change in manner performed by a different agent. Results support a neural model of motion processing in which manner more than path of motion is linked to the identification of objects.

G61

EFFECTS OF MULTIPLE REPETITIONS ON THE FUNCTIONAL NEUROBIOLOGY OF READING *Karen Aicher[1,2], Jay Rueckl[1,2], W. Einar Mencl[1], Stephen Frost[1], Shin-Yi Fang[1,2], Kenneth Pugh[1,3]; [1]Haskins Laboratories, [2]University of Connecticut, [3]Yale University School of Medicine* – Increased familiarity with words and nonwords has been associated with changes in cortical activation patterns. Whether the activation increases or decreases in response to a learning task has been hypothesized to be related to the extent to which the particular item has been overlearned at the time of measurement. We examined the response of twenty typical readers to different repetition conditions on a pseudoword oral reading task using functional magnetic resonance imaging (fMRI). During a pre-scanning training session, participants were asked to read monosyllabic, pronounceable pseudowords into a microphone. Pseudowords were presented once, twice, four times, or eight times during that session. Participants then completed a similar oral reading task in the scanner with the repeated items from the out-of-scanner training session, as well as novel pseudowords. Repetition related changes in activation were noted in left hemisphere areas strongly associated with reading functions. Specifically, more repetition led to increased activation in the middle temporal gyrus, which has been hypothesized to be part of a ventral reading system which may be semantically tuned. Increased activation was also noted in the supramarginal gyrus, which has been considered to be part of a dorsal reading system, and has been associated with phonological analysis. Nonmonotonic changes were noted as a function of repetition in some areas, including the inferior frontal gyrus, an area that has been postulated to be part of an anterior circuit which may be involved with phonological memory and recoding. Implications for normal and impaired readers are discussed.

G62

PERCEIVING CATEGORY, AFFECT AND GENDER IN THE SAME SET OF WORDS: AN MEG STUDY USING VISUAL-AUDITORY PRIMING TASK *Yang Zhang[1], Toshiaki Imada[2,3], Masaki Kawakatsu[3], Keita Tanaka[3], Atsushi Aoyama[3], Sharon Miller[1], Iku Nemoto[3]; [1]University of Minnesota, Speech-Language-Hearing Sciences, [2]Institute for Learning and Brain Sciences, University of Washington, [3]Research Center for Advanced Technologies, Tokyo Denki University* – Human speech contains not only the structure of a language but also important information about the speaker's identity and emotional affect. This study employed whole-head magnetoencephalography (MEG) to examine Japanese adults' perception of category, affect and gender for a set of English words. Seven subjects participated in the visual-auditory priming task. The visual stimuli that were presented 500 ms prior to auditory stimuli consisted of static pictures of letters ("L" or "R") for Category Condition, happy or sad cartoons for Affect Condition, and male or female cartoons for Gender Condition. The digitally edited auditory stimuli used the same set of words recorded from native English speakers (one male and one female) producing the words "right" and "light", intended to convey either happy or sad mood. Subjects were required to respond whether the auditory word was congruent with the preceding visual prime or not. The experiment started with a familiarization phase, which was immediately followed by the test phase. At least 80 trials were averaged for congruent and incongruent responses in each condition. As expected, behavioral results in both accuracy and reaction times revealed an increasing order of difficulty from gender to affect to category perception across the subjects. Minimum Current Estimate analysis of the MEG data indicated different patterns of hemispheric and regional involvement for the three conditions when the congruent responses were subtracted from the incongruent responses. Taken together, the results support the plurality of neural representations of speech at the cortical level and their dependency on selective attention.

G63

NEURAL CORRELATES OF LANGUAGE LEARNING IN EXCEPTIONAL CIRCUMSTANCES: AN EVENT-RELATED POTENTIAL STUDY *Nils Skotara[1,2], Monique Kügow[1,2], Uta Salden[1], Barbara Hänel-Faulhaber[3], Brigitte Röder[2]; [1]Research Centre 538: Multilingualism, University of Hamburg, [2]Biological Psychology and Neuropsychology, University of Hamburg, [3]Educational sciences, Section II: Perception & Communication, University of Hamburg* – Most studies investigating sensitive or critical periods for language acquisition compare native speakers and second language (L2) learners. A possible sensitive or critical period for the acquisition of a first language (L1) can only be investigated in people grown up in exceptional circumstances, for example in deaf people born to hearing parents unable to use a natural language with their child. The present study compared (1) native signers of German Sign Language (DGS) who had learned written German as an L2, (2) late signers who had learned both, DGS as an L1 and written German (as an L2) after school enrolment, and (3) hearing L2-learners of German. Written German sentences were presented while the EEG was recorded. In half of the sentences a semantic (implausible object) or a syntactic violation (verb agreement violation) was embedded. Participants had to decide whether or not the sentence was correct. The behavioural data revealed a better performance for hearing L2-learners and native signers than for late signers. A subgroup of late signers performed similarly as the native signers. In all groups, semantic violations elicited an N400 followed by a late positivity and syntactic violations elicited a P600. After syntactic violations a left lateral negativity was observed in hearing L2-learners. By contrast, a bilateral negativity was observed for the native and late signers. These data suggest that language deprivation affects the cerebral organization of language processing.

G64

MULTIPLE PHONOLOGICAL REPRESENTATIONS BECOME ACTIVE WHEN READING JAPANESE KANJI: CASCADING ACTIVATION AFTER ALL? *Rinus Verdonschot[1,2], Katsuo Tamaoka[3], Clemens Poppe[4], Niels Schiller[1,2]; [1]Leiden Institute for Brain and Cognition, [2]Leiden University Centre for Linguistics, [3]Graduate School of Language Education, Reitaku University, [4]Centre for Japanese and Korean Studies, Leiden University* – An unresolved issue in psycholinguistics is whether activation spreading is limited to selected instead of 'merely' activated lemmas. For instance, Levelt et al. (1991) found that a to-be-named target lemma (e.g. sheep) spreads activation to the word-form level but not to categorically or associatively related lemmas (like goat or wool), supporting discrete processing. Peterson and Savoy (1998), however, reported evidence for phonological activation of (near-) synonyms like couch and sofa, providing evidence for cascading processing. These latter results were attributed by discrete models to be special cases of processing. We employed a masked priming paradigm using Japanese kanji which are more commonly synonymous. Many kanji symbols are 'synonymous' in the sense that they have multiple readings though the meaning does not necessarily change (unlike homographs). For instance, the symbol for water, ?, can be read as /mizu/ or /sui/ and instances of both readings can easily be found, e.g. ?? (/kai-sui/; seawater) or ?? (/ama-mizu/; rainwater). Therefore, this symbol has two possible readings, but its meaning water does not change. Using katakana transcriptions (phonetic script) of these possible pronunciations we were able to show that multiple katakana targets could successfully be primed by the same kanji prime. These findings provide further evidence for cascaded processing in lexical access.

G65

RESPONSES TO TWO TYPES OF BEHAVIORALLY RELEVANT VARIABILITY IN SPEECH IN A PASSIVE FMRI PARADIGM *Jason D. Zevin[1], Jianfeng Yang[1], Jeremy I. Skipper[1], Bruce D. McCandliss[1]; [1]Sackler Institute for Developmental Psychobiology, Weill Cornell Medical College* – In order to explore the networks that underlie perception of different aspects of speech, we conducted a passive listening experiment designed to elicit change detection responses due to two different types of change -- change between speakers and change between phonetic categories -- relative to a repeat condition in which both speaker and phonetic category were held constant, but other acoustic parameters varied naturally (intonation, duration, voice quality, etc.). Contrasts comparing both change conditions to the repeat baseline revealed a common network engaged by behaviorally-relevant acoustic changes both with respect to voice and phonetic category, whereas contrasts between the two change conditions revealed independent networks specific to each type of change.Exploratory analyses of correlations among regions in the broader change network and how these are modulated by condition will complement the simple contrasts and provide greater detail about how the functional anatomy for speech perception flexibly reorganizes in the face of changes in the predictability of different stimulus attributes.

G66

RELATIVE CONTRIBUTION OF PHONOLOGICAL SKILLS AND MEMORY IN READING: THE CASE OF PROFOUNDLY DEAF INDIVIDUALS *Elizabeth A. Hirshorn[1], Matthew W.G. Dye[1], Peter C. Hauser[2], Daphne Bavelier[1]; [1]Brain and Cognitive Sciences & Center for Language Sciences, University of Rochester, [2]National Technical Institute for the Deaf, Research and Teacher Education, Rochester Institute of Technology* – In hearing people, one of the best predictors of reading fluency is phonological awareness, which depends heavily on access to sound. With little-or-no access to the sounds of spoken language, deaf individuals may need to rely on different routes to literacy. This work evaluates the cognitive processes through which profoundly deaf individuals achieve such literacy. We developed new deaf-friendly assessments for factors known to predict reading skills in hearing individuals. These include picture-based phonological tasks and tests of memory (serial and free recall). Factors hypothesized to predict reading in deaf individuals, such as speech-reading and sign language fluency, were also examined. Results confirmed the strong relationship between phonological skills and reading in hearing individuals. In contrast, memory measures, especially free recall, were the best predictors of reading skills in deaf individuals. Interestingly, speech-reading was a good predictor of reading in hearing but not in the deaf. Brain imaging during single word and sentence processing by deaf readers revealed similar neural networks to those previously described in the literature. Interestingly, phonological skills correlated strongly with activation in single word processing areas, whereas free recall correlated strongly with activation in sentence level processing areas. Deaf readers, therefore, seem to differentially weigh phonological and memory strategies as a function of task demands during reading. Since reading is typically used in the service of text comprehension, this work highlights the importance of memory skills in reading fluency in deaf individuals.

G67

BOTH BEHAVIORAL AND NEURAL INDICES OF PHONOLOGICAL ABILITY PREDICT READING FLUENCY IN SKILLED ADULTS: AN FMRI INVESTIGATION OF PASSAGE READING *Allison Zumberge[1], Frank Manis[1,2], Zhong-Lin Lu[1,2]; [1]Neuroscience Graduate Program, University of Southern California, [2]University of Southern California, Psychology* – Studies of reading development and disability have identified phonological ability as a major contributor to reading fluency in children. The relationship seems to hold across a wide range of adult, skilled readers, as well, but its neural basis has yet to be identified. Additionally, reading tasks used in functional MRI studies of phonological ability generally employ single-word stimuli, a design with many benefits but little ecological validity. The present study investigated the relationship between reading fluency and fMRI activity within the phonological processing network using a self-paced passage reading task. First, we identified regions of interest for phonological processing with fMRI, using adults' performance on a phonological lexical decision task involving judgments about whether a pseudohomophone or pseudoword sounded like a real word. This task activated a network of brain regions that only partially overlapped with

the network activated by the passage-reading task, which additionally recruited middle and polar temporal regions. In order to examine the predictive power of phonological ability on reading fluency, both behavioral and neural indices of phonological processing were correlated with behavioral scores on an oral passage reading task. While neural activity in anterior and posterior IFG during the passage-reading task was positively correlated with overall reading fluency, posterior IFG contributed to the accuracy component of fluency while anterior IFG and occipito-temporal region contributed to the rate component. The results reveal that somewhat different phonological and orthographic processing regions in the brain contribute to accuracy and rate components of oral reading skill.

G68

ASYMMETRIC PHONOLOGICAL PREDICTIONS IN SPEECH PERCEPTION: MEG EVIDENCE *So-One Hwang[1], Philip Monahan[1], William Idsardi[1,2]; [1]University of Maryland, Linguistics, [2]Neuroscience and Cognitive Science Program, University of Maryland* – Do phonological processes influence speech perception symmetrically? In this study, we examine a pervasive cross-linguistic generalization: coda obstruent clusters must agree in voicing. That is, in many languages (including English) word-final phonetic sequences such as [dz] and [ts] are acceptable whereas *[ds] and *[tz] are not. This grammatical constraint implies symmetric processing difficulties with heterogeneous clusters, e.g. *[tz], *[ds]. However, Lombardi (1991) proposes instead that only [+voice] is lexically represented, default [-voice] being underspecified, implying asymmetric processing of heterogeneous clusters. Using MEG, we examine the time course of the prediction of the upcoming signal comparing symmetric and asymmetric predictions. Given that early auditory processes are observable by 100ms and lexical effects by 300ms, we expect to find differences within this time-window. Four types of clusters were created by splicing or cross-splicing VCC tokens: vd-s [uds, ubs, ugs], vd-z [udz, ubz, ugz], vl-s [uts, ups, uks] and vl-z [utz, upz, ukz]. Participants (n=13) passively listened to randomly presented stimuli during MEG recording (160-channel; KIT, Japan). Because of the complexity of the stimuli, we analyzed RMS difference waveforms to cluster types with the same fricative. In the time window 100-300ms, we find significant differences between the MEG response to vd-s as compared to vl-s ($p<0.05$). This finding suggests that only marked features induce predictions about the upcoming speech signal, and these effects are present in early cortical responses. Such findings are consistent with phonological underspecification theories, e.g. Lombardi (1991) and Obleser, Lahiri and Eulitz (2004).

G69

EFFECTIVE FUNCTIONAL CONNECTIVITY OF PHONOLOGICAL AND SEMANTIC PROCESSING DURING WORD READING *Cheryl M. Capek[1,2], Simandeep Poonian[1], Joseph T. Devlin[1,2]; [1]Cognitive, Perceptual and Brain Sciences, University College London, UK, [2]Institute of Cognitive Neuroscience, University College London, UK* – Numerous lesion and neuroimaging studies of language processing have shown that reading reliably engages left hemisphere regions including the ventral occipito-temporal cortex (vOTC), temporo-parietal regions and the inferior frontal cortex (IFC). In addition, neuroimaging and neurostimulation studies have found evidence of functionally distinct subdivisions within the left IFC, with phonological processing preferentially involving more posterior regions (i.e., pars opercularis) and semantic processing preferentially involving more anterior regions (i.e., pars orbitalis/triangularis). Identifying the manner by which these brain regions are engaged in phonological and semantic processing offers valuable insight into how a distributed brain network mediates successful reading. In the present study, we used functional magnetic resonance imaging to identify the functional neural organization of word reading in monolingual speakers of British English as they read blocks of word pairs, alternating with a fixation baseline. For each word pair, participants performed either a phonological (rhyme) or semantic (category) judgment task. Participants displaying activation in four left hemisphere regions of interest (ROIs), namely vOTC, supramarginal gyrus, pars opercularis and pars orbitalis/triangularis were included in the effective functional connectivity (dynamic causal modeling; DCM) analysis (n=23). Bayes Factors (BFs) were employed to assess different DCM models of fronto-parietal-vOTC connectivity. The results showed strong bidirectional, intrinsic connections between the four ROIs, with the strongest connections from the vOTC to the parietal and frontal ROIs. The results provide evidence of both bottom-up and top-down processing in the brain network mediating reading.

G70

STATISTICAL CUES TO PHONETIC CATEGORY STRUCTURE *Emily Myers[1], Sheila Blumstein[1]; [1]Brown University, Cognitive and Linguistic Sciences* – Recent research suggests that the statistical distribution of speech sounds plays a role in shaping sensitivities to acoustic-phonetic space and ultimately in forming the sound categories of one's native language. These studies have shown that participants familiarized with stimuli from a non-native phonetic continuum show greater sensitivity to the endpoints of the continuum when they hear tokens sampled from a bimodal distribution than when they hear tokens sampled from a unimodal distribution. What is less clear are the neural mechanisms which mediate these effects. In the current study, functional magnetic resonance imaging was used to monitor activation patterns in participants who had been familiarized with tokens from a bimodal or unimodal distribution taken from a non-native continuum. Neural sensitivity to phonetic differences was measured using a short-interval habituation paradigm, in which four repeated phonetic tokens were followed by either a different token from the continuum (Change trials) or a fifth repeated token (Repeat trials). Behavioral sensitivity was also measured after scanning using a discrimination task. Both groups showed neural sensitivity to the endpoints of the novel continuum, as indicated by greater activation for Change trials than Repeat trials. However, the Bimodal group showed the greatest response in the left supramarginal gyrus and posterior superior temporal gyrus, whereas the Unimodal group showed the greatest response in the posterior and anterior left superior temporal sulcus. These results suggest that activation in the supramarginal gyrus reflects the emergence of phonetic category representations, whereas activation in temporal areas reflects earlier stages of acoustic processing.

G71

THE ROLE OF AWARENESS IN SEMANTIC AND SYNTACTIC PROCESSING: AN ERP ATTENTIONAL BLINK STUDY *Laura Batterink[1], Christina Karns[1], Yoshiko Yamada[1], Eric Pakulak[1], Helen Neville[1]; [1]University of Oregon* – The role that automatic and controlled processes play in semantic and syntactic processing is not well understood. In semantic priming studies, there is a lingering debate about whether the N400, an ERP component elicited by unexpected linguistic stimuli, reflects an automatic or controlled, post-lexical process. Syntactic priming, specifically word category priming, has been even less well characterized. We used an attentional blink (AB) paradigm, which can be used to manipulate the role of awareness in the processing of target words, to assess automaticity in semantic and syntactic processing. We compared ERP responses to targets occurring within the AB period to targets occurring outside the AB period, and compared ERPs to correctly-reported versus missed targets. In the semantic block, primes and targets were either semantically related or unrelated, and in the syntactic block, primes and targets formed either syntactically congruent or incongruent phrases. In the semantic block, targets occurring both within and outside the AB period elicited an N400. However, N400 amplitude was significantly reduced during the AB period, and missed targets did not elicit an N400. In the syntactic block, a late negative syntactic congruency effect was elicited by targets occurring outside the AB period while targets occurring within the AB period showed no effect of congruency. Semantic results support the argument that the N400 is primarily an index of a controlled, post-lexical process. Syntactic findings suggest that the brain

response to some syntactic violations depends on awareness and availability of attentional resources.

G72

INVESTIGATING THE DEFICIT IN PHONOLOGIC ALEXIA: AN EYE-TRACKING STUDY *Tamar D. Gefen[1], Elizabeth H. Lacey[1,2], Sarah Ferguson Snider[1], Susan Nitzberg Lott[1], David P. Roeltgen[1], Rhonda B. Friedman[1]; [1]Georgetown University Medical Center, Center for Aphasia Research and Rehabilitation, [2]Interdisciplinary Program in Neuroscience, Georgetown University* – Phonologic alexia (PhA) is an acquired disorder characterized by impaired reading of pseudowords relative to real words and, often, a greater difficulty reading functors (e.g., "it", "for") than concrete nouns. We hypothesize that the deficit is due to insufficient activation of phonological codes, causing impairment in reading words with low semantic value, especially when these words are surrounded by words with higher semantic value, as in text. This would predict that reading functors surrounded by words with high semantic value would be more difficult than reading functors surrounded by words with little, or no, semantic value. We investigated our hypothesis by testing functor reading in a chronic PhA patient, TJN, using an eye-tracking technique. Three sets of 40 functors were matched for frequency, number of syllables and number of letters. Functors were embedded in three-word phrases, surrounded by either two highly concrete words (CON), two abstract words (ABS), or two non-pronounceable letter strings (LS). TJN was asked to read aloud only the functor. Dwell times (DT) and number of fixations were evaluated. Results revealed longer DT on functor words in the CON condition (821 ms) than in the ABS (630 ms) or LS condition (598 ms); number of fixations on the functor displayed the same pattern. In contrast, DT on surrounding words (non-functors) or letter strings did not vary significantly across conditions. These results are consistent with our hypothesis that surrounding words with high semantic value interfere with the reading of functors in patients with PhA.

G73

DOMAIN-SPECIFIC OR SHARED MECHANISMS OF PROSODIC PHRASING IN SPEECH AND MUSIC? NEW EVIDENCE FROM EVENT-RELATED POTENTIALS *Karsten Steinhauer[1,2], Stefanie Nickels[3], Conrad Duncan[2], Kanwar Anit Singh Saini[1,2]; [1]Centre for Research on Language, Mind, & Brain, McGill University, [2]School of Communication Sciences & Disorders, McGill University, [3]Saarland University, Psychology* – Prosodic information (the intonation and rhythm of speech and music) has a major impact on how listeners parse and interpret the auditory signal. Prosody guides syntactic sentence analysis, supports language acquisition, and underlies our cognitive organization of melodies (Lerdahl and Jackendoff, 1983). Whether the neurocognitive mechanisms underlying prosodic phrasing are shared between language and music is controversial. In speech, prosodic boundaries reliably elicit a positive-going ERP component with short latencies (0-300ms) timelocked to PRE-boundary words: the Closure_Positive_Shift (CPS; Steinhauer et al., 1999). A CPS-like ERP pattern was also reported for musical boundaries, however much later (around 500ms following POST-boundary tones) and only for highly trained musicians (Neuhaus et al., 2006), while non-musicians displayed negativities. This contrasts strongly to the speech-CPS, which has been found for hummed sentences, and even in pre-linguistic infants (e.g., Pannekamp et al., 2006). Our ERP study employed a speech/music-continuum to localize the transition from music-like to speech-like boundary effects in 16 non-musicians. All stimuli were derived from sentences with boundaries that elicited a CPS in a previous study and ranged from (i) the original speech signals to (ii) computer-generated "hummed" versions and (iii) sine waves preserving the pitch contour to (iv) corresponding melodies played with either piano or horn timbre. Data revealed CPS components at boundaries across conditions, however with varying latencies. This finding demonstrates that musical phrasing can elicit a CPS even in non-musicians, compatible with common mechanisms in speech and language. Factors contributing to latency effects and differences among studies will be discussed.

G74

MORPHOMETRIC AND FUNCTIONAL NEUROANATOMY OF RAPID NAMING, PHONOLOGICAL PROCESSING AND WORD IDENTIFICATION IN CHILDREN WITH A WIDE RANGE OF READING ABILITY: IMPLICATIONS FOR THE DOUBLE-DEFICIT HYPOTHESIS OF DEVELOPMENTAL DYSLEXIA *Jessica M. Black[1], Masanori Nagamine[1], Allan L. Reiss[1], John D. E. Gabrieli[2], Fumiko Hoeft[1]; [1]Center for Interdisciplinary Brain Sciences Research, Stanford University School of Medicine, [2]Harvard-MIT Division of Health Sciences and Technology (HST) and Brain and Cognitive Sciences, Massachusetts Institute of Technology* – The double-deficit hypothesis (DD) posits that naming speed is an independent core deficit in addition to the phonological processing deficits seen in individuals with developmental dyslexia. According to this theory, individuals with a 'double-deficit' have more severe deficits in reading than those with single deficits or without any deficits. It is not yet clear, however, how these deficits are related to each other and to reading. Examination of the neural substrates of these processes may have substantial implications not only in understanding the DD, but also for the identification and treatment of reading disabilities. We therefore examined the relationship between morphometric and functional neuroanatomy and these skills. Participants were 62 children (age 13.5 + 2.6) representing a wide range of reading skills from severely impaired (meeting the criteria for dyslexia) to superior. A standard battery of neuropsychological assessment was given including rapid naming of letter and number (RAN) and real word identification (ID). In addition, we collected high-resolution MRI data to examine regional gray matter volume and functional magnetic resonance imaging (fMRI) data during a real word rhyme judgment task to examine phonological processing. Voxel-based morphometry (VBM) analyses identified overlapping regions that showed significant positive correlations with regional volume and RAN as well as ID in the left supramarginal, posterior superior temporal, precentral and inferior frontal gyri. Regions involving the cerebellum showed negative correlation. These regions also showed significant associations with fMRI activation during phonological processing. These findings suggest that these regions maybe critical in the DD.

G75

RETHINKING THE P600/P300 DEBATE: EVENT-RELATED POTENTIAL ADDITIVITY AS AN INDEX OF OVERLAP IN NEUROCOGNITIVE RESOURCES *Geoff Valentine[1], Lee Osterhout[1]; [1]University of Washington, Psychology* – Many claims have been made about the domain specificity of the neural mechanisms subserving syntactic processing using evidence from event-related potentials (ERPs). Violations of linguistic syntactic expectancy elicit the P600 component of the ERP waveform while a wide range of violations of expectancy across many domains elicit a P300b. Although superficially similar (both are late positivities), these components are additive which has lead some to conclude that, by definition, they are driven by at least partially distinct neurocognitive processes. We carried out two studies in which we recorded ERPs from 64 channels on the scalp while subjects read English sentences. In the first experiment a 2x2 design was employed in which the critical word was either consistent with or violated expectation in syntax and/or capitalization. In the second experiment we again used a 2x2 design in which the critical word could violate expectation in capitalization and/or text color. If the assumption of the independence of the electrophysiological sources of the P600 and the P300b components is correct, then additivity should only be present in the syntax/capitalization and not the capitalization/color conditions. The presence of substantial additivity in both experiments suggests that a binary division of the late positive complex into the P600 and P300b is artificial, and, moreover, that the amount of additivity between two conditions can be used as an index of the amount of neurocognitive resources they share.

G76

STRUCTURAL AND PRAGMATIC LANGUAGE PROFILES OF MALES AND FEMALES WITH AN EXTRA X CHROMOSOME

Nancy Raitano Lee[1], Gregory Wallace[1,2], Liv Clasen[1], Jonathan Blumenthal[1], Rhoshel Lenroot[1], Jay Giedd[1]; [1]Child Psychiatry Branch/NIMH/National Institutes of Health, [2]Laboratory of Brain and Cognition/NIMH/National Institutes of Health – The presence of an additional X chromosome characterizes Klinefelter (XXY) and Trisomy X (XXX) syndromes. Intelligence tends to be in the low average to average range for these disorders; however, language deficits are often reported. The nature of these deficits, and in particular, the presence of pragmatic (i.e., social) language impairment, has not been thoroughly investigated. This study utilized the Children's Communication Checklist - 2, a parent-report measure of structural and pragmatic language skills with eight scales divided into two domains (Structural language= Speech, Syntax, Semantics, Coherence; Pragmatic language= Initiation, Scripted Language, Context, Nonverbal Communication) to compare the language profiles of 17 XXY males (age: 12.09±2.94) and 21 XXX females (age: 9.06±2.32). Overall, both groups scored below the normative mean of 100 for the measure (Composite score means for XXY= 89.41±10.53 and XXX = 85.48±19.11; p's<.05). On the individual structural language scales, the XXY group scored below the normative mean on two scales, Semantics and Coherence (this latter scale measures the ability to communicate the content of one's thoughts clearly), while the XXX group scored significantly below the normative mean on all four scales (all p's <.05 with Bonferroni correction). For the pragmatic language scales, both groups scored below the normative mean on the Context scale (a scale that assesses abstract, nonliteral language, flexibility, and humor; p<.05 with Bonferroni correction). These results will be discussed in relation to the larger XXY and XXX neurobehavioral phenotypes.

G77

INFLUENCES ON LANGUAGE-RELATED LEARNING MECHANISMS: AN FMRI STUDY OF WORD SEGMENTATION IN CHILDREN

Kristin McNealy[1], Larissa Borofsky[1], John Mazziotta[1], Mirella Dapretto[1]; [1]UCLA Brain Mapping Center – Significant progress has recently been made in delineating the functional representation of language in the developing brain. However, we still know relatively little about the neural basis of the actual process of language learning, and even less about how the neural correlates of language learning might be related to individual differences in linguistic skills and experiential factors. In the present study, we began to address these issues by relating several behavioral measures collected in a large sample of ten-year-old children (n=78) to brain activity associated with a critical aspect of language learning (i.e., word segmentation, the detection of word boundaries in a novel stream of continuous speech). Using fMRI to examine online word segmentation, we previously demonstrated that children and adults exhibit learning-related signal increases over time in bilateral superior temporal gyri (STG) and left inferior parietal lobule (IPL). Here, we found that children's literacy skills were positively related to signal increases in bilateral STG; in contrast, both children's reading ability and verbal IQ were negatively correlated with signal increases in IPL. Interestingly, the degree of fluency in a second language was also positively correlated with signal increases in bilateral STG, suggesting that these regions play an important role in supporting successful language-related statistical learning. These findings begin to elucidate the complex relationship between linguistic experience and language learning and have implications for current theories of the neural basis of language acquisition. Support Contributed by: National Science Foundation, UCLA Ahmanson-Lovelace Brain Mapping Center, UCLA-FPR Center for Culture, Brain, and Development

G78

AN ELECTROPHYSIOLOGICAL STUDY OF THE EFFECTS OF READING SKILL ON WORD AND PSEUDOWORD PROCESSING IN ADULTS

Maya Misra[1], Beth Friedman[2], Joyce Tam[1], Kristen Mettley[1], Bridgid Zvirblis[1]; [1]The Pennsylvania State University, University Park, PA, [2]University of Pittsburgh, PA – Previous studies have shown that, even among typical adults, variations in language abilities may be associated with differing patterns of neural responses to linguistic stimuli measured with event-related potentials (ERPs). The current study focused on the effects of reading skill on ERPs, with a specific interest in evaluating evidence for sensitivity to phonology among adult readers. Prior research has suggested that while phonology is activated automatically during reading, phonological effects may vary with skill level, even among practiced adult readers. The current study was designed to further evaluate evidence that different reading strategies may be employed by proficient readers of English. Participants completed a detailed reading history questionnaire and were assessed with a battery of standardized tests designed to measure orthographic and phonological processing as well as connected text reading and comprehension. Participants then returned to the lab at a later date to complete a semantic monitoring task including word and pseudoword stimuli which varied systematically in their orthographic and phonological properties while 32 channels of ERPs were recorded. Preliminary results suggest that there was significant variability in performance on tests of phonological memory, spelling, and connected text reading fluency and comprehension among these skilled readers. Furthermore, the amplitude of the N400 component of the ERP waveform was sensitive to subtle variations in reading skill, particularly as indexed by the behavioral measures of connected text reading and comprehension. Results will be discussed in terms of models of skilled reading.

G79

PRIMING METHODS IN APHASIA: REVISITING SLOW LEXICAL ACCESS

Josee Poirier[1], Tracy Love[2,3], Lewis Shapiro[2]; [1]SDSU/UCSD Joint Docotral Program in Language & Communicative Disorders, [2]San Diego State University, [3]University of California, San Diego – A slowdown in lexical processing has been implicated in sentence comprehension deficits in aphasia. Support for such protracted processing comes from the use of Cross-Modal Priming (CMP). Sentences are presented aurally, while participants are required to make a decision on a visual probe that occurs at strategic points during the unfolding of the sentence. Faster RTs to associatively related probes compared to unrelated probes reflect priming of the target lexical item. Left anterior-lesioned aphasics, unlike unimpaired controls, do not show associative priming (AP) in the immediate vicinity of the target lexical item; instead, AP is only observed 'downstream' (Love et al., 2008). In fact, in List Priming Paradigm studies where lexical decisions are made to individual words that occur one after the other, aphasic individuals reveal AP only at Stimuli-Onset-Asynchronies of >1500ms (Henik et al, 1993; Prather et al.,1997). We hypothesized that the delayed activation patterns in sentences observed with CMP may be due to the long SOA required to elicit AP effects. In a CMP sentence comprehension study, we probed for an overt noun at its offset, using either associatively related probes (e.g., nurse–doctor), or identity probes (IP; e.g., nurse–nurse). Eight left anterior-lesioned aphasics completed the study. We computed related-to-control RT ratios, where a ratio <1 indicates priming. Identity priming was observed (mean:0.949, t(7)=-2.726, p=0.01,one-tailed) but associative priming was not (mean:1.000, t(7)=0.253, p>0.05,one-tailed). We discuss this distinction between CMP-AP and CMP-IP in terms of hypothesized lexical and syntactic deficits in aphasia.

G80

AN FMRI INVESTIGATION OF REPEATED NAME AND DEFINITE REFERENCE IN DISCOURSE

Amit Almor[1,2], Veena Nair[3], Jeremy May[1], Timothy Boiteau[2]; [1]University of South Carolina, Psychology,

[2]*University of South Carolina Linguistics Program,* [3]*University of Wisconsin Madison, Radiology* – Repeated reference is an important part of coherent discourse but very little is known about the brain basis of processing repeated reference in discourse. A recent functional magnetic resonance imaging (fMRI) study (Almor, Smith, Bonilha, Rorden, & Fridriksson, 2008) found that reading a repeated proper name reference (e.g., Joe) to a salient discourse referent leads to increased activation in temporal regions and intra-parietal sulcus (IPS) in comparison to reading a pronoun reference (e.g., he). This was interpreted as indicating the involvement of spatial brain circuits (IPS) in the management and manipulation of representations of discourse referents (temporal regions). Here we report two fMRI experiments that further evaluated this hypothesis. The first experiment tested whether the salience of referents in the context of the discourse affects these activations. In support of the original hypothesis, we found that the referent salience affected activation in parietal regions. The second experiment tested whether similar activations occur for definite description references (e.g., the man) to salient and non salient referents. Although we found that referent salience also affects the activation associated with repeated definite references, the activation was in different regions than for repeated names. Activations associated with repeated definite description references did not occur in any parietal regions but instead included several frontal areas as well as the left and right caudate. These findings thus suggest that the processing of linguistic reference in discourse involve multiple circuits and mechanisms that are associated with the use of different referential forms.

G81

THE BRAIN USES CO-SPEECH GESTURES TO SET THE CONTEXT FOR SPEECH UNDERSTANDING *Jeremy Skipper*[1], *Ran Liu*[1], *Bruce McCandliss*[1], *Jason Zevin*[1]; [1]*Sackler Institute for Developmental Psychobiology, Weill Medical College of Cornell University* – Does the brain use the wealth of contextual information that accompanies speech during real-world communication? Or is this information treated as noise, secondary to the process of linguistic interpretation? We collected fMRI data while participants watched a television game show. We used a combination of analysis techniques including independent component, peak-and-valley (based on extensive stimulus annotation), and directional functional connectivity (i.e., Granger causality) analysis to discover meaningful patterns in data resulting from a natural stimulus. Peak-and-valley analyses of the independent component time series identified different networks of interest (NOIs) with high selectivity for stimulus periods containing speech, co-speech gesture, and non-communicative hand and arm movements respectively. The speech selective NOI was comprised of primarily bilateral anterior superior temporal and ventral premotor cortex. The co-speech gesture selective NOI comprised bilateral SMA, dorsal premotor, insula, and parietal areas. The non-communicative hand and arm movement NOI comprised bilateral occipital and parietal areas. Functional connectivity analysis showed that the co-speech gesture NOI drove the speech NOI. This was not the case for the non-communicative hand and arm movement NOI. These results suggest that the motor system is involved in extracting meaningful information from co-speech gesture that later influences areas sensitive to verbal content. This supports a model of communication in which the brain actively makes use of context to predict forthcoming sensory information to constrain linguistic interpretation. At least some forms of context, therefore, are not secondary but integral to achieving understanding in natural settings.

G82

AN FMRI INVESTIGATION ON PAST TENSE PROCESSING OF NATIVE AND NONNATIVE ENGLISH SPEAKERS *So-Hee Kim*[1]; [1]*The University of Texas at Austin* – The goal of this study was to determine whether native (L1) and nonnative (L2) speakers of English use the same brain regions when they generate regular and irregular past tense verb forms. By using event-related functional magnetic resonance imaging (fMRI), the study compared the neural responses of 16 Korean speakers of English (16 males, age range 19-35, mean age ± SD = 25.12 ±5.12) with the neural responses of 16 native English speakers (1 female, age range 19-35, mean age ± SD = 25.87 ±5.00) as both types of speakers internally generated the morphologies of regular and irregular past tense verb forms in English. According to the neuroimaging data, both types of language speakers, at least to some degree, activated the same respective brain regions when they processed regular and irregular past tense verb morphological inflections. Specifically, in both L1 and L2 speakers, under non-contrast imaging analysis conditions, regular past tense generation involved left-hemispheric lateralization patterns, whereas irregular past tense generation elicited widespread bilateral brain responses. Thus, no notable imaging contrasts were found between L1 and L2 speakers when they generated regular and irregular past tense verbs, respectively. The study concluded that past tense morphological processing involved neural regions common to both native and nonnative English speakers.

G83

COMPREHENSION OF M-SEQUENCE MODULATED SPEECH SOUND: ACTIVATION IN THE RIGHT INFERIOR FRONTAL GYRUS AND THE LEFT INFERIOR PARIETAL LOBE AS REVEALED BY FMRI *Hiroshige Takeichi*[1,2,3,4], *Sachiko Koyama*[5,4], *Atsushi Terao*[6], *Fumiya Takeuchi*[7,4], *Yuko Toyosawa*[4,8], *Harumitsu Murohashi*[8,4]; [1]*BSI, RIKEN,* [2]*RNC, RIKEN,* [3]*IML, University of Tokyo,* [4]*RISTEX, JST,* [5]*RIES, Hokkaido University,* [6]*School of Social Informatics, Aoyama Gakuin University,* [7]*Faculty of Health Sciences, Hokkaido University,* [8]*Faculty of Education, Hokkaido University* – We have developed a new technique for a one-minute assessment of speech comprehension using degraded speech sound by m-sequence modulation and electroencephalograms (EEG) analyzed by circular-cross-correlation function and independent component analysis (Takeichi et al., 2007). As a result, a correlation peak was observed in an independent component correlation function with 400 ms delay. This peak was dependent on whether the modulated speech sound was comprehensible to the subjects. Here we report the results of an fMRI experiment on twenty three right handed Japanese speakers to examine brain areas related to verbal comprehension of the modulated speech sound. A question here was whether the neural system deals with the modulated speech either by increasing the activity of the areas for routine speech processing, or by recruiting additional areas. Activations were observed as follows: the left temporal cortex and a posterior cingulate retrosplenial area in a contrast between the non-modulated forward and reverse speech stimuli; the right inferior frontal gyrus (RIFG) in a contrast between the modulated forward and reverse speech stimuli; and the left inferior parietal lobe (LIPL) in a contrast between the modulated and non-modulated speech stimuli. RIFG and LIPL might have been recruited additionally for contextual processing in comprehension of the speech modulated by m-sequence. Estimated scalp projection of the component correlation function suggested posterior and leftward bias thus a signal source in LIPL.

G84

NEURAL CORRELATES OF DIFFERENCES IN PHONEME-PRODUCTION LOAD IN SCHIZOPHRENIC AND HEALTHY SUBJECTS *Alexander Herman*[1], *Leighton Hinkley*[1], *Mary Vertinsky*[1], *Sophia Vinogradov*[1], *Srikantan Nagarajan*[1]; [1]*University of California, San Francisco* – Schizophrenics exhibit significant executive function deficits, as assessed by a variety of methods, including digit recall, word recall and higher level tests. Furthermore, working memory deficits in schizophrenics have been linked to language comprehension deficits. The brain regions implicated in working memory dysfunction in past studies reflect the functional anatomy of healthy working memory: fMRI studies have shown, for instance, decreased activity in dorsal lateral prefrontal cortex and hippocampus, amongst other areas, even controlling for task performance. MEG and EEG studies also suggest altered activity within the superior temporal plane and diminished inter-hemispheric synchronization. We will present results from a study of the cortical oscillations associated with speech preparation in schizophrenics and controls. Subjects performed a verbal working memory task in which they heard a pre-

recorded two or four phoneme sequence and were instructed to repeat the phoneme sequence, while magnetoencephalographic neural responses were recorded. Schizophrenic subjects exhibited a large variance in the number of correct responses compared to healthy subjects. For this particular analysis, only correct trials were analyzed. Source localization and time-frequency analysis was performed using CTF and NUTMEG software packages. Response-locked differences in activation were computed between the four and two phoneme task for schizophrenic subjects and control subjects separately, and group statistical analyses were performed on contrasts between the conditions. Our results reveal a network of brain regions associated with a load-effect in phoneme-production preparation including the superior temporal gyrus, mouth pre-motor and and dorsolateral prefrontal cortical areas. Furthermore, we show that schizophrenic subjects devoted more cognitive resources in this network to increased phoneme-load than did healthy subjects, suggesting less efficient processing in speech preparation in schizophrenic subjects.

Perceptual processes: Other

G85

AN FMRI ANALYSIS OF STIMULUS SPECIFIC AND STIMULUS-INVARIANT ACTIVATION IN PERCEPTUAL LEARNING *Matthew Mundy[1], Kim Graham[1], Paul Downing[2], Rob Honey[3], Dominic Dwyer[3]; [1]Wales Institute of Cognitive Neuroscience, Cardiff University, [2]Wales Institute of Cognitive Neuroscience, University of Bangor, [3]School of Psychology, Cardiff University* – Unsupervised exposure to a pair of highly similar stimuli can improve subsequent discrimination between them. This is true with many types of stimuli e.g., pictures of faces, random chequerboards, dots and visual scenes (e.g. Mundy et al., 2007). Of particular importance, the schedule of exposure modulates this effect. Alternating two similar stimuli (e.g. AX, BX, AX, BX) during exposure produces larger improvements in discrimination than an equivalent amount of blocked presentation of the two stimuli (e.g. AX, AX... BX, BX...). This schedule effect is the same regardless of the nature of the stimuli used, which implies that the cognitive mechanism for perceptual learning is similar in all cases. However, an earlier imaging study we performed suggested that different neural mechanisms may be recruited in tasks using different types of stimuli (Mundy et al., 2008; see also Graham et al., 2006). In the current event-related fMRI study participants were given intermixed and blocked exposure to confusable face-pair, scene-pair and dot-pair stimuli and subsequently were asked to perform same/different judgements as an index of perceptual learning. Areas of cortex recruited during perceptual learning were identified by contrasting activation associated with discrimination following intermixed presentation with that following blocked presentation. Stimulus-invariant activation was seen in early visual cortex; the exact visual regions involved were pinpointed using a retinotopic mapping technique. Stimulus-selective activation was seen in the parahippocampal place area (scenes), fusiform face area, and perirhinal cortex (faces).

G86

BEHAVIORAL AND ELECTROPHYSIOLOGICAL EFFECTS OF GRADUAL BODY INVERSION *Denise Minnebusch[1], Philipp Keune[2], Boris Suchan[1], Irene Daum[1]; [1]Institute of Cognitive Neuroscience, Neuropsychology, Ruhr-University of Bochum, Germany, [2]Institute of Psychology, Clinical Psychology, University of Tübingen, Germany* – It is a matter of debate, whether the perception of human body forms, like the perception of human faces, is based on configural processing mechanisms. Evidence for configural face processing is the face inversion effect: Faces presented upside down are more difficult to recognize than uprightly presented stimuli and this behavioral face inversion effect correlates with an electrophysiological inversion effect. Body postures produce inversion effects similar to those found for faces both on behavioral and electrophysiological level. In a previous study, the inversion effect was inversed for human bodies presented without heads, with better recognition performance for inverted relative to upright bodies. Comparable findings were obtained on the electrophysiological level. However, the relationship between electrophysiological and behavioral inversion effects remains unclear. The present study aimed to investigate the development of behavioral and electrophysiological body inversion effects depending upon the degree of divergence from the 0? (360?) toward the 180? positions. Additionally, body stimuli were presented with heads (masked face) and without heads, in order to obtain a more detailed description of the effect of the presence of a head at different degrees of display. For human bodies presented with heads, there was a quadratic relationship between the angles of rotation and the behavioural performance as well as the electrophysiological effect. For human bodies presented without heads the results are inconsistent. The results indicate that for body forms presented with heads, different processing mechanisms appear to be involved than for body form presented without heads.

G87

CORTICAL MEG RESPONSE TO VISUAL SOCIAL INTERACTION: HOW GENDER MATTERS *Marina Pavlova[1,2], Michele Guerreschi[1,3], Werner Lutzenberger[2], Ingeborg Krägeloh-Mann[1]; [1]Children's Hospital, University of Tübingen Medical School, Tübingen, Germany, [2]MEG-Center, Institute of Medical Psychology and Behavioral Neurobiology, Tübingen. Germany, [3]University of Padova, General Psychology, Padova, Italy* – The ability of humans to predict and explain other people's actions is of immense value for adaptive behavior and non-verbal communication. Gender differences are often evident in the comprehension of social signals, but the underlying neurobiological basis for these differences is unclear. Combining visual psychophysics with magnetoencephalography (MEG), in healthy adult participants, we assessed gender effects in the induced oscillatory neuromagnetic response to visual social interaction through movement. A robust difference in the induced gamma response was found between females and males over the left prefrontal cortex, a region which has been implicated in perceptual decision making. The induced gamma response peaked earlier in females than in males. Contrary to popular wisdom, the outcome of this study indicates that gender effects are not evident in the network engaged in processing of visual social interaction, but in the regions engaged in perceptual decision making. We assume that differences in brain processing may not only elicit but also prevent behavioral differences, for example, impulsive perceptual decisions, if they are maladaptive.

G88

MOVEMENT-SELECTIVITY OF THE MIRROR SYSTEM DURING IMITATIVE AND COMPLEMENTARY ACTION CONTEXTS *Brenda Ocampo[1], Ada Kritikos[1], Ross Cunnington[1,2]; [1]School of Psychology, University of Queensland, [2]Queensland Brain Institute, University of Queensland* – Viewing actions performed by others activates neural circuits typically involved in the motor planning and execution of those very same actions. Some have suggested that this 'mirror system' is intrinsically involved in imitation, by matching perceived actions directly onto the corresponding motor representations of the observer. Recent evidence has shown, however, that the mirror system is active during the observation and preparation of complementary, non-identical actions (Newman-Norlund et al., 2007). This implies that the mirror system might activate internal motor representations that are dynamically (rather than directly) related to the actions that we observe. We do not know, however, whether the activations found within the mirror system during preparation of complementary actions were due to stimulus-response associations rather than an internal motor mapping of perceived actions. Using functional magnetic resonance imaging (fMRI), we examined the BOLD signal in the inferior frontal gyrus and bilateral inferior parietal lobes while participants observed and executed object-directed actions (whole hand and precision grips towards a wine glass) in

both imitative and complementary contexts. Importantly, in a control condition, participants responded to symbolic cues (upwards and downwards pointing arrows) in both action contexts. The degree of fronto-parietal activation (particularly in IFG) for the complementary condition that was specific to hand actions (and could therefore be attributed to the movement-selective mirror system) rather than more general response selection demands that were constant for both the hand and arrow conditions, will be discussed.

G90

LINE LENGTH, VELOCITY, AND ACCELERATION INTERACTIONS IN LINE BISECTION *Marc Hurwitz[1], James Danckert[1]; [1]University of Waterloo, Waterloo, Ontario, Canada* – When asked to bisect a line, right-handed people typically bisect lines to the left of centre - referred to as pseudo-neglect. Analyses of line bisections show that one of the strongest influences on performance is the scan direction participants take prior to making their judgment. Several theories to explain this phenomenon have been postulated including hemispheric specialization, allocation of visual attention, and endpoint weightings. However, it is also possible that there are space-time interactions involved in line bisection. Because experiments have used a 'free' scanning paradigm, i.e., participants are asked to scan in a certain direction and then bisect the line, it does not control for velocity or acceleration of the smooth pursuit eye movements being made. To control for these factors, we ran a number of line bisection experiments using a touch screen computer and eye tracking to record responses. Participants were first shown a line, followed by a marker that moved across the line at different acceleration and speed levels, and were then asked to quickly and accurately bisect the line by pointing to it. Independent manipulanda included line length, placement on screen, direction of scan, velocity and acceleration of the marker. Results replicated a number previous findings including an influence of line length and scan direction on bisection. While acceleration itself had no influence on line bisection, line length influenced the perception of the speed of the marker suggesting an influence of acceleration on perception but not action.

G91

ARTISTIC PRODUCTION FOLLOWING LEFT BRAIN DAMAGE *Page Widick[1], William B. Smith II[1], Rebecca Sternschein[1], Bianca Bromberger[1], Anjan Chatterjee[1]; [1]The University of Pennsylvania, Neurology and the Center for Cognitive Neuroscience* – Neuropsychological investigations of art production offer critical insight into the neural bases of aesthetics. However, progress in the field is hampered by inadequate measurement instruments. We designed The Assessment of Art Attributes (AAA) to quantify descriptive artwork attributes. The AAA assesses 6 formal-perceptual (color temperature, saturation, stroke, balance, depth, complexity) and 6 content-conceptual attributes (accuracy, animation, abstraction, fantasy, symbolism, emotionality) of art. Target slides consisted of 24 lesser-known paintings by well-known artists. Sixty artistically naïve young normal subjects judged each of the randomly presented paintings on each attribute on a 5-point Likert scale. Significant consistency in attribute judgment supported the use of the AAA. Thirty artistically naive subjects were then shown paintings from two artists with left hemisphere stroke, Zlattu Boyadzhiev and Katherine Sherwood, half of which were painted before their strokes and half of which were painted afterward. For each artist and each attribute paired t-tests were used to test the hypothesis that an attribute had changed following brain damage. After their stroke, both artists' paintings were judged as significantly more vibrant, loose, flat, and distorted ($p<0.004$). These painting were also judged as more abstract, fantastical and symbolic. These observations suggest that the artists may be drawing on a looser perceptual and semantic organizational structure mediated by their intact right hemisphere when producing art.

G92

INDIVIDUAL DIFFERENCES IN MEMORY FUNCTION PREDICT TIME PRODUCTION ACCURACY AND VARIABILITY INDEPENDENT OF AGE *Brian C. Rakitin[1]; [1]Cognitive Neuroscience Divsion, Taub Institute, Columbia University* – How does aging affect interval timing, and to what extent is the timing of intervals in the super-second range related to verbal episodic memory and other mental functions? In order to address these questions interval time production data were collected from thirty-two aging participants and thirty-two young participants. The repeated measures, factorial design crossed two tasks, single interval production (SIP) and repetitive tapping, and three target intervals - 0.55, 1.55, and 2.55 s for half the participants and 1.0, 3.0, and 5.0 s for the other half. Compared to young participants, aging participants had greater scalar and non-scalar intra-individual variability. The age difference was largest in SIP, which has greater memory and attention demands than tapping. Verbal memory-test scores were the best neuropsychological predictors of a number of timing performance variables, and the strength of this prediction varied by task (greater for SIP than tapping) but not by age group. These results suggest aging most affects temporal attention and memory, and that there is a relation between temporal and verbal memory function in both young and aging participants.

G93

BEHAVIORAL AND ERP RESULTS SUGGEST PUTATIVE ALARM PHEROMONES ENHANCE THREAT PERCEPTION IN HUMANS *Denis Rubin[1], Greg Hajcak[2], Lilianne Mujica-Parodi[1]; [1]Stony Brook University, Biomedical Engineering, [2]Stony Brook University, Psychology* – Mammals are known to possess alarm pheromones, which rapidly transmit warning of danger to others of the same species, via shared physiological and emotional stress response. Our previous fMRI research showed, for the first time, that humans activate the excitatory components of the limbic system (amygdala, hypothalamus), in response to fear, but not exercise, sweat. Our current study builds directly upon this work to examine how putative alarm pheromones affect behavior. Axillary sweat samples were collected from 32 Donor Subjects (50% female) during their first-time tandem skydive (stress condition) and, for the same Donor Subjects, while running on a treadmill (control condition). Pooled samples were used as olfactory stimuli, which were then presented via an olfactometer to an unrelated group of 8 Detector Subjects, all males. While inhaling stress or exercise sweat (counter-balanced for order) subjects were asked to rate male faces of varying emotional valence, ranging from neutral to angry, in order to assess perception of aggressiveness using psychometric curves. We also collected ERP data for subject responses, analyzing data for late-positive potentials, a neural marker for salience. Differences in slope between the fitted psychometric curves suggests that discrimination between threat and non-threat sharpened when subjects inhaled the putative alarm pheromone ($F=5.9$, $p=0.045$). Likewise, the late-positive potential component of the ERP was increased for the stress sweat condition ($F = 26$, $p = 0.004$). Our preliminary results suggest that humans, like other mammals, may possess alarm pheromones, which have behavioral implications for threat assessment.

G94

AGING REDUCES NEURAL SELECTIVITY AND INCREASES FACE ADAPTATION *Joshua Goh[1], Atsunobu Suzuki[1], Denise Park[2]; [1]Beckman Institute, University of Illinois at Urbana-Champaign, [2]Center for Brain Health, University of Texas at Dallas* – Age-related ventral-visual activity is characterized by reduced selectivity between categories of visual stimuli such as faces and houses that typically elicit highly specialized responses in the fusiform and parahippocampal brain regions respectively of young adults (Park et al., 2004). This study demonstrates that older adults' less selective neural response (dedifferentiation) to faces is due to a coarser neural representation than that of young adults for individual faces. In this event-related fMRI adaptation study, 20 young and 20 older participants made same-different judgments to serially presented face-pairs that

were either identical (repetition of the same face), moderately different (second face was morphed with 40% of prior face), or completely different (faces from two individuals). In the fusiform regions, older adults showed greatest adaptation during the exact-repetition condition and intermediate adaptation during the moderately-different condition relative to the completely-different condition. Young adults showed a similar pattern of adaptation, but with reduced adaptation magnitudes. This suggests that older adults' fusiform area was not able to represent facial differences at the same level of sensitivity as young adults. Individual subjects' adaptation magnitudes positively correlated with behavioral face discrimination thresholds for morphed faces (r = .38). Greater age-related adaptation during the exact-repetition condition suggests older adults' fusiform face region is particularly sensitive to similarity, whereas young adults have a neural response that is more sensitive to facial differences. The data provide strong evidence for an age-related decrease in representational contrast in the fusiform area that is linked to behavioral differences during perceptual discrimination.

G95

NEUROIMAGING OF TEMPORAL PROCESSING: RESULTS OF A VOXEL-WISE META-ANALYSIS *Martin Wiener[1], Peter Turkeltaub[2], H. Branch Coslett[2]; [1]University of Pennsylvania, Psychology, [2]University of Pennsylvania, Neurology* – The past decade has witnessed an explosion of neuroimaging studies investigating the neural correlates of time perception. Unfortunately, little concordance exists among these studies for which neural regions are necessary. We addressed this important issue by conducting a comprehensive, voxel-wise meta-analysis, using the Activation Likelihood Estimation (ALE) algorithm, which models each stereotactic coordinate as a 3D Gaussian distribution, then tests the likelihood of activation across all voxels in the brain (Turkeltaub et al. 2002). We included 463 sets of activation foci across 51 experiments, constituting the majority of neuroimaging studies explicitly investigating temporal processing. Only results from control-task subtractions were employed. Additionally, we divided the data set along two dimensions: whether the durations tested were subsecond or suprasecond, and whether the duration was dependent on a motor response or not; these data sets were then analyzed by a series of subtraction analyses (Laird et al. 2005). The results of the total meta-analysis revealed a bi-hemispheric network of cortical and sub-cortical structures, including the cerebellum, thalamus, basal ganglia and supplementary motor area, as well as several right-hemispheric cortical structures. The results of the subtraction analyses further revealed a much smaller number of structures depending on the task constraints. These results will be discussed in the context of contemporary neural theories of timing and constitutes the first quantitative neuroimaging meta-analysis of temporal processing.

G96

NAVIGATING ACROSS THE LIFESPAN: PATH INTEGRATION DEFICITS IN PATIENTS WITH MILD COGNITIVE IMPAIRMENT *Naohide Yamamoto[1], John W. Philbeck[1], Paul Fedio[2], Samuel J. Potolicchio[3], Anthony J. Caputy[3], Mateja de Leonni Stanonik[3], Carly E. Kontra[1]; [1]George Washington University, [2]Catholic University of America, [3]George Washington University Medical Center* – Impaired navigation is prevalent among patients with Alzheimer's disease (AD). It appears even in patients with mild cognitive impairment (MCI), a disorder sometimes interpreted as an early stage of AD. Currently, a common interpretation of this navigation impairment is that AD/MCI patients tend to get lost easily because they cannot remember correct routes or appropriate landmarks. In other words, the navigation impairment is largely attributed to their memory problems. However, given that successful navigation requires not only good spatial memory but also intact perception of 3-D space and self-motion, it is important to examine whether these patients have deficits in perceptual processes as well. The present study addressed this issue by testing MCI patients' abilities to determine their current position in space by monitoring internally-generated self-motion signals, a process known as path integration. We employed a variety of path integration tasks: Some required participants to keep track of either linear or rotational motion, and others required taking into account both types of motion. MCI patients performed many of these tasks less accurately than young neurologically-intact adults, even though the patients showed little or no impairment in visually perceiving object locations and remembering them over a brief period of time. The findings to date suggest that MCI patients have selective deficits in path integration, and indicate that deficient path integration may play a role in the navigation problems commonly seen in AD-related disorders. On-going work will compare these results with tests of patients with mild AD and non-demented elderly control participants.

G97

EVENT RELATED POTENTIAL AND EEG MU FREQUENCY ANALYSIS OF EMOTIONAL FACE PROCESSING: PRE AND POST 20 WEEKS OF NEUROFEEDBACK TRAINING IN CHILDREN TYPICALLY DEVELOPING AND WITH AUTISM SPECTRUM DISORDERS *Oriana R. Aragon[1,3], Jia-Min Bai[1], Jaime A. Pineda[1,2]; [1]University of California, San Diego, Cognitive Science, [2]University of California, San Diego, Neuroscience, [3]California State University, San Marcos, Psychology* – The significance of emotional face processing in understanding nonverbal cues in our everyday social interactions has prompted researchers to look for specific neural correlates involved in this fundamental ability. Research has shown deficits for those with ASD in the perception of faces, emotional content displayed in facial expressions, and reduced activation in hallmark face processing brain regions. Research suggests that these differences may indicate deficits in mirror neuron system (MNS) engagement as evidenced by a lack of activation in inferior frontal gyrus during imitation tasks and the lack of mu suppression, an index of MNS activity, during observed actions. Two recent electrophysiological (EEG) studies done in our laboratory focused on the mu rhythm, an oscillation over the sensorimotor cortex believed to reflect downstream modulation from premotor mirror neurons during the observation of biological motion. Data showed that operant conditioning of mu rhythms via neurofeedback training (NFT) normalizes mu suppression during observed actions. The current study assessed mu suppression and the N170, P280 and N400 ERP components, pre and post 20 weeks of NFT. Matched ASD and typically developed (TD) participants underwent a 1-back paradigm with static emotional faces (anger, disgust, happy) and buildings for control. Pre-assessment data show differences in ERP components between ASD and TD groups. Furthermore, ERP differences in the TD group when comparing faces and buildings were diminished in the ASD group. Post training ERP and mu data is in analysis. The findings to date provide further evidence of impaired facial processing in individuals with ASD.

G98

EFFECTS OF PSILOCYBIN ON NEURAL SUBSTRATES OF VISUAL GESTALT PROCESSING *B. Rael Cahn[1,2,3,4], Michael Kometer[3,4], Mark Geyer[1], John Polich[2], Franz Vollenweider[3,4]; [1]UCSD, Psychiatry, [2]The Scripps Research Institute, [3]University of Zurich, Psychiatry, [4]Heffter Research Center Zurich* – Psilocybin is a naturally-occurring hallucinogen and potent serotonin agonist previously shown to depend on 5HT-2a agonism to produce much of its psychological effects. A Kanizsa stimulus visual paradigm was presented to healthy volunteers during placebo, low-dose, and high-dose psilocybin conditions to elicit event-related brain potentials (ERPs) in the different brain states, followed by the administration of a standardized questionnaire to assess induced altered state of consciousness. The stimuli consisted of Kanizsa and non-Kanizsa stimuli at equal probability with stimulus categorization response required. Psilocybin caused a more focal V1-distributed increased P1 amplitude as well as signficantly decreased N170 and P300 ampiltudes. LORETA analysis indicated that N170 amplitude was significantly enhanced in V1/V2 and right lateral occipital cortex for Kanizsa vs. non-Kanizsa stimuli in placebo condition, but not different in psilocybin conditions. These findings suggest that psilocybin induces a

brain state wherein there is increased early processing of visual stimuli and strongly decreased processing at the stimulus-categorization (N170) and attentional engagement (P300) stages. Theoretical implications related to induced altered state of consciousness are discussed.

G99

SELF PERCEPTION IN HANDWRITING - AN ERP STUDY *Reiko Sawada[1], Hirokazu Doi[2], Nobuo Masataka[1]; [1]Primate Research Institute, Kyoto University, [2]Nagaski University* – Self perception is a fundamental capability for social cognition, and one of most noticeable phenomena. There is no doubt that humans can identify the products of their past action, such as handwritten characters and voices. When we open the old diary, we can recognize our handwriting easily and immediately. Why we can identify self handwriting? By several recent studies, self processing is unique and distinct from other types of semantic processing. However, the neural mechanism underling self perception of handwriting has not been clearly elucidated. We investigated neural correlates for the process of the self information in handwriting. We measured event-related potentials (ERPs) during the observation of self and other handwriting under known and unknown character conditions. When analyzing the peak amplitudes of P1, N170 and P250, larger N170 and smaller P250 were recorded for self handwriting only at the right hemisphere than other handwriting. In addition, larger N170 was recorded for known characters at both hemispheres, smaller P250 was recorded only at left hemisphere than unknown characters. We found the self information is processed in different way from characters' familiarity after 300 ms stimulus onset. As previous studies, our results shows that perception of self information in handwriting is correlated with neural activity in the right hemisphere and the information for characters were processed in left hemisphere.

G100

THE PREDICTION OF OCCLUDED ACTIONS DEPENDS ON PREMOTOR CORTEX FUNCTIONS *Waltraud Stadler[1], Ricarda I. Schubotz[2], Anne Springer[1], Wolfgang Prinz[1]; [1]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, [2]Max Planck Institute for Neurological Research, Cologne, Germany* – Lateral and medial portions of the premotor cortex seem to play a core role in action simulation. As a consequence, activation in these areas should increase with the length of the simulated action sequence. To investigate this supposition, an fMRI study was designed in which participants watched short movies showing everyday actions that were repeatedly occluded. In order to vary the length of the simulated action, occluder duration varied between one and three seconds. The same stimuli were used in three different conditions. In the PREDICTION condition, participants were asked to indicate whether actions continued with coherent timing after occlusions. In contrast, the FREEZING condition required to hold visual action information in memory during occlusion. In a non-action related condition, occlusions were just counted (COUNTING). In premotor regions of interest (dorsal premotor cortex, PMd, and pre-supplementary motor area, pre-SMA), activation was significantly higher in the PREDICTION condition as compared to the other two conditions. Moreover, pre-SMA responded to increasing occluder duration with sustained activation in PREDICTION but not when action dynamics were not task-relevant (COUNTING condition). Premotor activation being particularly high during the prediction of dynamic action information replicates earlier findings from our laboratory. Sustained pre-SMA activation with longer occlusions is in line with the involvement of this area in the organisation of motor sequences and with its role during internal action guidance. The present results underline the relevance of the premotor cortex in driving action simulation.

G101

INCREASED COHERENCE IN PARIETAL CORTICES OF TIME-SPACE SYNESTHETES: A HIGH-DENSITY EEG STUDY *Ursina Teuscher[1,2,3], David Ruhl[2,3], David Brang[1], David Stone[2], Seana Coulson[1], Vilayanur S. Ramachandran[1], Claudia Tesche[2]; [1]University of California, San Diego (UCSD), [2]University of New Mexico, Albuquerque (UNM), [3]Mind Research Network, Albuquerque (MRN)* – Synesthesia is a condition in which stimuli presented in one modality consistently and involuntarily evoke sensations in another, unrelated modality. For example, sound may be experienced as flavored or numbers as colored. An often-overlooked form of this condition is time-space synesthesia, in which elements of temporal sequences are perceived as being at discrete locations in space. The most common manifestation of this is for a synesthete to perceive the months of the year in a particular shape in their visual field. To investigate the basis of time-space synesthesia, we collected 128-channel EEG data from five synesthetes and five individually-matched controls in a modified Posner spatial-cuing paradigm. Centrally-presented month terms were tailored to direct synesthetes' attention to either the left or right side of the screen depending on the shape of their perceived calendar (e.g., if a synesthete perceives January on the right, we used 'January' to direct their attention rightward). Subjects were then required to identify a target in either the attended or unattended area. Since a large number of neuroimaging studies have implicated the posterior parietal cortex in the perception of both spatial patterns and temporal sequences, we hypothesized that, regardless of behavioral performance, synesthetes would exhibit increased EEG coherence in parietal areas. We report here preliminary results finding altered patterns of parietal coherence in time-space synesthetes. Such coherence differences indicate more synchronous activation within areas of the parietal cortex in synesthetes when processing time units as spatial cues. Implications for neural models of synesthetic experience are discussed.

G102

A BEHAVIORAL METHOD FOR STUDYING MIRROR NEURON ACTIVITY: REPETITIVE ACTION AFFECTS VISUAL PERCEPTION *Arthur Glenberg[1,2], Gabriel Lopez-Mobilia[1], Michael McBeath[1], Michael Toma[1], Marc Sato[3], Luigi Cattaneo[4]; [1]Arizona State University, [2]University of Wisconsin, [3]GIPSA-LAB - UMR CNRS 5216, University of Grenoble, [4]Center for Mind/Brain Sciences, University of Trento* – Mirror neurons may underlie the ability to make sensorimotor predictions when observing action, and thus they may contribute to "reading" intentions of other animals and facilitating social interaction. Neurophysiological and brain imaging studies have shown that observation of both biological and non-biological movements activates a fronto-parietal netwok of motor regions which forms the core of the human mirror-neuron system (MNS). However, these results are intrinsically correlational, and whether mirror neurons contribute to action understanding remains debated. We have developed a behavioral method based on use-induced plasticity to study mirror neurons. Participants engage in a repetitive motor task such as moving beans from one location to another. This activity adapts neural systems used in the control of the action. Participants then engage in a second task. We know that the second task uses the same neural systems adapted in the motor task when the second task is affected by the direction of bean movement. We report the data from experiments in which the second task is the measure of bias to see ambiguous motion in one direction or another. The direction of bean movement (toward or away from the participant) influences the bias such that previous action toward the participant increases the bias to see ambiguous movement in the away direction. Similar results have been found when the second task is a language task. These results suggest that a MNS is being tapped, and they provide method for studying the causal contribution of MNS to cognitive and social processes.

Poster Session H

Methodological Issues: Electrophysiology

H1

AFFECTIVE SEMANTIC PRIMING AS PUTATIVE ENDOPHENOTYPE OF PSYCHOSIS: AN EVENT-RELATED POTENTIAL STUDY *Stefanie Pfeifer[1], Niels Schiller[2], Jim van Os[1,3], Wim Riedel[4], Lydia Krabbendam[1]; [1]South Limburg Mental Health Research and Teaching Network, EURON, Psychiatry and Neuropsychology, Maastricht University, Maastricht, The Netherlands, [2]Faculty of Social Sciences and Cognitive Psychology Unit, Leiden Institute for Brain and Cognition (LIBC), Leiden University, Leiden, The Netherlands, [3]Division of Psychological Medicine, Institute of Psychiatry, London, UK, [4]Maastricht University, Neuropsychology and Psychopharmacology, The Netherlands* – Background: Evidence is accumulating that semantic networks are abnormal in patients with psychosis. The effect of emotionality on the semantic network is less well understood. The aim of the present study was to investigate with Event-Related potentials whether the N400 of patients is abnormal when presented with positive and negative affective words and whether the affective semantic priming effect can be seen as putative endophenotype. Method: Thirteen patients with non-affective psychosis, 14 siblings and 16 controls participated in an affective lexical decision task with three conditions (positively, negatively and unrelated) and two stimulus onset asynchronies (SOAs), 250ms and 500ms. Results: For SOA250, controls showed no difference between the three conditions in N400 amplitude. Patients showed a decrease in N400 amplitude in the unrelated condition compared to the affective conditions, and an earlier onset of the N400 in the positive condition. Siblings showed no difference between the three conditions in N400 amplitude, but the positive condition showed the earliest onset, followed by the negative and the unrelated condition. For SOA500, controls showed an increased N400 amplitude for the unrelated condition compared to the affective conditions. An increased N400 amplitude for the unrelated condition was also found in patients, as well as an N400 priming effect for both affective conditions, which was strongest for the positive words. This priming effect was also seen in siblings. Conclusion: Patients with psychosis and siblings showed an increased sensitivity to words with affective valence. Affective semantic priming abnormalities can be considered an endophenotypic marker of psychosis.

H2

CROSS-DOMAIN EFFECTS OF LANGUAGE AND MUSIC EXPERIENCE ON THE REPRESENTATION OF PITCH IN THE HUMAN AUDITORY BRAINSTEM *Gavin M. Bidelman[1], Jackson T. Gandour[1], Ananthanarayan Krishnan[1]; [1]Purdue University, Speech Language Hearing Sciences, West Lafayette, IN* – Neural encoding of pitch in the auditory brainstem is known to be shaped by long-term experience with language or music, implying that early sensory processing is subject to experience-dependent neural plasticity. In language, pitch patterns consist of sequences of continuous, curvilinear contours; in music, pitch patterns consist of relatively discrete, stair-stepped sequences of notes. The aim of this study was to determine the influence of domain specific experience (language vs. music) on the encoding of pitch in the brainstem. Brainstem frequency following responses (FFRs) were recorded from native Chinese, English amateur musicians, and English non-musicians in response to iterated rippled noise homologues of a musical interval (major third; M3) and a lexical tone (Mandarin tone 2; T2). Pitch strength (?50ms sections) and tracking accuracy (whole contour) were computed from the FFRs using autocorrelation algorithms. The Chinese and musicians showed higher pitch tracking accuracy than the non-musicians regardless of domain. Relative to non-musicians, musicians showed more robust pitch strength across all sections whereas Chinese did so only in those sections containing the most rapid changes in pitch. Musicians, moreover, exhibited greater pitch strength than Chinese in one section containing an instantaneous change in pitch (onset of the second note, M3) and two sections within T2 corresponding to notes along the diatonic musical scale. We conclude that despite mutual benefits of their divergent pitch experience, cross-domain enhancement of pitch representation from music to language is greater than the reverse in the brainstem.

H3

STIMULUS-DRIVEN OSCILLATORY RESPONSES TO NUMERICAL CHANGES: A NOVEL FREQUENCY-TAGGING EEG PARADIGM *Melissa Libertus[1,2], Elizabeth Brannon[1,2], Marty Woldorff[1,2,3]; [1]Duke University, Center for Cognitive Neuroscience, [2]Duke University, Psychology & Neuroscience, [3]Duke University, Psychiatry* – Frequency-tagging paradigms have been successfully used in previous research to investigate neural indices of conscious perception and attentional modulation. Here we employ this technique to investigate neural tuning to non-verbal numerical information in the absence of a task. Twelve adults passively viewed rapid streams of multiple-element images that flickered at a frequency of 12.5 or 25 Hz. Every 400 ms across a period of 2400 ms, a new flickering image of stimulus elements was presented that contained the same number of elements. After 2400 ms, the number of elements changed by a 1:3, 1:2, or 2:3 ratio (e.g., from 8 to 24 elements). Extraction of the power at the flicker frequency using a Fast-Fourier transformation showed an increase in power over repeated presentation of the same numerosity across the 2400-ms periods over posterior scalp sites (adaptation effect) for both the 12.5 and 25 Hz stimulation frequencies. Furthermore, the power change at these locations over the first 400 ms after a change in numerosity was smallest following a 2:3 ratio change and largest following a 1:3 ratio change (ratio effect). Thus, the adaptation and ratio effects together suggest a driven oscillatory stabilization of the neural network encoding numerosity and a destabilization pattern following a numerosity switch that follows Weber's Law, i.e. following the ratio rather than the absolute difference in a numerosity change determines the power at the stimulation frequency. Future research will be aimed at applying this method to studies with human infants.

H4

ENHANCING DOMINANT MODES IN EVENT-RELATED BRAIN POTENTIALS BY MEANS OF THE SYMBOLIC RESONANCE ANALYSIS *Peter beim Graben[1], Heiner Drenhaus[2], Stefan Frisch[3,4]; [1]School of Psychology and Clinical Language Sciences, University of Reading, UK, [2]Institute of Linguistics, University of Potsdam, Germany, [3]Day-Care Clinic of Cognitive Neurology, University of Leipzig, Germany, [4]Max-Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany* – We present the symbolic resonance analysis (SRA) as a viable method for addressing the problem of enhancing a weakly dominant mode in a mixture of evoked responses obtained from a nonlinear dynamical system. We demonstrate this using results from a numerical simulation with Duffing oscillators in different domains of their parameter space, and by analyzing event-related brain potentials (ERPs) from a language processing experiment in German as a representative application. In this paradigm, the averaged ERPs exhibit an N400 followed by a sentence final negativity. Contemporary sentence processing models predict a late positivity (P600) as well. We show that the SRA is able to unveil the P600 evoked by the critical stimuli as a weakly dominant mode from the covering sentence final negativity. Reference: beim Graben, P., Drenhaus, H., Brehm, E., Rhode, B., Saddy, D.

& Frisch, S. (2007). Enhancing dominant modes in nonstationary time series by means of the symbolic resonance analysis. Chaos: An Interdisciplinary Journal of Nonlinear Science, 17, 043106.

H5

INTRINSIC FUNCTIONAL CONNECTIVITY IN MEG *Avniel Ghuman[1], Jonathan McDaniel[1], Alex Martin[1]; [1]Laboratory of Brain and Cognition, NIMH* – Determining functional connectivity is critical for understanding the dynamics of the normal and disordered brain. Recent functional magnetic resonance imaging (fMRI) studies demonstrate that measuring correlations between brain regions in intrinsic activity can be used to reveal specific neural networks. This approach holds great promise for studying networks in both the healthy and impaired brain because it allows functional connectivity to be assessed without concern for the influence of task-related modulations on intrinsic patterns of functional connectivity. Because of its superior temporal resolution, examining resting state connectivity with magnetoencephalograpy (MEG) or electroencephalography (EEG) should further enhance our knowledge of neural circuitry. However, traditional MEG/EEG analysis methods are not well suited for resting state data. Moreover, there is a lack of consensus as to the best method for examining connectivity in resting state MEG/EEG data. To address this problem, we adapted wavelet-based methods for determining functional connectivity and assessed the performance of these methods using physiologically plausible synthetic data. We found that the relative performance of the methods varied with the proportion of coherent activity and the duration of coherent bursts. These results suggest that our ability to reveal functional connectivity using resting state electrophysiological data will depend on the use of multiple measures. We apply these methods to resting state data collected in MEG and examine their ability to identify functional networks in the brain.

H6

ANALYSIS OF SPEECH AND SLEEP EEG IN CHILDREN WITH NEURODEVELOPMENTAL DISORDERS *Vladimír Komárek[1], Lenka Neuschlová[1], Zbynek Hrncir[1], Jana Tuková[2]; [1]Charles University Hospital Motol, Prague, Czech Republic, [2]Czech Technical University, Prague, Circuit Theory, Czech republic* – Purpose: To determine role of epileptiform activity in our samples of children with neurodevelopmental disorders and to evaluate sensitivity of computerized methods of speech and EEG analysis. Method: Subjects - 37 children aged 39 - 112 months with developmental language disorder (DLD group) and 27 children (mean age 7,1 years) with pervasive developmental disorder (PDD group)underwent overnight sleep video-EEG monitoring. The control group was 20 mentally non-retarded deaf children with cochlear implantation (mean age 8,4 years). Psychological evaluation : Standford-Binet Intelligence scale-4th Revision, Gessel Developmental Schedules. Speech analysis : vowel classification by a supevised Self-Organizing Maps (SSOM). EEG evaluation: 31 linear and non-linear (CER) analysis. Statistics: multiple regression analysis, Wilcoxon test, Mann- Whitney test, Spearman and Pearson correlations. Results: Our study confirmed higher incidence of epileptiform discharges (12/37) in DLD group. Computerized speech analysis differentiated dysphatic and healthy children. The Spearman correlation was most sensitive tool for correlation between computerized speech analysis (SSOM) and slow sleep EEG signal in DLD group. We also found a significant decrease in EEG coupling and information drive in the PDD group in comparison with control. This result support the hypothesis of underconnectivity in children with PDD. Conclusion: Correlation of computerized speech and EEG analysis can be in future suitable tool for assesing degree of neurodevelopmental impairment as well as of possible therapeutical effect.

H7

ALPHA NEUROFEEDBACK TRAINING AND ITS IMPLICATIONS FOR STUDIES OF COGNITIVE CREATIVITY *Henk Haarmann[1], Timothy George[1], Alexei Smaliy[1], Kristin Grunewald[1], Jared Novick[1]; [1]University of Maryland College Park* – We report a method for increasing alpha brain waves through Electroencephalography neurofeedback training (NT), intended for subsequent research on cognitive creativity. Increased alpha power over right posterior cortex is associated with greater originality in divergent thinking (Grabner et al., 2007) and overcoming impasses during insight problem solving (Jung-Beeman et al., 2004; sensor location PO8). NT aimed at increasing alpha power has successfully demonstrated a causal connection between alpha activity and cognitive function, particularly mental rotation (Hanslmayr et al., 2005). This finding creates the prospect of using alpha NT to also test a hypothetical causal connection between alpha activity and cognitive creativity. To identify an alpha NT protocol appropriate for such a study, thirteen college students participated in three sessions of alpha NT. The neurofeedback information was derived from a sensor placed over right lateral parietal-occipital scalp (PO8) and displayed as a moving bar whose height corresponded to degree of alpha activity. Participants' task involved increasing the height of this bar by adopting a calm and alert state during nine 2.5-minute NT segments interleaved with four 1-minute baseline segments. The alpha NT resulted in a statistically reliable within-session increase in alpha and theta (but not beta) activity and a between-session increase in alpha activity. There was also a within-session reduction in state anxiety. Thus, alpha NT is a reliable method for increasing alpha activity in regions associated with cognitive creativity. Implications for the use of this method to understand and improve performance on cognitive creativity tests will be discussed.

H8

SPACE-TIME-FREQUENCY ANALYSIS OF EEG DATA IN SEMANTIC MEMORY *Thomas Ferree[1], Matthew Brier[2], John Hart[2,3], Michael Kraut[4]; [1]University of Texas Southwestern Medical Center at Dallas, Radiology, [2]Center for Brain Health, School of Behavioral and Brain Sciences, University of Texas at Dallas, [3]University of Texas Southwestern Medical Center at Dallas, Neurology, [4]Johns Hopkins University School of Medicine, Radiology, Baltimore, Maryland* – Time-frequency analysis is a valuable tool for studying event-related oscillations during cognitive tasks. In a complete experiment, however, the numerical results span space, time, frequency, task conditions, and subjects. The goal of this study was to develop a method for combining statistical testing with data reduction. For data reduction, we used principal component analysis (PCA) applied sequentially to spectral, spatial, and temporal dimensions. We contrasted two methods for combining statistical testing with PCA. The first method, used widely to analyze event-related potentials, places data reduction prior to statistical testing. The second method, which was developed in this study, places statistical testing prior to data reduction. The results of both methods were compared in a semantic memory task, in which twenty-five subjects decided whether word pairs elicited recall of a third object. Sixty-two channel EEG data were analyzed with short-window Fourier transform. In numerous tests of stability and validity, we found that the second method, which we call STAT-PCA, performed vastly better. We also found that the principal components returned by STAT-PCA agreed well with the group-averaged data, confirming that this multistep analysis method reveals the most prominent features in the data. Finally, STAT-PCA permits the detection of activity that is not only different between conditions, but also common to both conditions, for the most complete yet parsimonious view of the data. It is concluded that STAT-PCA is well suited for analyzing event-related oscillations during cognitive tasks, and its foundations imply that it should generalize well beyond this particular task.

H9

NEUROELECTRIC ASSESSMENT OF BINGE DRINKING: GENDER AND TASK EFFECTS *Kelly Courtney[1], John Polich[2]; [1]San Diego State University, [2]The Scripps Research Institute* – Young adult university students were assessed with a battery of electroencephalographic (EEG) and event-related brain potential (ERP) tasks to assay the effects of "binge drinking" amount in non-binge drinking controls, low-binge drinkers (5/4 drinks/occasion, NIAAA definition), and high-binge (?10 drinks/occasion) drinkers (n=8/group x 3 binge categories x 2 genders). Resting EEG

mean frequency was greater in non- and low-bingers compared to high-binger subjects, with the largest group difference in the alpha band (8-12 Hz). A mental head rotation task found high-bingers produced smaller P300 amplitudes for both easy and hard conditions than non- and low-binge subjects, especially in females. A polygon shape matching task yielded a group by condition by gender interaction, such that female high-bingers exhibited smaller P300 amplitudes than the non- and low-bingers in the match condition but similar amplitudes in the mismatch condition. Male high-bingers exhibited similar patterns to the male low- and non-bingers. A memory scanning task generated a group by gender interaction, with female non-bingers exhibited significantly higher amplitude than the female non- and low-bingers. Males exhibited a diminished group difference. A Stroop ERP task produced similar outcomes for the congruent and incongruent stimuli. No binge group effects were obtained for the distracter or target stimulus in a visual three-stimulus oddball task. The findings suggest that high-binge drinking is associated with subsequent neuroelectric changes relative to non- and low-binge drinking, especially in female bingers.

H10

LOOKING FORWARDS AND BACKWARDS: STIMULUS AND RESPONSE LOCKING WITH EVENT RELATED POTENTIALS DURING OVERT LANGUAGE PRODUCTION *Trevor Blackford[1], Krysta Chauncey[1], Phillip J. Holcomb[1], Gina R. Kuperberg[1,2]; [1]Tufts University, Medford MA, [2]Massachusetts General Hospital, Charlestown, MA* – An overwhelming majority of event related potential (ERP) studies have focused on brain responses to external stimuli such as pictures or tones. ERP studies appear in stark contrast to the majority of psychological studies that examine overt behavioral responses. This difference is due to the nature of the electroencephalogram (EEG) recordings ERPs are derived from. EEG recordings are very sensitive to electrical signals produced by muscle activity during behavioral response initiation, which obscure the electrical signals produced by the cognitive activity of interest. These drawbacks have discouraged the study of ERPs evoked by initiation of behavioral responses. In the current study we examined EEG data collected during an overt language production task through ERPs derived separately by stimulus-locking forward and response-locking backwards. Participants were shown pictures of objects in a cross modal priming task and were asked to name the object upon presentation. Production ERPs were created by time-locking to the onset of the participants' articulation. Although large articulation related artifacts were present following the analysis window, we did observe a reliable effect prior to articulation. Differences were seen according to the relationship of the prime to the target. This finding suggests that time-locking to articulation is a viable method of investigating language processing. Furthermore, the results provide converging evidence with the stimulus locked ERPs which showed an modulation of the N400 component associated with object understanding to the relationship of the prime and the target.

Methodological Issues: Neuroimaging

H11

NEUROCHEMISTRY OF HUMAN COGNITION *Rajendra Badgaiyan[1,2,3]; [1]Division of Nuclear Medicine, Massachusetts General Hospital, Boston, [2]Harvard Medical School, Boston, [3]Shriners Hospital, Boston* – Neuroimaging study of human cognition is focused primarily on localization of the brain areas involved in the processing of cognitive components. There is therefore, little or no information concerning neurochemical changes associated with the processing. We explored the possibility of detecting and mapping neurochemical changes during task performance using a dynamic molecular imaging technique. Since the technique exploits the competition between a neurotransmitter and its ligand for receptor occupancy, by dynamically measuring the concentration of a radiolabeled dopamine ligand (11C-raclopride or 18F-fallypride) during a control and a task condition, we have been able to detect and map changes in dopaminergic activity during performance of a number of cognitive and behavioral tasks. The data acquired in these experiments indicate that in some tasks dopamine is released in the areas that are activated in fMRI experiments. These tasks include emotional memory (amygdala, medial temporal lobe, prefrontal cortex), implicit motor memory (right caudate, bilateral putamen), explicit motor memory (bilateral caudate and putamen) and response inhibition (right caudate). In a cued-recall task (word stem completion) however, we observed significant dopamine release in the striatum, even though most fMRI experiments have not reported striatal activation. Because fMRI findings are not consistent with the observation of impaired task performance in patients with striatal lesions, it was unclear whether the striatum is involved in the processing of explicit memory. These findings suggest that molecular imaging can be used to resolve controversies in cognitive concepts and to investigate an unexplored aspect (neurochemistry) of human cognitive control.

H12

CONSISTENCY AND VARIABILITY IN FUNCTIONAL LOCALISERS *Joseph T. Devlin[1,2], Keith J. Duncan[1,2], Chotiga Pattamalidok[1,3], Iris Knierim[1,4]; [1]Cognitive, Perceptual and Brain Sciences, UCL, [2]Institute of Cognitive Neuroscience, UCL, [3]Fonds de la Recherche Scientifique-FNRS & Université Libre de Bruxelles, [4]Université Pierre et Marie Curie, Ecole Normale Supérieure* – A critical assumption underlying the use of functional localiser scans is that the voxels identified as the functional region-of-interest (fROI) are essentially the same as those activated by the main experimental manipulation. Intra-subject variability in the location of the fROI violates this assumption, reducing the sensitivity of the analysis and biasing the results. Here we investigated consistency and variability in fROIs in a set of 45 volunteers. They performed two functional localiser scans to identify word- and object-sensitive regions of ventral and lateral occipito-temporal cortex, respectively. In the main analyses, fROIs were defined as the category-selective voxels in each region and consistency was measured as the spatial overlap between scans. Consistency was greatest when minimally selective thresholds were used to defined "active" voxels ($p < 0.05$ uncorrected), revealing that approximately 65% of the voxels were commonly activated by both scans. In contrast, highly selective thresholds ($p <$ 10-4 to 10-6) yielded the lowest consistency values with less than 25% of the voxels active in both scans. In other words, intra-subject variability was surprisingly high with between one third and three quarters of the voxels in a given fROI not corresponding to those activated in the main task. This level of variability stands in striking contrast to the consistency seen in retinotopically defined areas and has important implications for designing robust but efficient functional localiser scans.

H13

IN-VIVO ANATOMICAL DISSECTION OF A CASE OF RIGHT-SIDED NEGLECT AFTER LEFT HEMISPHERE DAMAGE *Monica Toba[1,2], Michel Thiebaut de Schotten[1,3,4], Francesca Ciaraffa[1,2,6], Marianne Blanchard[5], Catherine Loeper-Jeny[5], Paolo Bartolomeo[1,2]; [1]Inserm Unit 610, Neuropsychology of the focal cerebral lesions, GH Pitié Salpêtrière, Paris, France, [2]UPMC - Paris VI, Paris, France, [3]Natbrainlab, Section of Brain Maturation, Institute of Psychiatry, King's College London, London, UK, [4]Centre for Neuroimaging Sciences, Institute of Psychiatry, King's College London, London, UK, [5]Hôpital National de Saint-Maurice, Saint-Maurice, France, [6]Dipartimento di Neuroscienze - Istituto di Neuropsicologia - Università Cattolica Sacro Cuore (UCSC) - Policlinico A.Gemelli-Roma, Italy* – Spatial neglect usually affects left-sided objects after right hemisphere damage. The anatomical correlates are debated, with recent evidence suggesting an important role for fronto-parietal disconnection in the right hemisphere. Here we describe the less usual occurrence of a patient with neglect for right-sided objects after left hemisphere damage. The patient presented 2 focal strokes in the left hemisphere, affecting respectively the left occipital lobe and the region extending from the post-

central gyrus to the temporal-parietal junction. After the second stroke, the patient presented with fluent aphasia, agraphia, working memory impairment and mild right-sided neglect (bells cancellation, 4 omissions on the right, 1 on the left; Ogden figure, 1 omission on the right; line bisection, leftward deviation by 13.5%). DTI-tractography demonstrated disconnections in the fronto-parietal and temporo-parietal regions, concerning principally the left superior longitudinal fasciculus (SLF) and the U-shaped fibers linking the superior and inferior frontal gyri. The corpus callosum was disconnected at the level of each lesion. In vivo white matter dissection in this patient with right-sided neglect suggests a role for left SLF disconnection, which complements analogous evidence for right SLF disconnection in left neglect.

H14

GROUP ANALYSIS OF WORD-PSEUDOWORD EFFECTS IN MAGNETOENCEPHALOGRAPHY VIA SENSOR- AND SOURCE-LEVEL STATISTICAL PARAMETRIC MAPPING *Jason R Taylor[1], Richard N Henson[1]; [1]MRC Cognition and Brain Sciences Unit* – Population inference from Magnetoencephalographic (MEG) data is complicated by MEG's sensitivity to neuroanatomical variability between individuals and to differences in head position relative to the sensors. Further, existing approaches rarely compensate for multiple comparisons over space and time. In the present study, these problems were overcome by (i) virtually transforming all subjects' heads to a common location, (ii) applying random field theory to statistical parametric maps (SPMs), and (iii) constraining distributed source dipoles to a canonical cortical mesh, inverse-normalised to each subject's native space. Nineteen right-handed English adults saw words (W) and pronounceable pseudowords (PW; 480 each; duration 300 ms; presented sequentially at fixation) and indicated whether each was a word or nonsense word (button-press; hand counterbalanced). Whole-head MEG was acquired with 306 sensors (Elekta Neuromag). Neuromag's MaxFilter utility was used to apply signal-space separation to remove noise, for head-movement compensation, and for head-position transformation. Blink artefacts were removed using independent component analysis (EEGLAB). All further processing was done with SPM/Matlab. 3D SPMs on sensor data (2D topography x time) revealed significant W/PW differences from 300-400ms and 525-675ms, with topographies suggesting dipolar sources in bilateral temporal (left>right) and parietal regions. For each subject, source localisation was performed on epochs (-300 to 1000 ms; several approaches were evaluated). Source estimates were converted to image volumes for each condition in time-windows identified by sensor SPMs, smoothed (12-mm Gaussian kernel), and normalised. Group SPMs revealed activity (pseudowords>words) in perisylvian language regions; activity showing the opposite pattern (words>pseudowords) was localised to right parietal cortex.

H15

AN IMPROVED TOOLBOX FOR THE VISUALIZATION AND META-ANALYSIS OF FUNCTIONAL ACTIVATIONS ON THE CORTICAL SURFACE *Timothy Herron[1], Xiaojian Kang[2,3], David Woods[1,2,3,4]; [1]US Veterans Affairs, Neurology, Research, Martinez, CA, [2]University of California Davis, Neurology, Davis, CA, [3]Center for Neuroscience, University of California Davis, Davis, CA, [4]Center for Mind and Brain, University of California Davis, Davis, CA* – The recently introduced MatLab toolbox VAMCA (Visualization And Meta-analysis on Cortical Anatomy) provides surface-based visualization of mean cortical functional activations using data published as stereotaxic 3D coordinates [Herron et al, CNS 2008; Herron et al, SfN 2008]. VAMCA uses a database of cortices from 72 healthy subjects to locate activations on a standardized cortical surface by extending the technique of multi-fiducial mapping [van Essen, Neuroimage, 28:635, 2005]. Non-parametric statistical tests are provided for determining (a) whether two groups of foci have distinct cortical locations; (b) the extent of overlap of the two groups' foci; and (c) whether two groups of foci are differentially concentrated in any anatomically defined regions of interest (ROI). Here, we extend VAMCA's functionality in three ways. First, we permit the inclusion of data from normalized 3D functional activation images (e.g., from published illustrations) using semi-automated image capture, normalization and projection onto the cortical surface. We also add the capability of mapping stereotaxic coordinates with standard errors and/or volumes (mapped as 3D ellipsoids). Second, we describe improved procedures for mapping an individual subject's activations to VAMCA's normalized cortical surface by using brains in the database with similar cortical anatomy. Third, a new distance metric, the "least axon distance", is described. This new metric provides a functionally relevant alternative to the stereotaxic 3D and spherical 2D distance metrics currently used in VAMCA's statistical tests.

H16

CEREBRAL CORTICAL COMPLEXITY MEASURES IN NORMAL AGING AND ALZHEIMER'S DISEASE *Richard King[1,2], Kristen Kennedy[2], Karen Rodrigue[2], Naftali Raz[3], Denise Park[2]; [1]University of Texas Southwestern Medical Center, [2]University of Texas at Dallas Center for BrainHealth, [3]Wayne State University* – Fractal dimension is a compact metric for shape complexity. The human cerebral cortex acquires fractal properties (i.e. shape invariance over a limited range of spatial scales) secondary to folding. Changes in cortical shape due to normal aging or neurodegenerative disease may differentially affect the value of fractal dimension. Quantification of these effects may help to identify neurodegenerative processes. Design/Methods: High-contrast (MP-RAGE) magnetic resonance images were acquired from two sources: 1) Cross-sectional images from 230 healthy adults ranging in age from 20 to 80. 2) Control and moderate AD images (N=50) from the Alzheimer's Disease Neuroimaging Initiative (ADNI) database. Three-dimensional tessellated polygon models of the cortical ribbon were generated from the MR images using FreeSurfer. Fractal dimension was computed using custom software. Results: For the healthy adults, values for each age grouping were as follows: 20-39: 2.59; 40-49: 2.58; 50-59: 2.57; 60-69: 2.58. Within the ADNI control subject dataset, the values were as follows: 60-70: 2.59; 70-80: 2.60; 80-90 2.60. Trends with aging were not significant. Moderate AD patients had a significantly lower fractal dimension than age-matched controls (2.599 vs. 2.575; $p<0.05$). Conclusions: 3D Bi-hemispheric fractal dimension values are less sensitive to structural effects associated with aging, but do detect more severe changes associated with moderate Alzheimer's disease. Local measures or non-biased atlas generation methods may improve sensitivity. Fractal dimension of the cortex may serve as a biomarker for identifying neurodegenerative disease.

H17

MULTIMODAL NEUROIMAGING OF EARLY WORD KNOWLEDGE IN HUMAN INFANTS: A NOVEL MEG-MRI APPROACH REVEALS A N400M-LIKE MEG RESPONSE *Katie Travis[1], Jeff Elman[2], Matt Leonard[2], Tim Brown[1,3], Megan Curran[2], Eric Halgren[4]; [1]University of California, Neuroscience, San Diego, [2]University of California, Cognitive Science, San Diego, [3]University of California, Psychiatry, San Diego, [4]University of California, Radiology, San Diego* – Due to the difficulties of imaging infants, the neural bases of normal language development remain obscure. In adults, good spatiotemporal accuracy in localizing brain activation during word processing has been achieved by combining magnetoencephalography (MEG) with magnetic resonance imaging (MRI). In the present study, we apply this method to infants (12-15 months). Functional measures of brain activity are obtained with MEG when an infant is engaged in a language task. Anatomical information is acquired with MRI while the infant is asleep. Sources of brain activity are estimated with anatomically constrained MEG (aMEG). We demonstrate that it is feasible to use aMEG to measure and localize brain activity related to semantic word knowledge in infants. Semantic word knowledge was assessed as infants viewed pictures and listened to words that were either paired congruently or incongruently. To observe differences related to semantic and not perceptual processes, picture and word stimuli were balanced across conditions. Preliminary event-related analyses

reveal a differential response to the incongruent condition at approximately 420ms following word onset. The timing of the observed response is consistent with adult MEG (Halgren et al., 2002) and infant EEG (Friedrich and Friederici, 2005) studies employing similar semantic tasks. To our knowledge, we present some of the first evidence of a N400m-like response in younger (<14 months) infants. Future analyses will integrate MEG-MRI to address the spatiotemporal dynamics of the observed response. Results are considered in the context of applying aMEG as a tool for studying the neural dynamics of early language processes.

H18

DISTINGUISHING EVENTS DURING FREE RECALL WITH FMRI

Ilke Öztekin[1], Nicole M. Long[1], David Badre[1]; [1]Brown University – Free recall has been a central paradigm in behavioral memory research and has provided core data for computational models of memory. Unfortunately, to date, the neural mechanisms that support recall have not been fully investigated due to technical challenges associated with probing individual recall events using neuroimaging methods. Of particular concern is the extent to which the latencies and uncontrolled lags associated with recall events can confer sufficient design efficiency. In order to investigate the feasibility of testing free recall with fMRI, we used both theoretically (Rohrer & Wixted, 1994) and empirically derived free recall latency distributions to generate simulated fMRI data sets and assessed design efficiency (Dale, 1999; Friston et al., 1999) across a range of parameters that describe free recall performance and fMRI designs. Results specify the design and performance parameters that can provide comparable efficiency between free recall designs and more traditional jittered event-related designs. These findings suggest that assessing BOLD response during free recall using functional magnetic resonance imaging (fMRI) is possible, under certain conditions, and can serve as a powerful tool in understanding the neural basis of memory search and overt retrieval.

H19

A BETTER APPROACH TO IDENTIFYING FUNCTIONAL REGIONS OF INTEREST: USING RIDGE LOGISTIC REGRESSION FOR VOXEL SELECTION

Joonkoo Park[1], Ji Zhu[2], Thad Polk[1]; [1]University of Michigan, Psychology, [2]University of Michigan, Statistics, – Multivariate pattern analysis techniques are powerful methods for using neuroimaging to read the mind, that is, determining the perceptual or cognitive state associated with a specific pattern of brain activation. These techniques are typically employed to classify activation patterns over a predetermined region of interest (or potentially the whole brain). Here, we show how a multivariate approach (ridge logistic regression) can be used to identify voxels whose collective activity best discriminates among different experimental conditions. We demonstrate that this approach is superior to the conventional univariate approach to identifying functional regions of interest (ROIs), both in a simulated dataset and in a real fMRI dataset involving the visual processing of faces, houses, chairs, and pseudowords. In particular, mind reading is more accurate when based on activity from an ROI identified using this multivariate approach compared with ROIs identified using the conventional univariate approach.

H20

THE IMPACT OF EXPERIMENTAL DESIGN ON THE DETECTION OF INDIVIDUAL VARIABILITY IN FMRI

Craig Bennett[1], Scott Guerin[1], Michael Miller[1]; [1]University of California, Psychology, Santa Barbara – Experimental design in functional neuroimaging is a compromise between several competing goals. Statistical power, hemodynamic response estimation, counterbalancing, and stimulus constraints all influence design layout. In this study we sought to examine how these compromises impact the estimation of individual hemodynamic variability across two types of memory tasks. The experiment was a 2x3 design with principal factors of task type (episodic word recognition and n-back working memory) and stimulus presentation strategy (block, m-sequence, and genetic optimization). Participants completed 12 functional imaging runs to yield 100 stimulus presentations per condition. We used multiple methods to quantify individual variability in the data. First was cross-correlation of the whole-brain t-statistic maps from each participant. This analysis yielded a normalized global measure of similarity between subjects. We also calculated a voxelwise measure of variance from the t-statistic maps. This allowed for the direct comparison of regional variability between levels of each factor. Event-related designs (m-sequence, genetic optimization) generated greater between-subject variability in the t-statistic maps. This was observed in the cross-correlation data as a lower average correlation between volumes. This effect was also observed in the voxelwise variance data as greater average variability within each super-threshold cluster of voxels. The pattern of results was similar across both episodic and working memory tasks. Together, this evidence supports the idea that event-related experimental designs are best for the detection of individual hemodynamic variability in memory. [Supported by the Institute for Collaborative Biotechnologies through grant DAAD19-03-D-0004 from the U.S. Army Research Office]

H21

VISUAL CORTEX IN YOUNGER AND OLDER ADULTS: A COMPARISON OF ACTIVATION FROM DIFFERENT BASELINE STATES

Joanna Hutchison[1,2], Hanzhang Lu[3], G. Andrew Hillis[1], Traci Sandoval[1], Bart Rypma[1,2]; [1]University of Texas at Dallas-BrainHealth, Brain and Behavioral Sciences, [2]University of Texas Southwestern Medical Center-Psychiatry, [3]University of Texas Southwestern Medical Center-Advanced Imaging Research Center – When comparing functional magnetic resonance (fMRI) signals across different population groups, differences in baseline activation levels can cause misinterpretation of results if one uses typical statistical analyses that assume equivalent baseline activation levels. The present study was conducted to determine whether or not older and younger persons differ in baseline activation levels in visual cortex, based upon the observation that several studies have documented differential cortical activation in older individuals compared to younger individuals (for overviews, see Cook et al., 2007; and Rajah & D'Esposito, 2005); differing baseline activation levels in older versus younger persons could account for this apparent difference in activation levels between the groups during task activity. We tested this hypothesis by presenting three types of stimuli to younger and older subjects (cf. Pasley et al., 2007): a foveal annular sinusoidal grating (resulting in a negative baseline), a parafoveal annular sinusoidal grating (resulting in a resting baseline), and a combined stimulus in which the negative (i.e., foveally-presented) stimulus was presented earlier in onset than the positive (i.e., parafoveally-presented) stimulus such that a negative baseline state was achieved prior to the initiation of the positive stimulus. Preliminary blood oxygen level dependent (BOLD) response amplitude data indicate different cortical activation levels in older compared to younger persons, suggesting that older persons have an altered resting baseline. Such results suggest the need to adopt data analysis and interpretation methods that account for population differences in baseline activation levels.

H22

COMBINING STRUCTURAL AND FUNCTIONAL MEASURES OF NEURAL CONNECTIVITY USING WHITE MATTER ANISOTROPY AND CONSTRAINED PRINCIPAL COMPONENT ANALYSIS

Liang Wang[1,2], Paul Metzak[1,2], Jennifer Whitman[1,2], Todd Woodward[1,2]; [1]University of British Columbia, Psychiatry, Vancouver, Canada, [2]BC Mental Health and Addictions Research Institute, Vancouver, Canada – The purpose of this study was to investigate the relationship between white matter tracts and functional magnetic resonance imaging (fMRI) networks involved in source memory. FMRI and diffusion tensor imaging (DTI) data for 15 healthy subjects were acquired on a 3Tesla scanner. Fractional anisotropy (FA) of white matter tracts in the whole brain was estimated using FSL software, and tract-based spatial statistics (TBSS) were computed to align FA images from multiple subjects for voxelwise statistical analysis. Using constrained principal component analysis (cPCA) with a finite impulse response (FIR) basis set, three components were extracted, and rotated using promax rotation. The subject-specific

structure matrix for each component was used as an index of functional connectivity (FC), and was correlated with FA values for each voxel in the FA skeleton. The first functional component involved bilateral cerebellum and parahippocampus, typically associated with motor and memory networks. The second involved the primary visual cortex and parietal areas, typically associated with visual attention. The third involved the dorsal anterior cingulated and parieto-temporal cortex, typically associated with executive and decision-making processes. Using cluster mass correction for multiple comparisons, significant correlations between FA values and the indices of functional connectivity were detected in inferior longitudinal tracts for all functional components, and for the superior longitudinal tracts for the third component. This suggests that during a source memory task, all functional systems are supported by inferior longitudinal tracts, but executive and decision making systems are additionally supported by superior longitudinal tracts.

H23

THE NEUROIMAGING INFORMATICS TOOLS AND RESOURCES CLEARINGHOUSE (NITRC) *David Kennedy[1]; [1]University of Massachusetts Medical Center* – We report on the use of a new neuroimaging informatics knowledge environment for MRI entitled: Neuroimaging Informatics Tools and Resources Clearinghouse (NITRC). Initiated in October 2006 through the NIH Blueprint for Neuroscience Research (1,2), NITRC's mission is to create a user-friendly knowledge environment for the functional magnetic resonance imaging (fMRI) and associated structural analysis community. Through the identification of existing tools and resources valuable to this community, NITRC's goal is to develop a knowledge environment to enhance, adopt, distribute, and contribute to the evolution of neuroimaging tools and resources. Located on the web at www.nitrc.org, this site promotes tools and resources, vocabularies, and databases, thereby extending the impact of previously funded, neuroimaging informatics contributions to a broader community. It is anticipated that this will give fMRI researchers greater and more efficient access to the tools and resources they need, better categorize and organize existing tools and resources, facilitate interactions between researchers and developers, promote better use through enhanced documentation and tutorialsóall while keeping the set of resources up-to-date with the most recent resource upgrades and updates. In Summary, NITRC, a new neuroimaging knowledge environment, is now online. We encourage the fMRI community to try it out and provide feedback on its design, tools, resources, and content. NITRC is a knowledge environment for the fMRI community where tools and resources are presented in a coherent and synergistic environment for the advancement of MRI-based neuroscience research.

Methodological Issues: Other

H25

ASYNCHRONY OF BOLD SIGNAL ACROSS BRAIN REGIONS *Xu Cui[1], Allan Reiss[1]; [1]Stanford University* – The hemodynamic response of neural activation as measured by fMRI has different characteristics across different brain regions. Here we studied the temporal aspect of BOLD signal; that is, the asynchrony (lead-lag) of BOLD signal across different brain regions, in a large dataset of about 200 subjects crossing 5 different fMRI experiments. We found that (1) the middle part of the brain (motor cortex) usually leads anterior and the posterior regions (prefrontal and occipital cortex); (2) this pattern of temporal activation is generally task independent; (3) inter-subject variance is large; (4) intra-subject variance - the variance of a single subject at different times - is very small if the two time points are close (e.g., within a few hours) but can be larger when the two times are distant (e.g., 1 year). The cause of this newly detected temporal pattern is unknown; though it likely reflects the asynchrony of vascular events rather than conduction of electrical signals. Our result shows that it is important to consider individual variance during fMRI data analysis, and that a standard hemodynamic function may not fit some brain regions as well as others when considered across a population sample. The correlation of this temporal activation pattern with age, gender and psychiatric disease is currently being investigated; our results may provide a new signature of developmental or mental states. Future work, including investigation of hemodynamic response using near infrared spectroscopy imaging, is required to reveal the mechanism underlying the pattern we have detected.

H27

TMS STIMULATION INTENSITY IN COGNITIVE CONTROL TASKS: THE ADEQUACY OF THE MOTOR THRESHOLD *Franziska M. Korb[1,2], Jakob A. Kaminski[1,3], Derek V. M. Ott[1], Arno Villringer[1,3]; [1]Max Planck Institute for Human Cognitive & Brain Sciences, Leipzig, [2]University Clinic, Cologne, [3]University Clinic, Leipzig* – Transcranial Magnetic Stimulation (TMS) has become an important experimental tool for exploring brain functional neuroanatomy. However, the use of TMS in the investigation of higher level cognition (e.g. cognitive control) is complicated by the difficulty in determining the appropriate stimulation intensity needed to influence cortical regions supporting such functions. Typically, TMS studies use the motor threshold (MT) to determine stimulation intensities, even if the employed tasks place no particular demands on the motor system. Here, we evaluated the adequacy of MT as reference in determining individual stimulation intensities in the study of non-motor, higher-level cognition. To this end, systematically varying stimulation intensities of repetitive TMS were applied to an individually localized region of the posterior middle frontal gyrus (pMFG) involved in working memory immediately prior to performance of an n-back task. We propose that MT-sensitivity of non-motor cortical regions such as the pMFG should result in similar between-subjects behavioral effects. If that is not the case, behavioral effects should rather correlate with absolute stimulation intensities. Results indicated that task-related behavioral effects were dependent on stimulation intensity variation. Thus, an empirical determination of the appropriate stimulation intensity may be necessary for valid employment of TMS in the study of non-motor processes.

H28

HOW DOES RTMS WORK? EVALUATING DISRUPTION VS. BIASING MECHANISMS *Jeffrey S. Johnson[1], Massihullah Hamidi[3,4], Bradley R. Postle[1,2], Giulio Tononi[2]; [1]University of Wisconsin-Madison, Psychology, [2]University of Wisconsin-Madison, Psychiatry, [3]University of Wisconsin-Madison Neuroscience Training Program, [4]University of Wisconsin-Madison Medical Scientist Training Program* – Although transcranial magnetic stimulation (TMS) has become a valuable tool in cognitive neuroscience, the mechanisms by which it affects brain function remain unclear. One commonly held view holds that repetitive (r)TMS influences behavior by producing transient "virtual lesions" in targeted tissue. Although consistent with reports of rTMS-induced declines in performance, this "disruption" assumption is difficult to reconcile with instances of rTMS-induced improvements in performance. One such case is that 10 Hz rTMS applied to the superior parietal lobule can improve performance on a spatial (but not object) delayed-recognition task. A replication with simultaneous EEG found that 10 Hz rTMS affects alpha-band power at parietal electrodes, with individual differences in these effects (rTMS increasing vs. decreasing alpha-band power) predicting whether rTMS impairs or improves behavioral performance (Hamidi et al., CNS 2007). But did 10-Hz rTMS produce these effects by imposing an (exogenous) oscillatory rhythm (i.e., by disrupting) or by biasing endogenous task-related oscillations? In the present study, three subjects from Hamidi et al. (CNS 2007) participated in a second experiment in which delay-period rTMS was replaced with 10 Hz visual flicker. We reasoned that 10 Hz flicker would produce widespread entrainment of neural activity to the flicker frequency, and comparison of these EEG results with those from the rTMS study would shed light on whether the latter also reflected (disruptive) entrainment to an exogenous stimulus. Results

indicated that the effects of 10 Hz rTMS are qualitatively different from those of visual flicker, and thus favor a biasing account of rTMS.

H29

SOURCE LOCALIZATION FOR COGNITIVE NETWORK DETERMINATION USING DUAL INDEPENDENT COMPONENT ANALYSIS OF HUMAN EEG AND FMRI DATA *Kevin Brown[1], Stephanie Ortigue[1], Scott Grafton[1], Jean Carlson[1]; [1]University of California, Santa Barbara* – Understanding the brain as a complex system requires integration of fine spatial and fast temporal information processing linked to cognitive operations. We present novel source localization algorithms for cognitive network determination that combine data from human EEG and FMRI studies acquired at separate sessions. Our methods make heavy use of independent component analysis (ICA) in order to (i) separate task-related activity from nontask-related activity and artifacts and (ii) reduce the size and complexity of the source determination inverse problem. Our methods match EEG and FMRI information simultaneously, either by fitting both EEG and FMRI dynamics or by regularizing the underdetermined EEG inverse problem using information about areas of activity obtained from ICA decomposition of FMRI. We focus particular attention on solution robustness as a function of choices made during inversion: the amount of head model detail, the relative weighting of the two imaging modalities, and the form of the model used to calculate the expected blood oxygenation level dependent (BOLD) response. We also investigate source localization efficacy as experimental design parameters are varied. We demonstrate the efficacy of our algorithms using human rapid event-related evoked visual response data. An important conclusion of this work is the link between source localization and experimental design; the appropriate algorithm for solving the EEG inverse problem will be dependent on the goals of the study and the details of its design.

Neuroanatomy

H30

FUNCTIONAL TOPOGRAPHY OF THE HUMAN CEREBELLUM: AN FMRI STUDY *Catherine Stoodley[1,2], Eve Valera[1,2], Jeremy Schmahmann[1,2]; [1]Massachusetts General Hospital / Harvard Medical School, [2]Athinoula A. Martinos Center for Biomedical Imaging* – The role of the cerebellum in motor control is well-established, but there is increasing interest in the non-motor role(s) of the cerebellum. Studies in patients indicate that motor control is somatotopically organized in the cerebellar anterior lobe; and clinical data also demonstrate that patients with damage to the cerebellar posterior lobe can experience a variety of non-motor symptoms, including difficulties in language, spatial and executive functions, and affective processing (the Cerebellar Cognitive Affective Syndrome). Tract tracing studies in animals show that cerebro-cerebellar and spino-cerebellar connections map to different regions of the cerebellum, providing anatomical support for our hypothesis that there are functional subdivisions of the cerebellum: the anterior lobe processes sensorimotor information; the posterior midline is involved in affective processing; and lateral hemisphere regions of the posterior lobe are engaged with information related to cognitive tasks. Additionally, we have predicted that the right cerebellar hemisphere is preferentially active during language tasks, and the left cerebellar hemisphere during spatial processing. This functional topography has yet to be shown experimentally in the cerebellum of healthy controls. We therefore used 3T functional MRI to investigate the patterns of cerebellar activity in healthy adult males (n=5; mean age 26.4 years) during motor (finger tapping), language (verb-for-noun generation), spatial (mental rotation), working memory (n-back) and affective tasks (viewing images from the International Affective Picture Scale). The data will be analyzed to investigate group activation patterns as well as within-subject topography. These findings may provide new insights into the functional topography of the human cerebellum.

H31

EFFECTS OF AGING ON MAXIMIZING GAINS AND MINIMIZING LOSSES IN A CHOICE TASK *Darrell Worthy[1], Jennifer Pacheco[1], Bo Zhu[1], David Schnyer[1], W. Todd Maddox[1]; [1]University of Texas at Austin* – Previous research suggests that the dorsolateral prefrontal cortex and the basal ganglia are especially susceptible to the effects of aging (Raz, 2000). These areas have also been implicated in reward processing and representation (Schultz, 2000). We hypothesized that elderly participants' ability to maximize gains and minimize losses will be attenuated. To test this we had healthy elderly participants (61 - 81 years old) and matched controls perform two decision-making tasks where they drew from one of four decks of cards on each trial and received points for each draw. In the Gains task they gained points on each draw and attempted to maximize points earned. In the Losses task they lost points with each draw and attempted to minimize losses. As predicted, gains maximization and loss minimization was attenuated in the elderly, with a larger attenuation for losses than for gains. Model-based analyses using a simple reinforcement learning model indicated that elderly participants were unable to adequately exploit the option with the highest expected value compared to younger participants. When attempting to minimize losses elderly participants showed a tendency to give less weight to recent information than younger participants. These results suggest that age-related cognitive decline may negatively affect one's ability to choose from alternative options in order to maximize reward and minimize losses.

H32

ATYPICAL READING/LATERALITY PROFILE ASSOCIATED WITH REVERSED PLANUM TEMPORALE ASYMMETRY *Christine Chiarello[1], Suzanne Welcome[1], Christiana Leonard[2]; [1]University of California, Riverside, [2]University of Florida, Gainesville* – Reading skill varies substantially among college students. We are investigating the neuroanatomical correlates of this variation. Two hundred students performed reading assessments and seven divided visual field (DVF) tests of word processing, and received structural MRI scans. A cluster analysis of the reading and DVF data classified 183 individuals into one of four groups differing in their reading skill and the strength of their VF asymmetries. Here we focus on the 17 individuals whose performance profiles could not be classified (i.e., outliers). Although they did not form their own cluster based on the variables used in the cluster analysis, they shared some characteristics that differed from those in the four groups. They obtained high scores for IQ and Passage Comprehension, but not Word Identification. Their responses were slower (but not less accurate) in the DVF tasks. Their VF asymmetries were highly variable across tasks and persons. These individuals were also more likely than those in the four clusters to have very consistent hand preferences. Remarkably, 41% of these outliers showed reversed (e.g., rightward) asymmetry of the planum temporale (compared to 19% in the rest of the sample). Thus, individuals with atypical profiles of reading and VF lateralization also evidenced atypical asymmetry in a language-relevant region. Within a population of normal readers, reversed planar asymmetry is not associated with poor reading skill, and hence may not be a predictor of dyslexia. However, this structural feature may be associated with an unusual reading/asymmetry profile.

H33

A COMPARISON OF CORTICAL ANATOMY BETWEEN COLLEGE STUDENTS WITH DIFFERENT READING SKILLS *Suzanne Welcome[1], Christine Chiarello[1], Paul Thompson[2], Elizabeth Sowell[2]; [1]University of California, Riverside, [2]University of California, Los Angeles* – Resilient readers are characterized by poor phonological processing skills in the absence of a deficit in reading comprehension. Such individuals may rely on alternate neural mechanisms to support skilled reading. We compared the cortical anatomy of resilient readers to that of poor readers (with impaired phonological processing and comprehension) and proficient readers (with no deficits in reading). We used cortical pattern matching algorithms to obtain measurements of radial expansion and

gray matter thickness (in millimeters) from structural MRI data. Compared to proficient readers, both resilient and poor readers show less leftward asymmetry of gray matter thickness in the temporo-parietal region, a region thought to support print-to-sound conversion. Resilient readers show greater gray matter asymmetry in medial frontal and medial posterior regions than either poor or proficient readers. It is possible that medial morphology relates to compensatory processing in resilient readers. Poor, but not resilient readers, show a reduction in radial expansion in the frontal region. This suggests that frontal anatomy may relate to text comprehension ability rather than phonological processing skill. The results of this study indicate that resilient readers may represent a separate population of readers, distinguishable from poor and proficient readers by their cortical anatomy. Additionally, phonological and comprehension skills may be associated with different aspects of brain morphology.

H34

MICROSTRUCTURAL BRAIN ALTERATIONS AND WORKING MEMORY IN PSYCHOSIS: RELATIONSHIP WITH GENETIC LIABILITY *Petra Habets[1], Jim van Os[1,2], Rainer Goebel[3,4], Machteld Marcelis[1]; [1]South Limburg Mental Health Research and Teaching Network, EURON, Psychiatry and Neuropsychology, Maastricht University, Maastricht, The Netherlands, [2]Division of Psychological Medicine, Institute of Psychiatry, De Crespigny Park, London, UK, [3]Maastricht University, Cognitive Neuroscience, The Netherlands, [4]F.C. Donders Centre for Cognitive Neuroimaging, Nijmegen, The Netherlands* – Background: Working memory (WM) deficits in schizophrenia seem to reflect dysfunction of cortical regions such as the anterior cingulate gyrus, the prefrontal and parietal cortex. Cortical thickness measurements can be used to identify small cytoarchitectural alterations. We hypothesized that alterations in cortical thickness in the above mentioned brain regions are associated with changes in WM performance, which was tested in patients and their siblings. Methods: T1-weighted MRI scans were acquired on a 3 Tesla scanner from 92 patients with schizophrenia and 100 non-psychotic siblings. BrainVoyager QX was used to measure cortical thickness in 77 regions of interest, using the Laplace method. With multilevel random regression, the association between cortical thickness and performance on the Auditory Verbal Learning task was examined within patients and siblings, adjusted for potential confounders. Results: In the patients, decreased cortical thickness in the anterior cingulate and left superior temporal gyrus was associated with impaired WM. In the siblings, decreased cortical thickness in Broca's area and the right inferior frontal sulcus was associated with impaired WM. In addition, there were some negative associations, mainly in parietal (patients) and temporal (relatives) regions. Conclusions: Psychotic patients and their siblings showed positive and negative associations between cortical thickness and WM, in brain regions previously identified as components of a distributed WM network, although the involved cortical regions differed between the groups. These differential relationships could indicate distinct WM neurocircuitry problems in patients and relatives and possibly explain the differences in WM performance between these groups.

H35

MORPHOLOGICAL STUDY ON THE CORRELATION BETWEEN IQ AND CREATIVITY *Judith Segall[1], Ranee Flores[1], Shirley Smith[3,1], Jeremy Bockholt[1], Robert Chavez[1], Alison Marshall[1], Rachael Grazioplene[1], Rex Jung[1,2,3,4]; [1]Mind Research Network, [2]University of New Mexico, Neurosurgery, [3]University of New Mexico, Psychology, [4]University of New Mexico, Neurology* – Numerous psychometric studies have noted an association between measures of creativity and intelligence up to an IQ of 120, but not thereafter (Sternberg, 1999). We sought to determine the morphological relationship between creativity and cortical thickness in a cohort of healthy subjects, who were grouped between those with a Full Scale Intelligence Quotiont (FSIQ) of ?120 and those >120. We obtained T1 images and creativity measures (Miller & Tal, 2007) in a cohort of 37 neurologically and psychiatrically normal subjects (FSIQ ? 120 – 8 females and 11 males; FSIQ ?121 – 8 females 10 males) ranging in age from 18 to 29. Five independent judges rated creative products of each subject, with high inter-rater reliability (?= 0.89), from which a "Creativity IQ" (CIQ) was calculated. T1 images were analyzed using FreeSurfer to obtain cortical measurements, which were then used in the general linear model to correlate cortical thickness to CIQ controlling for gender and FSIQ. We found that CIQ was significantly related ($p < .0001$) to decreased cortical thickness, bilaterally, in the superior parietal gyrus for subjects with a FSIQ ?120, increased left parsorbitalis thickness, and increased right caudal anterior cingulate thickness. For subjects with FSIQ ?121 there was a stronger correlation between the FSIQ and thickness than between CIQ and thickness. The results support the notion that creativity and cortical thickness are correlated up to an IQ of 120, but that FSIQ predominates in terms of cortical thickness correlates at FSIQ >120.

H36

GREY MATTER DENSITY AS ENDOPHENOTYPE FOR ADHD AND AUTISM *Hilde Geurts[1,2], Steven Scholte[1]; [1]University of Amsterdam, Psychonomics, Psychology, [2]Leo Kanner Huis, Autism Team Amsterdam* – Background: ADHD and autism are well known overlapping neurodevelopmental disorders of which the etiology is not fully understood. One way to unravel the relationship between the associated behavioral symptoms and the neurobiological underpinnings is to study endophenotypes. A potential endophenotype are structural differences in grey matter. Identification of overlapping and disease-specific brain abnormalities might help to explain similarities and differences in the neurocognitive profiles of ADHD and autism. The assumption is that also in the normal population this link between brain characteristics and disorder characteristics can be made. Method: Structural MRI (method voxel based morphometry) was obtained from 96 healthy adults who filled out ADHD and autism questionnaires. Results: Characteristics of both disorders are associated with grey matter density in the frontal cortex, while only ADHD characteristics are related to grey matter density in the striatum and only autism characteristics with the middle temporal gyrus. Not only are these the know brain areas related to these disorders, but also the direction of the correlations were as expected. Hence, the results showed that the association between questionnaire scores and the patterns of grey matter density are in line with findings in patients with ADHD and autism. Conclusion: This study shows that structural differences in grey matter indeed are a potential endophenotype for neurodevelopmental disorders such as ADHD and autism.

H37

SEX, HAND PREFERENCE AND BRAIN ASYMMETRY *Christiana M. Leonard[1], Stephen D. Towler[1], Suzanne Welcome[2], Christine Chiarello[2]; [1]University of Florida, [2]University of California, Riverside* – It is commonly believed that women and individuals with mixed hand preference have less strongly lateralized brains than men with consistent hand preference. We were able to test this idea in a sample of 200 normal young adults with volumetric MRI scans. Individuals were classified as consistent if they performed all actions on the 5 point Bryden scale with the same hand. Perisylvian measures (planum temporale, planum parietale and Heschl's gyrus) and medial frontal measures (cingulate and paracingulate gray matter) were entered into a discriminant analysis in order to classify hemispheres as either right or left. Contrary to our prediction, these measures were more successful in classifying the hemispheres of mixed handed women ($n = 41$, $F(5,76) = 21.74$) than consistent handed women ($n = 59$, $F(5,112) = 9.88$), mixed handed men ($n = 56$, $F(5,106) = 9.61$), or consistent handed men ($n = 44$, $F(5,82) = 8.88$). (All F's were significant, $p < .0001$.) In mixed handed women, all five measures contributed significantly ($p < .01$). In consistent handed women and mixed handed men all measures with the exception of the paracingulate contributed significantly. In consistent handed men, neither of the medial frontal measures contributed significantly to successful hemisphere classification. These findings remained unchanged when left handers ($n = 26$) were excluded. The relationship between sex, hand preference and brain

asymmetry continues to resist simple conceptualizations. This research was supported by NIH grant DC006957 to CC.

H38

FUNCTIONAL AND STRUCTURAL CONNECTIVITY OF THE HUMAN INTRAPARIETAL SULCUS AND ANGULAR GYRUS *Lucina Uddin[1], Kaustubh Supekar[1], Hitha Amin[1], Daniel Nguyen[1], Michael Greicius[1], Vinod Menon[1]; [1]Stanford University School of Medicine, Psychiatry and Behavioral Sciences, Stanford, CA* – The caudal inferior parietal lobe (IPL) of the human brain is a heterogeneous region involved in a wide array of cognitive functions ranging from spatial attention to language and mathematical cognition. We examined functional and structural connectivity of distinct subregions within the IPL using resting state fMRI and diffusion tensor imaging (DTI) in order to better understand its functional architecture and relationship to associated neural networks. We used probabilistic cytoarchitectonic maps to divide the caudal IPL into five regions of interest (ROIs) per hemisphere: the anterior and posterior angular gyrus (PGa, PGp), and three subregions within the intraparietal sulcus (hIP2, hIP1, and hIP3). Resting state functional connectivity results indicated differential coupling between the ROIs, with each ROI being functionally coupled to distinct networks. The PGa was linked to the basal ganglia and ventral premotor areas, while the PGp showed connectivity with ventromedial prefrontal cortex, precuneus, posterior cingulate, and hippocampal cortices. The anterior-most IPS ROI, hIP2, was linked with ventral premotor and insular cortex, while the posterior-most IPS ROI, hIP3, showed connectivity with the striate and extrastriate visual cortex. Deterministic tractography revealed structural connectivity between many, but not all, of the functionally connected regions. Our findings provide new evidence for functional heterogeneity of the IPL in relation to its cytoarchitectonically-defined subdivisions and offer a novel framework for interpreting the growing body of functional neuroimaging literature reporting activations in the IPL.

H39

GENETIC MARKER OF PRO-INFLAMMATORY RESPONSE IS ASSOCIATED WITH AGE-DEPENDENT REDUCTION IN WHITE MATTER INTEGRITY *Kristen Kennedy[1], Naftali Raz[2]; [1]Center for BrainHealth, University of Texas at Dallas, Dallas, TX, [2]Institute of Gerontology, Wayne State University, Detroit, MI* – Reduced white matter microstructural integrity is found in normal aging throughout the brain. The mechanisms of this age reduction are poorly understood, but may be partly under genetic control. The purpose of the current study was to investigate the influence of a genetic marker of inflammation, interleukin-1 beta G allele, on regional white matter integrity (fractional anisotropy, FA and apparent diffusion coefficient, ADC) as assessed by Diffusion Tensor Imaging (DTI) in a sample of 41 normal, healthy adults (44-81 years old). We found that carriers of the G allele displayed lesser integrity in the genu and splenium of the corpus callosum and in prefrontal and occipital white matter than IL-1? A homozygotes, and the effect of the marker became stronger with advancing age. These preliminary data suggest that persons who are genetically predisposed to stronger pro-inflammatory response may acquire greater white matter damage with age than individuals without this predisposition. It is these individuals who may most benefit from anti-inflammatory intervention. Supported in part by grant R37 AG-11230 from NIH.

Memory: Other

H40

HUMAN LONG-TERM ASSOCIATIVE MEMORY CAPACITY *Joel L. Voss[1,2]; [1]Northwestern University, Psychology, [2]The Beckman Institute, University of Illinois Urbana-Champaign* – Long-term memory depends on the retention of associative information, such as the relationship between a friend's face and his name, a home and its neighborhood, and a mint and its odor. Many have considered memory's overall capacity, but relevant data are scant. Some previous experiments on humans have assessed memory capacity by testing retention for thousands of visual impressions, and have concluded that there are virtually no constraints on how much information can be successfully retained. However, no previous studies of capacity have investigated associative memory processing that is essential to long-term memory. I studied long-term associative memory with 58,560 memory trials for picture-response associations during approximately one year of testing. Estimated capacity was on the order of several thousand associations, and this and other indicators of memory function were remarkably similar to those obtained for baboons (Papio papio) under comparable circumstances. These findings suggest conservation of long-term memory mechanisms and effectiveness in humans relative to nonhuman primates, despite at least 20 million years of divergent evolution and vastly different behavioral and cognitive repertoires. Furthermore, in contrast to the limitless capacity estimates derived from studies on the retention of visual impressions in humans, the current findings indicate more profound limitations for the associative processes that support our ability to remember the past.

H41

SUBJECTIVE LIKELIHOOD OF IMAGINED FUTURE EVENTS INFLUENCES ACTIVITY IN THE MENTAL TIME TRAVEL NETWORK *Julia A. Weiler[1,2,3], Boris Suchan[1], Irene Daum[1,2]; [1]Institute of Cognitive Neuroscience, Neuropsychology, Ruhr-University Bochum, Germany, [2]International Graduate School of Neuroscience, Ruhr-University Bochum, Germany, [3]Ruhr-University Research School, Bochum, Germany* – Humans possess the remarkable ability to vividly imagine past events as well as potential future scenarios, an ability termed mental time travel. For past events, a clear distinction can be made into events that did happen (true memories) and those that did not happen (false memories). However, no such distinction is possible for future events at the time of imagination. Nevertheless, we have a sense of the likelihood of occurrence of future events and this might influence brain activity. We conducted a functional magnetic resonance imaging study in which 16 healthy human subjects had to vividly envision potential personal future events for the upcoming Christmas holiday. After Christmas had passed, subjects had to judge for each of the previously imagined future events, whether it actually took place during Christmas or not (termed "true" and "false" future events in analogy to the memory literature). A comparison of the activation patterns for true and false future events revealed significant differences. True future events elicited higher activation in the left middle frontal gyrus, right inferior frontal gyrus, right precuneus, and left middle temporal gyrus, while the reverse contrast mainly activated the right anterior cingulate. In line with our expectations, subjects rated those events that were later classified as true as more probable than those that were later defined as false. These results show that distinct brain regions are modulated by this judgment of the likelihood of future events.

H42

ERPS REVEAL THE ROLE OF REMINDING IN THE SPACING EFFECT IN MEMORY *Laura Matzen[1], Kara Federmeier[2], Aaron Benjamin[2]; [1]Sandia National Laboratories, [2]University of Illinois at Urbana-Champaign* – The spacing effect, where participants have better memory for repeated items that are spaced far apart in a study list than for repetitions that are massed together, is a robust finding in the memory literature. One explanation for this effect is that the second presentation of an item reminds the participants of the first, reactivating the original memory trace and giving them practice with retrieving the item. At long lags, more effort is required to reactivate the memory trace, leading to a bigger benefit to later memory performance. In the present experiment, we used event-related potentials (ERPs) to test this explanation for the spacing effect. Participants studied words that were presented once or repeated at a lag of 2 or 10. At short lags, repeated words had a reduced N400 and a large LPC, indicating both priming and explicit processing. At long lags, there was no reduction in the N400 for repeated words but the large LPC remained. Critically, the ERPs elicited at study were backsorted

based on subsequent memory for the words. We found that the amplitude of the LPC for the repetitions was predictive of subsequent memory, and that the Dm effect for repeated items appeared only for the second presentation of the word, not for the first. Both of these findings support the hypothesis that the spacing effect is caused by explicit reminding during study.

H43

NEURAL MARKERS OF INHIBITION IN EPISODIC MEMORY

Maria Wimber[1,2], Karl-Heinz Baeuml[2], Zara Bergstroem[1], Gerasimos Markopoulos[1], Hans-Jochen Heinze[1], Alan Richardson-Klavehn[1]; [1]University of Magdeburg, Neurology and Stereotactic Neurosurgery, [2]University of Regensburg, Experimental Psychology – Retrieving particular episodes from memory strengthens the retrieved information, but at the same time also weakens related, non-retrieved information, causing so called retrieval-induced forgetting of the non-retrieved episodes. Such forgetting is thought to be the consequence of inhibitory control processes that reduce interference from concurrently active memory traces, thereby supporting retrieval of the relevant information. We studied the neural correlates of retrieval-induced forgetting using event-related functional magnetic resonance imaging during the final cued recall. Across participants, forgetting showed a strong positive correlation with neural activity in the left inferior prefrontal cortex (BA 47) and the left lateral temporal cortex (BA 22), regions associated with the retrieval of weakly represented memories. By contrast, retrieval-induced strengthening was correlated with activation increases in medial (BA 7) and lateral (BA 40) parietal areas, possibly reflecting the increased episodic strength of previously retrieved memories. Our findings demonstrate that retrieval-induced facilitation and forgetting involve distinct neural processes, and provide the first direct evidence for a possible functional-anatomical marker of inhibition in human episodic memory.

H44

THE PROSPECTIVE BRAIN: HOW FUTURE ACTIONS BREED INTRUSIVE COGNITIONS AND INTERFERE WITH CURRENT TASKS

Meredith Lanska[1], Taylor Rigby[1], Timothy Gerrits[1], Ezequiel Morsella[1,2]; [1]San Francisco State University, Psychology, [2]University California, Neurology, San Francisco – Based on neuropsychological evidence that simulating future events depends on neural machinery that is also used for remembering past events, it has been proposed that the function of episodic memory is to simulate potential future actions (Schacter & Addis, 2007). Together with research revealing the future-looking tendency of perception, memory, cognitive control, language, and action-production, this has led to the view of the 'prospective brain' (Schacter, Addis, & Buckner, 2007). To add to this literature, we propose that intrusive cognitions, too, reflect the prospective nature of the brain. These cognitions can occur when one is trying to clear one's mind before going to sleep, only to have thoughts about future tasks perturb consciousness. We hypothesize that these cognitions are triggered automatically by future tasks that may benefit from forethought. Accordingly, during a meditation-like exercise requiring one to clear the mind of excess thought and focus on just one thing (breathing), participants (n = 149) reported more intrusive cognitions about a future task that could benefit from forethought than when they anticipated no future task or anticipated a task that, though of comparable difficulty and content, could not benefit from forethought, $F(2, 146) = 4.974$, $p < .01$. We also examined how merely knowing that one must perform a future task interferes with a current task requiring cognitive control. Together, these findings have implications for understanding basic mechanisms in psychopathological conditions such as rumination and obsessive-compulsive disorder. More generally, they illuminate under-explored aspects of the prospective brain.

H45

ENHANCED BY EXPERIENCE: SUPERIOR SOURCE MEMORY FOR FAMILIAR OVER NOVEL SCENES IS ASSOCIATED WITH POSTERIOR HIPPOCAMPAL ACTIVATION AT ENCODING

Jordan Poppenk[1,2], Morris Moscovitch[1,2]; [1]University of Toronto, [2]Rotman Research Institute – Memory formation is associated with activation of the anterior hippocampus at encoding, although most studies reporting this effect have used only novel materials. These materials, according to the novelty-encoding hypothesis, are better encoded than familiar ones. We tested this hypothesis behaviorally while exploring whether novel and familiar materials were associated with different neural predictors of subsequent memory. We scanned participants using functional magnetic resonance imaging (fMRI) while they studied novel and familiarized scenes under two sets of instructions. In a subsequent source memory task, participants determined which instructions had been associated with each scene. Responses on the memory test were used to back-sort fMRI encoding trials into remembered and forgotten categories, which were compared to identify brain regions that predicted memory. This contrast was performed separately for novel and familiarized scenes. There were two major findings: first, by eliminating confounding effects of source confusion which plague studies on novelty effects, we showed that source memory associated with familiariarized scenes was in fact better than memory associated with novel ones. Second, memory for both scene types was predicted by a common network in occipital and parietal cortices but by unique loci in the hippocampus: the right anterior hippocampus predicted memory for novel scenes only, whereas posterior hippocampii predicted memory for familiarized scenes only. We conclude, contrary to the novelty- encoding hypothesis, that memory is superior for familiar than for novel items, and that this superiority is associated with activation of the posterior hippocampus during encoding.

H47

DISSOCIATING THE ELECTROPHYSIOLOGICAL CORRELATES OF RECOLLECTION AND FAMILIARITY IN OLDER AND YOUNGER ADULTS

Tracy H. Wang[1], Marianne de Chastelaine[1], Brian Minton[1], Michael D. Rugg[1]; [1]Center for the Neurobiology of Learning and Memory and Neurobiology & Behavior, UC Irvine, Irvine, CA – Previous aging studies investigating the contributions of recollection and familiarity to recognition memory have shown that recollection declines more markedly with age than does familiarity. There is considerable evidence that recollection and familiarity have distinct event-related potential (ERP) correlates. The aim of the present study was to determine to what extent ERP correlates of recollection and familiarity differ between older and younger adults, focusing on the question whether the seeming resistance of familiarity to aging is mirrored in its neural correlate. Twenty-four older adults (63-77 yrs) and 16 young adults (18-29 yrs) participated in a recognition memory study employing a modified R/K procedure in which subjects rated the confidence of their familiarity-based recognition decisions. The older adult group was split into two subgroups based on estimates of mean familiarity strength (n=12 each). This allowed us to equate estimates of familiarity-driven recognition between the young subjects and the high-strength subgroup of older adults. Strikingly, the putative ERP correlate of familiarity - the 'mid-frontal old/new effect' - was evident in the young subjects only, and was undetectable in both older sub-groups. By contrast, the putative ERP correlate of recollection - the left parietal effect - was evident in all three groups. The absence of the mid-frontal old/new effect in our older subjects raises the possibility that familiarity-based recognition depends upon qualitatively different memory signals in older and young adults.

H48

THE RECOLLECTION OF TO-BE-REMEMBERED AND TO-BE-FORGOTTEN ITEMS IN ITEM-METHOD DIRECTED FORGETTING

Liang-Tien Hsieh[1], Daisy Hung[1,2], Ovid Tzeng[1,2], Shih-kuen Cheng[1]; [1]Institute of Cognitive Neuroscience, National Central

University, Taiwan, [2]Institute of Neuroscience, Laboratory for Neuropsychology, National Yang-Ming University, Taiwan – The recollection processes associated with the retrieval of To-Be-Remembered (TBR) and To-Be-Forgotten (TBF) items in item-method directed forgetting were examined by using a two-step source judgment task. At study, each study word was accompanied with either a "Remember" or a "Forget" instruction directing the subjects to remember or to forget the accompanied study word respectively. At test, both TBR and TBF items intermixed with unstudied new words were presented and the subjects performed an initial old/new judgment to identify both TBR and TBF items and then determined their source information (i.e., being accompanied with a "Remember" or a "Forget" instruction at study). The recollection of TBR and TBF items were examined by the correct source identifications. Results from the initial old/new identification revealed that the hit rate to TBR items was higher than the hit rate to TBF items, showing the directed forgetting effect. However, no difference was found in the percentage of correct source judgments between TBR-Hits and TBF-Hits, suggesting that the percentage of recollected items among TBR-Hits was similar to the percentage of recollected items among TBF-Hits. Despite of such similarity, however, it is likely that the recollected TBR items may differ from the recollected TBF items in terms of the contextual richness of the recollected information. Such speculation gained support from another ERP study showing that the parietal old/new effect ? which is an electrophysiological signature of the recollection process ? was more pronounced for TBR-Hits than for TBF-Hits in the time window of 400-900 ms.

H49

PERFORMANCE ON A STRIATAL LEARNING TASK DISTINGUISHES ADDICTED FROM CASUAL CIGARETTE SMOKERS *Lesley Fellows[1], Tal Ben-Simhon[1], Alain Dagher[1], Michael Frank[2]; [1]McGill University, [2]University of Arizona* – Addiction is characterized by a loss of control over drug use, a process that is thought to be mediated by drug-related dopamine effects in the striatum. Cigarettes are highly addictive for most people, but about 8% of those who smoke cigarettes retain control over their smoking behavior. We aimed to determine if individual differences in striatal learning help explain why these so-called 'tobacco chippers' are resistant to the development of full-fledged addiction despite repeated exposure to cigarettes. We compared performance of demographically-matched addicted smokers (N=30) and tobacco chippers (N=27) on a probabilistic reinforcement learning task that has been shown to be sensitive to differences in dopamine neurotransmission. Participants were tested twice, once after overnight abstinence, and once while smoking at their usual rates. Overall learning did not differ between the two groups, or across conditions. However, the basis of that learning was significantly different: 'Go' learning from positive feedback was relatively better in chippers, while 'no go' learning from negative feedback was relatively better in addicted smokers when they were tested while smoking as usual. This suggests that chippers may be in a relatively hyperdopaminergic state compared to smokers while smoking at their usual rate, a claim supported by neuro-computational modeling. These data are consistent with the hypothesis that drug-induced dopamine release is blunted in the addicted state, and are the first demonstration of neurobehavioral differences in smokers who differ in their resistance to addiction.

H50

IDENTIFICATION OF A NOVEL ROLE OF PROTEIN INHIBITOR OF ACTIVATED SIGNAL TRANSDUCER AND ACTIVATOR OF TRANSCRIPTION I IN FACILITATING SPATIAL MEMORY FORMATION IN RATS *Eminy Lee[1]; [1]Institute of Biomedical Sciences, Academia Sinica, Taipei, Taiwan* – It is well known that long-term memory formation requires de novo RNA and protein synthesis. By using PCR differential display, we have previously identified the serum- and glucocorticoid-inducible kinase gene whose expression level is much higher in the dorsal hippocampus of fast-learning rats than slow-learning rats from the Morris water maze learning task. Recently, we have identified another cDNA fragment that also showed a significantly higher expression level in the fast-learning rats. After cloning and sequencing of this cDNA fragment, it shows 100% sequence homology to the 3'-end region of the rat protein inhibitor of activated STAT1 (pias1) gene. To confirm that pias1 expression is associated with spatial learning, naïve rats were either subjected to water maze training (n=6) or assigned to the non-trained group with the platform and visual cues been removed (n=6). The dorsal hippocampus was dissected out at the end of training and subjected to protein measure by western blot. Results revealed that water maze training significantly increased PIAS1 protein level in the hippocampus. In further examination of the role of PIAS1 in spatial memory formation, we have found that transfection of the wild-type PIAS1 plasmid to rat hippocampus facilitated, whereas transfection of PIAS1 siRNA impaired spatial memory performance (n=8 each group). PIAS1 was well known to play an important role in the immune system, but the present results suggest that PIAS1 also plays an important role in spatial memory formation.

H51

SLEEP-DEPENDENT EXTRACTION & CONSOLIDATION OF EPISODIC MEMORY DETAILS *Els van der Helm[1], Ninad Gujar[1], Caitlin Watts[1], Matthew P. Walker[1]; [1]Sleep and Neuroimaging Laboratory, Psychology, and Helen Wills Neuroscience Institute, University of California, Berkeley* – Although the benefit of sleep on procedural-skill consolidation is well established, the role of sleep in declarative memory processing remains incomplete. Using a nap paradigm, here we investigated the impact of wake and sleep on the offline consolidation of ITEM versus CONTEXT memory. Participants (n=27) studied two lists of words at 12noon, which were each associated with a different set of contextual cues. Post-learning, subjects were assigned to either a Nap group (n=13), obtaining a 90min sleep opportunity, or a No-Nap group (n=14) which remained awake. Six hours post-learning (6PM) subjects performed a recognition test. For each recognition trial, subjects made two possible responses indicating 1) whether the item was old or new (ITEM-memory), and 2) if old, which study list the item came from (CONTEXT-memory). No offline difference in ITEM-memory was found between the two groups. In contrast, a significant consolidation benefit for CONTEXT-memory occurred following sleep in the Nap group ($p=0.04$). Furthermore, within the Nap group, the extent of CONTEXT-memory retention was positively correlated with the amount of stage-2 NREM sleep ($r=0.57$, $p=0.04$). Most interestingly, CONTEXT-memory not only correlated with Stage-2 NREM, but a specific electrophysiological signature of NREM-sleep spindles, especially in prefrontal regions ($r=0.72$, $p<0.01$). The findings clarify the role of sleep in declarative memory processing, indicating that sleep preferentially benefits more hippocampal-dependent aspects of episodic representations (contextual details). Moreover, sleep does not appear to represent a passive time of minimal interference, but a proactive state modulating episodic memory by way of specific electrophysiological oscillations.

H52

ANTICIPATORY ELECTROPHYSIOLOGICAL CORRELATES OF VOLUNTARY MEMORY CONTROL *Simon Hanslmayr[1], Bernhard Pastötter[1], Karl-Heinz Bäuml[1]; [1]Regensburg University* – For the proper functioning of our memory system voluntary control processes are needed. In everyday life, voluntary suppression of episodic memories is important to keep our memory free from e.g. outdated information (the old address of a friend) or emotionally straining events (traumatic experiences). In the laboratory, such voluntary suppression can be studied using the Think/No-Think paradigm, in which previously learned item associations are suppressed several times, inducing later forgetting of the information. The present study investigated whether anticipatory mechanisms mediate such voluntary forgetting. Doing so, the subjects received a cue whether to prepare to think or not to think of a previously studied face-word association. This Think/No-Think cue appeared prior to a

memory cue (face) which pointed to a previously studied word. Examining event-related potentials (ERP) we identified an early anticipatory process which was related to the Think/No-Think cue, and a later process which was related to the memory cue. Both ERP effects were due to a decreased positivity over anterior and temporal electrode sites, and both effects predicted later forgetting. In addition, the memory-cue-related ERP effect could be predicted by the anticipatory ERP effect. The results demonstrate the existence of anticipatory voluntary memory control processes mediating the forgetting of unwanted memories. We suggest that the effects reflect the action of top-down driven control processes which down-regulate the activity in memory-relevant brain areas already prior to the presentation of a memory cue.

H53

NEURAL INDICES OF CONTENT-DEPENDENT RETRIEVAL PROCESSING *Damian Cruse[1], Edward Wilding[1]; [1]CUBRIC, School of Psychology, Cardiff University, UK* – Functional magnetic resonance imaging (fMRI) studies of episodic retrieval have demonstrated patterns of neural activity that depend upon the kinds of information which are retrieved. The poor temporal resolution of fMRI data, however, makes it difficult to determine whether these activations reflect a) recollection of different kinds of information or b) subsequent processing resulting from recollection. The high temporal resolution of ERPs allows investigation of the timing of content-specific retrieval processing, and toward this end participants studied one of two lists of words. Half studied an equal number of words shown in pink or yellow. The remainder studied an equal number of words spoken by a male or female voice. At test, all participants made old/new judgments followed by a source (pink/yellow or male/female) and confidence (high/low) judgment. The ERPs associated with high confidence correct source judgments strongly suggest qualitative differences in neural activity depending upon whether colour or voice information was retrieved. Furthermore, the 800-1100 ms post-stimulus time course of these differences is important, because it follows a common lateralised posterior positivity (the left-parietal ERP old/new effect) which is a content-independent index of recollection. As a result, the content-dependent ERP signature identified here likely reflects processes that are engaged differentially as a consequence of recollection. In combination with previous ERP findings in which these classes of retrieval processes either overlapped with or preceded the left-parietal ERP old/new effect, these data points emphasise that these kinds of retrieval processing operations operate at multiple loci during memory retrieval and assessment.

H54

ERP OLD/NEW EFFECTS ELICITED BY FACES THAT ATTRACT HIGH OR LOW CONFIDENCE MEMORY JUDGMENTS *Yee-Ying Yick[1], Edward Wilding[1]; [1]CUBRIC, School of Psychology, Cardiff University, UK* – Event-related potential (ERP) studies of memory retrieval where faces have been used as stimuli have revealed inconsistent and sometimes contradictory results, notably regarding whether ERPs index two fundamental memory processes - recollection and familiarity. We investigated the sensitivity of ERPs to these processes using faces as stimuli and a different retrieval task to those employed previously. In two experiments, participants made old/new memory judgments to faces and rated their confidence (high/low) in their decisions. In keeping with one account of the natures of recollection and familiarity, ERP signatures of recollection were assumed to be indexed by old/new effects that were evident for high confidence old judgments only. ERP signatures of familiarity were assumed to be indexed by effects that co-varied with recognition confidence for old and for new test faces. The two experiments differed at encoding only, and old/new discrimination was superior in the second experiment, due primarily to a larger proportion of high confidence old judgments. There were ERP old/new effects associated with high confidence old judgments in both experiments, but in neither were there robust old/new effects associated with low confidence correct judgments to old faces. These data points provide little support for the view that ERPs index familiarity associated with faces, although an alternative interpretation is that the null result reflects the limited degree to which familiarity is a useful basis for distinguishing between old and new stimuli in these kinds of tasks.

H55

REPETITION PRIMING IN MUSIC: AN ERP STUDY *Sean Hutchins[1,2], Caroline Palmer[3], Karsten Steinhauer[4,5]; [1]International Laboratory for Brain, Music, and Sound Research, Université de Montréal, [2]Université de Montréal, Psychology, [3]McGill University, Psychology, [4]School of Communication Sciences & Disorders, McGill University, [5]Centre for Research on Language, Mind, & Brain, McGill University* – Repetition is very common in the musical domain. Previous experiments have demonstrated that repetition of musical tones is associated with faster production times and decreased error rates for those tones (Hutchins & Palmer, 2008). These effects are similar to repetition priming effects in language. In addition, event-related potential studies have shown that repetition priming elicits a postivity that reduces the N400 amplitude (Kutas & Van Petten, 1994). This study examines whether repetition of musical tones has an effect on EEGs. Trained musicians heard short sequences of computer-generated music and made delayed judgments as to whether the timbre of the final tone was different from that of the first four tones. This final tone (target) was either a pitch repetition of a previous melodic tone (prime), or was previously unheard. Primes were either adjacent to the target tones, or were separated by two intervening tones. Melodic tonality was also controlled for. ERPs were collected across 64 scalp sites for the 1000 ms immediately following the final tone. Repetition yielded both a late posterior positivity and a small early frontal negativity. In addition, strong differences were found between neural responses to same and different timbre tones. These results show a distinct neurological effect of repetition, and provide evidence that repetition priming in music may be similar to priming in the language domain.

H56

THE BRIGHTEST CANDLE: COGNITIVE AND PHARMACOLOGICAL ADVANTAGES FOR YOUNG E4 CARRIERS *Natalie Marchant[1], Sarah King[1], Naji Tabet[2], Jennifer Rusted[1]; [1]University of Sussex, [2]Institue of Postgraduate Medicine, Brighton and Sussex Medical School* – The presence of the apolipoprotein (APOE) e4 allele increases the risk of developing Alzheimer's Disease (AD) later in life. Little is known however, about the cognitive consequences of possessing this allele in earlier years, nor about its interaction with the cholinergic system (which is compromised in AD). The current study administered 1 mg of the cholinergic agonist nicotine via nasal spray to healthy non-smoking young adults (aged 18-30) with either e3/e3 or e4+ (at least one e4 allele) genotype. They were matched on age, sex and IQ, in a placebo controlled, double blind 2 (drug: placebo, nicotine) x 2 (genotype: e3/e3, e4+) between subjects design. Cognitive functioning was investigated with a test of prospective memory (PM). PM, which requires the interruption of an ongoing activity to retrieve and act upon a previously-formed intention, incorporates both memory and attentional components, is impaired in early AD patients and is facilitated by nicotine. Sustained attention, verbal fluency and episodic recall were also measured. Paradoxically, e4+ participants outperformed e3 participants on all placebo measures of cognitive performance. In addition, this genotype advantage was potentiated by nicotine on all measures of PM performance. These results confirm the suggestion that the e4 allele confers a cognitive advantage in younger adulthood before producing detrimental consequences in later life. Moreover, these results are the first to demonstrate that young adults carrying an e4 allele show an enhanced response to nicotinic receptor stimulation.

H57

RETRIEVAL INFLUENCES ON THE ENCODING OF NEW MATERIAL *Stacey Danckert[1], Colin MacLeod[1], Myra Fernandes[1]; [1]The University of Waterloo* – Based on a procedural account of memory, retrieval involves concurrent encoding of new information (Kolers &

Roediger, 1984). Yet, few studies have considered how new information is processed during retrieval. In the context of a recognition memory test, Jacoby and colleagues (2005) showed that when new wordsóthe foils on the recognition testówere presented among 'old' words that had been deeply encoded during prior study, they were subsequently better recognized than were foils presented among 'old' words that had been shallowly encoded. In Experiment 1 of the current study, we replicated this "memory-for-foils" effect. In Experiment 2, we showed that the effect was not simply a consequence of strength differences created during encoding. In Experiment 3, we contrasted pictorial to non-pictorial imagery and demonstrated that the effect is robust enough to occur under a different encoding state. In Experiment 4, we examined the quality of memory for foils, demonstrating that the effect was based primarily on recollection and not on familiarity. Overall, we provide support for the source-constrained retrieval hypothesis of Jacoby et al. (2005): During attempts at recognition, subjects may re-enter the initial encoding state, which in turn influences encoding of new items. In a broader sense, we show that new information can be significantly influenced by how surrounding items are encoded and retrieved. Future studies will use functional neuroimaging to provide a deeper understanding of the neural processes underlying the memory-for-foils effect.

H58

NEURAL AND BEHAVIORAL MARKERS OF INCORPORATING RECOMMENDATIONS INTO RECOGNITION JUDGMENTS *Akira OConnor'[1], Ian Dobbins[1]; [1]Washington University, Psychology, St. Louis* – Outside the laboratory individuals often make use of extra-mnemonic information when evaluating their own memories. Although the neural systems that directly support episodic retrieval are heavily studied, those enabling observers to incorporate extra-mnemonic information into memory assessments are unknown. Using event-related functional magnetic resonance imaging (fMRI) we investigated this inferential skill, specifically examining the ability of observers to optimally incorporate external recommendations into recognition judgments. Participants underwent recognition memory scans in which a previously validated computer recommendations ("likely old" or "unlikely old") preceded each recognition probe item, and they were free to use or ignore each recommendation when rating each subsequently appearing memory probe. Behavioral measures suggested considerable individual variability in the ability or willingness to effectively incorporate the recommendations into memory judgments, and fMRI data suggested this ability relies upon prefrontal cortex (PFC). Whereas dorsolateral prefrontal cortex (PFC) regions were sensitive to the validity of the recommendation, anterior PFC regions were sensitive to the direction of recommendation. These findings suggest dissociable roles across regions that are often jointly implicated during episodic recognition research.

H59

THE EFFECT OF SLEEP AND TASK-RELATED COGNITION ON EGOCENTRIC AND ALLOCENTRIC SPATIAL MEMORY PERFORMANCE *Erin Wamsley[2,1], Joseph Benavides[1], Robert Stickgold[2,1]; [1]Beth Israel Deaconess Medical Center, [2]Harvard Medical School* – Several studies now demonstrate that post-training sleep is beneficial for the retention of hippocampus-dependent memory following encoding. However, the most fundamental role of the sleeping brain may not be to "enhance" memory performance, but to facilitate the systems-level reorganization of memory traces across time. Here, we examined the effects of post-training NREM sleep on qualitative aspects of spatial memory. Participants (n=39) were trained on a 3D-style virtual maze task at 12:30pm. Following training, subjects either immediately lay down to begin a 1.5 hr nap opportunity (n=18), or else remained awake (n=21). At retest (5:30pm), participants completed recognition tests from an Egocentric Perspective (1st person view) and Allocentric Perspective (overhead map view), regarding critical decision points in the maze. Each participant was also classified as having an egocentric or allocentric spatial representation preference, using the "Tunnel Task" of Gramann et al (JEP, 2005). Rather than exerting a particular effect on egocentric vs. allocentric test performance, sleep was selectively beneficial for the test format which matched participants' spatial representation preference (sleep x preference interaction: p=.04). Furthermore, the overall effect of sleep on maze completion times was dependent on whether participants reported mentation (thoughts, feelings, dreams) related to the maze task between learning and retest (sleep enhanced performance only when related cognition was reported: p=.006). These observations suggest that the process of sleep-dependent memory consolidation is contingent upon the specific manner in which a task in encoded, and is correlated with task-related cognition during the retention interval.

H60

EMOTION AIDS ATTENTIONAL PROCESSES IN BINDING SOURCE AND ITEM INFORMATION IN OLDER ADULTS: A BRAIN FMRI STUDY *Amanda Kutz[1], Paul Newhouse[1], Julie Dumas[1]; [1]University of Vermont, Psychiatry* – This study examined the effect of emotion on source memory, item memory, and related brain activation in older and younger adults. Source memory has been consistently found to decline with age, while the effect of aging on memory for emotional stimuli has been inconsistent. Emotional information has also been shown to interrupt binding processes between source and item information. Importantly, binding processes are also thought to be impaired in aging. Using event-related fMRI, 12 younger (ages 18-30) and 12 older adults (ages 60 and older) viewed emotional (positive and negative) and neutral words during an incidental encoding task. Each word appeared in a frame that was either red or blue. Recognition memory was tested after the scanning session and measures of subsequent memory were used to examine brain regions activated during encoding for words that were correctly recognized. Age differences in memory were only found for source memory for neutral items. No age differences were found for source memory for emotional words or any of the item memory measures. The activation data showed that older adults had greater activation in right frontal regions for both item and source memory when encoding emotional information. When examining source memory for negative information, older adults also had greater activation in right parahippocampal regions compared to younger adults. These data showed that emotional information did not impair item and source binding for older adults. Compensatory activation of right frontal regions may aid in attentional processing of emotional information for older adults.

H61

SUPPRESSING UNWANTED VISUAL MEMORIES BY EXECUTIVE CONTROL *Ean Huddleston[1], Emily Peterson[2], Michael Anderson[1]; [1]University of St. Andrews, [2]University of Oregon* – Recent neuroimaging work using the Think/No-Think (TNT) paradigm has shown that when people suppress retrieval of unwanted memories, hippocampal activation is reduced. It remains unclear, however, whether retrieval suppression also modulates regions of neocortex supporting the representation of the memory itself. To examine this issue, we developed a modified TNT paradigm wherein people attempt to suppress the retrieval of faces and scenes. Faces and scenes are ideal stimuli in that the cortical bases for processing these types of stimuli are well documented, providing specific brain regions in which to search for evidence of neocortical suppressionóthe fusiform face area for faces, and parahippocampal place area for scenes. Here we report a behavioral experiment using these stimuli. During the learning phase, participants studied word-picture pairs. Then, during the Think/No-Think phase, participants were shown the cue words for numerous word-picture pairs. For some words, participants were instructed to think of the associated picture, and for other words, participants were instructed to not think of the associated picture. Results showed impaired memory for those pictures participants tried to suppress, compared to pictures from baseline pairs, extending retrieval suppression effects to memories of faces and scenes. This paradigm validates a procedure that can be used to target neocortical contributions to retrieval suppression using fMRI.

H62

FUNCTION AND ACTION KNOWLEDGE REPRESENTATIONS IN LEFT MIDDLE TEMPORAL GYRUS *Michael Souza[1,2], Espen Helskog[2,3], Pedro Paz-Alonso[2], Carter Wendelken[2], Silvia Bunge[1,2]; [1]UC Berkeley, Psychology, [2]Helen Wills Neuroscience Institute, UC Berkeley, [3]University of Oslo, Psychology, Norway* – Accessing and utilizing action-relevant knowledge about manipulable objects is an important aspect of human behavior. Left posterior middle temporal gyrus (pMTG) activation is frequently observed in neuroimaging studies employing manipulable objects (Johnson-Frey, 2004; Lewis, 2006). However, it is unclear whether left pMTG represents knowledge regarding how objects can be used, or whether this region more generally represents knowledge about actions and functions associated with a stimulus. To address this question, we conducted an initial functional MRI study specifically designed to test the hypothesis that left pMTG represents functional semantics for manipulable objects (N=13). We asked participants to view manipulable objects and to (1) consider the object's primary use (Function), (2) rehearse the most prominent color in the object (Repeat), (3) imagine using the object (Imagery), or (4) mentally rotate the object (Rotate). Activation in left pMTG was solely driven by the Function condition, consistent with a role in functional semantics. However, it could be argued that differences in difficulty between conditions drove this effect. To address this possibility, participants in Experiment 2 are asked to consider (1) the object's primary use (Function), (2) how one's body moves when using the object (Action), or (3) the physical properties of the object (Appearance). We predict that left pMTG activation will again be driven by Function, even though participants report that Function is less difficult than Appearance. Thus far, our data suggest that action-relevant knowledge is housed in the posterior temporal lobes, just anterior to area V5, which processes biological motion.

H63

HOW SLOW CAN YOU GO? UNIQUE FMRI CORRELATIONS WITH EEG ACTIVITY BELOW 0.1 HZ DURING SLEEP *Dante Picchioni[1], Silvina Horovitz[2], Masaki Fukunaga[2], Walter Carr[3], Thomas Balkin[1], Jeff Duyn[2], Allen Braun[2]; [1]Walter Reed Army Institute of Research, [2]National Institutes of Health, [3]Naval Medical Research Center* – Activity in slow EEG bands during sleep is associated with the restorative aspects of sleep. There is a growing interest in activity below 0.1 Hz, which may mediate these restorative effects and the putative cortical plasticity associated with sleep-dependent learning. Assessing the fMRI correlates of the fluctuations in spectral power in this EEG band can provide information on the neural correlates of these restorative processes. We sought to determine the unique fMRI correlates of activity in the 0.05-0.099 band, as differentiated from activity in the 0.66-0.99 and 1.0-3.9 bands. Each band was modeled separately and the three sets of correlations were subjected to a conjunction analysis. The relative uniqueness of each band was assessed by comparing the percentage of voxels in the conjunction category where there was a significant correlation for the band in question and a non-significant correlation for the other two bands. The category for the 0.05-0.099 band contained the largest percentage. The significant positive correlations for unique activity in the 0.05-0.099 band were mostly in sub-cortical areas (medial thalamus, hypothalamus, hippocampus) while negative correlations were mostly in neocortical areas that represent the default-mode network. These data suggest that EEG activity below 0.1 Hz plays the most prominent role in sleep-dependent processes compared to other slow bands. Correlations in the thalamus could be related to the generation of this activity. Correlations in the hippocampus and neocortical areas (including nodes in the default-mode network) could reflect interactions between these brain systems that subserves a process of selective cortical plasticity.

H64

THE GENERATION OF PICTURES CAN BENEFIT BOTH ITEM AND SOURCE MEMORY *Zachary Rosner[1,2], Kaiping Peng[1,2], Arthur Shimamura[1]; [1]University of California, Psychology, Berkeley, [2]Peking University, Psychology, China* – Previous research has demonstrated that generating responses such as rhymes, antonyms, or semantic associates to stimuli during encoding facilitates memory for items as compared to passively reading the same information (Slamecka & Graf, 1978). However, this generation effect has been found to impair memory for source information such as stimuli color or font (Mulligan, Lozito & Rosner, 2006). Still, generation effects on less object-oriented features of source memory remain controversial, as Marsh (2006) manipulated procedural aspects to find both positive and null generation effects for location memory. Two contrasting accounts for the positive and negative effects of generation on item and source memory are item-context tradeoff, which argues that active generation forces one to attend to a target item at the expense of forming contextual associations, and transfer-appropriate processing, which claims that item recognition benefits from more conceptual processing during generation, while source memory benefits from more perceptual processing during passive learning. In this study, a picture fragment completion task was used in a series of three experiments in which source was manipulated for object color, object location, and background color. While generation improved item recognition universally, it improved object color memory, had no effect on object location memory, and slightly (non-significantly) impaired background color memory. These findings suggest that impaired source memory is not a necessary consequence of enhanced item memory, which directly disputes the item-context tradeoff account. Rather, picture fragment completion likely increases conceptual processing and differentially affects perceptual processing of distinct aspects of an item's features.

H65

EFFECTS OF MULTIPLE SOURCE CHARACTERISTICS ON WORD AND SPEAKER RECOGNITION: AN ERP STUDY *Sandra Campeanu[1,2], Claude Alain[1,2], Fergus Craik[1,2]; [1]Rotman Research Institute, Baycrest Centre, Toronto, Canada, [2]University of Toronto, Psychology, St. George Campus, Canada* – Context reinstatement has been shown to facilitate word and source recognition. In an auditory ERP experiment, participants performed both recognition tasks with words spoken in four voices. Two voice parameters varied between speakers, with the possibility that none, one or two of these parameters was congruent between study and test. Results indicate that reinstating the study voice at test facilitates both word and speaker memory, compared with no benefit when only one voice parameter is similar. This implies that voices are encoded as acoustic patterns rather than as the sum of their vocal attributes. ERPs revealed, in addition to three expected memory-related modulations, a pre-recollection positivity associated with this reinstatement benefit in both tests. This positivity, likely reflecting acoustic recognition, occurred at 400ms over parietal regions in the word test and started as early as 120ms and 175ms over right frontal and right temporal areas, respectively, in the speaker test.

H66

NEURAL CORRELATES OF SUCCESSFUL MEMORY ENCODING ARE INFLUENCED BY SUBJECTIVE PROBABILITIES OF FUTURE RECOGNITION: EVIDENCE FROM EVENT-RELATED POTENTIALS *Ida-Maria Skavhaug[1], Edward L. Wilding[2], David I. Donaldson[1]; [1]University of Stirling, [2]Cardiff University* – The neural correlates of successful memory encoding differ depending on the nature of the task performed at study (Otten and Rugg, 2001). We investigated the influence of Judgments of Learning (JOLs - subjective judgments of the likelihood of remembering studied material on a later test) on the neural correlates of successful memory encoding using Event-Related Potentials (ERPs). In Experiment One, participants saw word pairs and made a JOL for each pair. In Experiment Two, participants completed the same task, but were instructed to simply press a button to initiate the next trial,

rather than to make a JOL. In both experiments memory for the pairs was assessed on subsequent old/new recognition memory tasks. Discrimination was higher in Experiment One than in Experiment Two. Moreover, there were different ERP correlates of successful encoding in the two experiments: Experiment One produced a relatively early (550-1000ms) onsetting ERP effect with a focus at parietal electrodes, whereas the effects in Experiment Two onset later and lasted longer (1000-2000ms) with a focus at frontal electrodes. One explanation for the changing pattern of memory encoding ERP effects is that it reflects nothing more than poorer discrimination in Experiment Two. This is unlikely, however, because the differences across task remain for a subset of participants for whom discrimination is comparable in the two experiments. The ERP findings therefore provide evidence for the existence of JOL-specific neural correlates of subsequent memory.

H67

EXAMINING RECOGNITION MEMORY PROCESSES USING A SLOW-REVEAL PARADIGM: A RESPONSE-LOCKED EVENT-RELATED POTENTIAL STUDY *Catherine A. MacLeod[1], Mark E. Wheeler[2], David I. Donaldson[1]; [1]University of Stirling, [2]University of Pittsburgh* – Dual-process models propose that two independent retrieval processes support recognition memory; familiarity and recollection. Using stimulus-locked averaging, Event-Related Potential (ERP) studies of recognition memory have identified a set of old/new effects, including putative correlates of familiarity (the 300-500msec mid-frontal effect) and recollection (the 500-800msec left-parietal effect). ERPs reveal a close temporal relationship between these effects, with the potential for overlap between the termination of activity associated with familiarity and the onset of that associated with recollection. Moreover, despite extensive investigation, relatively little is known about their causal role in making recognition decisions. In an attempt to investigate the functional significance of the ERP effects we examined old/new effects using response-locked averaging during a recognition memory test for pictures - considering neural activity leading up to the recognition response. Furthermore, to reduce the temporal proximity between retrieval processes (and hence allow for better differentiation between them) we introduced a slow-reveal paradigm, whereby stimuli were gradually uncovered at test over a 5 second period. The response-locked ERPs showed an old/new effect in the 400msec preceding the response; this effect was maximal over fronto-central electrodes and resembles the traditional stimulus-locked activity associated with familiarity. Intriguingly, despite good behavioural performance and the use of pictures as stimuli, ERP activity typically associated with recollection was not apparent; suggesting perhaps that the slow-reveal paradigm encourages retrieval based solely on familiarity. Regardless, the results highlight the utility of response-locking procedures, and suggest a contributory role for the mid-frontal old/new effect in making recognition memory decisions.

H68

DIRECTED FORGETTING OF NEGATIVE AND NEUTRAL PICTURES - AN EEG STUDY *Anne Hauswald[1], Johanna Kissler[1]; [1]University of Konstanz* – People are able to intentionally segregate and differentially rehearse or inhibit elements in episodic memory, resulting in reduced retrieval of irrelevant elements. So far, it is largely unclear, whether this ability extends to emotional memories. The present study investigated behavioral and electrophysiological mechanisms of intentional forgetting of neutral and negatively arousing complex pictures using the item method variant of directed forgetting. Event-related potentials (ERPs) were recorded as participants viewed series of neutral and negative complex colored pictures, each followed by a cue designating the previous picture as 'to-be-remembered' or 'to-be-forgotten'. Results from a subsequent forced choice recognition memory task using the 'remember-know' procedure indicated that directed forgetting occurred for neutral, but not for negative pictures. Moreover, both directed forgetting and emotion affected the recollection, but not the familiarity component of recognition memory. ERPs revealed three distinct effects: First, a parietal positivity between 450 and 700 ms after picture on-set was more pronounced for negative than for neutral pictures. Second, regardless of the content of the preceding picture 'remember', but not 'forget' cues were associated with a larger parietal positivity between 400 and 500 ms after cue on-set. Third, an enhanced frontal positivity between 450 and 700 ms after cue on-set appeared selectively for 'forget' cues following neutral pictures. The results indicate that negative pictures are exempt from directed forgetting and suggest that processes of selective rehearsal (parietal positivities) as well as additional frontal mechanisms, possibly indicative of inhibitory processes contribute to successful directed forgetting of neutral pictures.

H69

A RIGHT HEMISPHERE ADVANTAGE IN FACE PROCESSING MODULATES HEMISPHERIC ASYMMETRIES IN FACE PRIMING: BEHAVIOURAL AND FMRI EVIDENCE *Elias Mouchlianitis[1], Rik Henson[1]; [1]MRC Cognition and Brain Sciences Unit* – Our previous studies on repetition priming of faces (Mouchlianitis & Henson, EPS January 2008) found larger left-hemisphere (LH) effects, when primes were central and probes lateralised. Contrary, Bourne & Hole (2006, Experiment 1) presented lateralised primes and central probes and found a right-hemisphere (RH) priming advantage. We postulated that RH encoding is critical for inducing facilitation in repetition priming, but when probes are lateralised LH priming is larger due to lower baselines in the RH, that suppress priming. Experiment 1 used long lag familiar face priming with two sessions, one with lateralised probes, and one with central probes. Results showed that the prime/probe location indeed modulates priming effects, with more LH priming for lateralised probes, and RH priming for central probes. In Experiments 2 and 3 we used short-lag priming with both primes and probes being lateralised, and sessions with 120ms and 80ms to control for baseline differences. Results showed that reliable priming was only found in the RH-prime/LH-probe condition, for both presentation times. In Experiment 4, fMRI was used with a similar paradigm, with the inclusion of houses as control stimuli. Results showed a main effect of the right FFA, which, however, did not interact with neither priming or visual field (possibly due to low temporal resolution of fMRI). . These results indicate that there is a RH advantage in early face processing stages that possibly modulates hemispheric differences in face priming.

H70

NEUROPLASTICITY-BASED COGNITIVE TRAINING IMPROVES SELF-REFERENTIAL PROCESSING IN SCHIZOPHRENIA PATIENTS: BEHAVIORAL AND FMRI ASSESSMENTS *Karuna Subramaniam[1], Tracy Luks[1], Stephanie Aldebot[1], Adelaide Hearst[1], Arul Thangavel[1], Melissa Fisher[1], Coleman Garrett[1], Gregory V. Simpson[1], Srikantan Nagarajan[1], Sophia Vinogradov[1]; [1]UCSF* – Prior research indicates that schizophrenia patients are impaired at identifying themselves as the source of self-generated information and show decreased activation within the dorsal medial prefrontal cortex (dMPFC) compared to healthy controls (HCs) during this task. Here, we investigate whether this deficit is amenable to a behavioral intervention. Twenty-four patients and 12 HCs underwent an fMRI self-referential source-memory task at baseline. Twelve patients were then randomly assigned to 16 weeks of computerized targeted cognitive training (TCT) focusing on auditory and visual processing, affect recognition, and mentalizing tasks, while the remaining 12 patients played computer games (CGs). All subjects repeated the fMRI task after 16 weeks. In this task, before scanning, subjects are presented with semantically constrained sentences where the final word is either experimenter-supplied or left blank for subjects to fill in themselves. During scanning, subjects are presented with these words, and decide whether they were experimenter-presented or self-generated. BOLD fMRI was measured on a 3T-GE scanner. Whole-brain analyses focused on regions showing greater activation for correctly remembered self-generated versus externally-presented items (self-referential effect). At baseline, HCs showed dMPFC activity, while patients showed bilat-

eral frontal deactivation. After behavioral intervention, compared to baseline, CGs showed increased activation in bilateral occipital gyri, while TCTs showed increased activation in dMPFC. These fMRI results indicate a possible "restorative" effect of training in schizophrenia patients, not observed in control group patients, whereby behavioral and neural activation patterns during self-referential processing are "normalized."

H71

SLEEP AND STIMULUS REWARD VALUE BENEFIT VISUAL DECLARATIVE MEMORY *Matthew Tucker[1], Robert Stickgold[1,2]; [1]Beth Israel Deaconess Medical Center, [2]Harvard University* – Research examining the benefits of sleep for declarative memory performance has never addressed the influence of motivational factors on this relationship. The current study (N=173 Harvard undergraduate students) examined differences in performance on a visual paired associates task (picture pairs) after 12hr and 24hr intervals, and when performance was rewarded ($1 for every correct answer at retest) or unrewarded (flat fee for participation). All groups performed similarly on a cued recall test at training, recalling 21.9 picture pairs out of 30. Following a 12hr interval, wake subjects that were unrewarded performed the worst, while sleep subjects that were rewarded performed the best, actually recalling more picture pairs than at training. The overall benefit of reward was significant (main effect, p=.01), while the effect of sleep was profound (main effect, p<.000001). Interestingly, at the 24hr time point performance in all groups converged such that there were no between-groups differences in performance. The effect of sleep (p<.01), but not reward (p=.16), remained significant, indicating that sleep, regardless of when it occurs over a 24hr interval, benefits performance compared to equivalent intervals filled with wakefulness. The magnitude of the effect of sleep on visual declarative memory observed in this study appears to be more pronounced than in studies that have used more traditional verbal memory tasks (word pairs).

H72

INDIVIDUAL DIFFERENCES IN PROCESSING SPEED AND RESTING STATE NEURAL ACTIVITY *Rajasekhar Byrapureddy[1,3], Michel Motes[1,2,3], Bart Rypma[1,2,3]; [1]School of Behavioral and Brain Sciences, University of Texas at Dallas, [2]University of Texas Southwestern Medical Center, Psychiatry, [3]Center for Brain Health, University of Texas at Dallas* – Individual differences in processing speed appears to account for individual differences in cognitive task performance. Previous work from our lab suggests relationships between regional connectivity and processing speed. Baseline resting-state brain activity has been suggested to explain activation decreases in certain brain areas during cognitive task performance but relationships between resting-state activity and cognitive performance are not well understood. In this study, we assessed relationships between individual differences in processing speed and resting state activity. Subjects performed a computerized Digit-Symbol Substitution Test (DSST) and a resting task with eyes closed during fMRI scanning. Subjects were divided into faster and slower performers based on reaction times obtained on the DSST task. Preliminary results indicate differences in resting state correlation maps and Granger connectivity maps, and between faster and slower performers.

Perceptual processes: Low-level vision

H73

LONGITUDINAL EVALUATION OF VISION FUNCTION IN CHILDREN WITH CORTICAL VISUAL IMPAIRMENT *Tonya Watson[1], Deborah Orel-Bixler[1], Gunilla Haegerstrom-Portnoy[1]; [1]University of California, Berkeley* – PURPOSE: Cortical visual impairment (CVI) is bilateral visual impairment caused by damage to the posterior visual pathway (optic radiations, visual cortex, or both). Current literature reports great variability in the prognosis of CVI. The purpose of this study was to evaluate change in vision function in patients with CVI using a quantitative assessment method. METHODS: Visual acuity and contrast sensitivity was assessed using the sweep VEP. 39 children participated in the visual acuity assessment and 34 of the 39 children participated in the contrast threshold assessment. At the time of the first VEP, the children ranged in age from 1 to 16 years (mean: 5.0 years). The time between measures ranged from 0.6 to 13.7 years (mean: 6.5 years). RESULTS: 49% of the children studied showed significant improvement of visual acuity. The average improvement was 0.43 log unit (20/205 to 20/76) in those who improved. The initial visual acuity was worse in those who improved compared to those who did not improve (p<0.001). 47% of the children studied showed significant improvement of contrast threshold. In those who improved, the average amount of improvement was 0.57 log unit (10% to 2.6% Michelson). The initial contrast threshold was significantly worse in those who improved (p=0.001). Also, the change in contrast threshold was related to age of the child (p=0.017). CONCLUSIONS: Significant improvement in vision can occur over time in some children with CVI. Further investigation is warranted to better understand the prognosis for visual recovery in children with CVI.

H74

VISUAL GIST OF NATURAL SCENES DERIVED FROM IMAGE STATISTICS PARAMETERS *H.Steven Scholte[1], Sennay Ghebreab[2], Arnold Smeulders[2], Victor Lamme[1]; [1]University of Amsterdam, Psychology, [2]Intelligent Systems Lab, University of Amsterdam* – Natural images are highly structured in their spatial configuration. In the past it has been shown that the contrast distribution of natural images is almost always adequately described by a Weibull type distribution (Geuseboek & Smeulders, 2003) in which 2 free parameters are fitted. We have recently shown that these parameters explain up to 50% of the variance in the early ERP and these parameters correlate 0.84 and 0.93 with the modeled output of X and Y cells of the LGN (Scholte et al., submitted). Here we will present BOLD-MRI data that show that beta and gamma also explain single trial activity in the occipital and temporal cortex and the parietal cortex respectively. Also, the beta and gamma parameters seem to order the natural images along the dimensions of the number of objects that are present in the scene and depth organization of the scene. We will test this hypothesis by estimating beta and gamma for artificial stimuli with a predetermined number of objects and depth organization, and by evaluating brain responses to such stimuli. Our results indicate that the summary statistics of the Weibull distribution (beta and gamma) may be used by the brain to efficiently and very rapidly extract information about the visual gist of natural scenes.

H75

THE EARLY VISUAL SYSTEM SELECTIVELY POOLS FROM SCALE-TUNED NEURONS TO IDENTIFY DISTINCTIVE EDGES AT ALL NATURAL SCALES *Sennay Ghebreab[1], Steven Scholte[2], Victor Lamme[2], Arnold Smeulders[1]; [1]University of Amsterdam, Informatics Institute, [2]University of Amsterdam, Psychology* – Natural images contain edges over a broad range of spatial scales. It has been shown that the power spectra of natural images fall with increasing spatial frequency and that visual neurons are well matched to this property: visual neurons have roughly equal power in any given frequency bandwidth (Field, 1997). We hypothesized that if the visual system evolved to process edges at multiple spatial scales with equal probability, then it must be using a scale pooling mechanism reflecting this. We tested two well-known scale pooling mechanisms: the neuron with strongest response determines the post synaptic response (Riesenhuber & Poggio, 1999), and the smallest neuron with reliable response defines post-synaptics (Elder & Zucker, 1998). Here, we show that only minimum reliable scale selection leads to constant power over spatial scales. In addition, we show that the distribution of edges at minimum reliable scales has Weibull properties strongly correlating with early brain activity: the two Weibull distribution parameters, beta and gamma, explain 67% and 58% respectively of the variation in ERP. In contrast, beta and gamma estimations from dis-

tributions of maximum edge responses explain 64% and only 41% respectively. In other work we have shown that beta and gamma correlate 93% and 84% with modeled output of small X and large Y cells of the LGN (Scholte et al., submitted). These results taken together suggest that the early visual system uses a mechanism like minimum reliable scale selection to process all distinctive image structures, from fine (beta) to course (gamma) scale.

H76

ELECTROPHYSIOLOGICAL CORRELATES OF LOW LEVEL VISUAL PERCEPTION IN AUTISM SPECTRUM DISORDERS *Hwan Cui Koh[1], Elizabeth Milne[1], Olivier Pascalis[1]; [1]University of Sheffield, UK* – Individuals with Autism Spectrum Disorders (ASD) have shown greater sensitivity for orientation of 'simple' stimuli, but poorer sensitivity for orientation of more 'complex' stimuli, than typically developing (TD) individuals (Bertone et al, 2005). According to the authors of this work, 'simple' stimuli are processed pre-dominantly in primary visual cortex, whereas perception of more 'complex' stimuli requires engagement of extra-striate cortex. This study investigates electrophysiological correlates of perceiving visual stimuli of varying complexity. EEG was recorded from 11 ASD children/adolescents (mean age=130months, mean FSIQ=107) and 11 TD children/adolescents (mean age=133months, mean FSIQ=109), while they passively viewed 'simple' stimuli i.e. parallel 1st order gratings, and more 'complex' stimuli i.e. parallel 2nd order, and hyperbolic 1st and 2nd order gratings. ERP analysis focused on P100, a positive peak occurring 100-200ms post stimulus-onset. P100 amplitudes were larger in the ASD group than in the TD group ($F(1,20)=6.536$, $p=0.019$). ICA analysis investigated gamma power (35-40Hz). One cluster of components showed gamma power to peak sooner (before 114ms post stimulus-onset) in the ASD group, than in the TD group ($F(4,148)=10.8$, $p<0.001$). A second cluster showed gamma power was higher to 'simple' gratings than 'complex' gratings in the ASD group, but not in the TD group ($F(1,21)=9.1$, $p=0.007$). Furthermore, gamma power was higher in the ASD group than TD group for parallel 1st order gratings ($t(df=21)=2.10$, $p=0.048$), but lower for parallel 2nd order gratings ($t(df=21)=2.63$, $p=0.016$). Results from this cluster provide electrophysiological support for differential processing of 1st and 2nd order gratings in individuals with ASD.

H77

PEELING PLAIDS APART: CONTEXT COUNTERACTS CROSS-ORIENTATION CONTRAST MASKING *Elliot Freeman[1], Preeti Verghese[2]; [1]Brunel University, Uxbridge, UK, [2]Smith Kettlewell Eye Research Institute, San Francisco* – Contrast discrimination for an image is usually harder if another is superimposed on top. We asked whether such contrast masking may be enhanced or relieved depending on cues respectively promoting integration of both images as a single pattern, versus segmentation into two independent patterns. We measured contrast discrimination thresholds for a foveal grating masked by a superimposed orthogonally-oriented grating. For drifting gratings, contrast discrimination thresholds were sharply elevated for equal-diameter components, but doubling mask diameter returned thresholds to baseline levels. Both such masking and 'unmasking' effects were much weaker for static stimuli. Our results are consistent with common-fate motion reinforcing perception of a single coherent plaid pattern, while the extended surround helps to identify each component independently, thus peeling the plaid apart again. These results challenge current models of early vision, suggesting that higher-level surface organization influences contrast encoding, determining whether the contrast of a probed grating may be recovered independently from that of its mask.

H78

INTERMEDIATE LEVELS OF UNCOORDINATED GAMMA-BAND ACTIVITY FACILITATE BEHAVIORAL REPONSES TO SIMPLE VISUAL STIMULI *Lauren Emberson[1,2], Keiichi Kitajo[3], Lawrence Ward[4]; [1]Sackler Institute for Developmental Psychobiology, Weill Medical School of Cornell University, [2]Cornell University, Psychology, [3]Lab for Dynamics of Emergent Intelligence, RIKEN Brain Sciences Institute, [4]University of British Columbia, Psychology* – Activity in the brain is ongoing and dynamic. In most experimental paradigms, neural activity can be characterized in two ways: the large-scale coordinated response to a stimulus presented in isolation and the relatively 'quiet', uncoordinated activity in-between. As a field, we almost exclusively study the former by relating levels and patterns of coordinated post-stimulus activity to behavior. By contrast, the current study relates uncoordinated activity in gamma-band in EEG recordings prior to stimulus onset to the resulting behavioral response. We examined pre-stimulus gamma-band activity (30-to-50Hz) for two reasons: first, pre-stimulus gamma is truly uncoordinated activity having no spectral peaks (coordinated neural activity at a particular frequency) and incoherent phase. Second, previous research provides evidence that differences in reaction time in the current task are related to post-stimulus gamma-band activity. Thus, we relate the effect of uncoordinated activity present at stimulus onset and the coordinated activity evoked in the same frequency band after stimulus presentation. After determining each participant's threshold for detecting a change of luminance, experimental stimuli (presented just above threshold) were held constant. The task was carefully designed to prevent anticipation effects by thwarting temporal prediction of the stimulus. Even though, participants were unable to predict stimulus onset, we find that power in the gamma-band for one second prior to stimulus presentation significantly and non-linearly predicts to reaction time. Thus, we assert that an intermediate amount of pre-stimulus gamma-band activity facilitates the coordinated responses evoked by stimulus onset. These results provide evidence that ongoing uncoordinated activity is behaviorally-relevant.

H79

INTERACTION EFFECTS OF HUE AND SPATIAL FREQUENCY ON PERCEIVED EQUILUMINANCE *Alissa Winkler[1], Charles Chubb[1], Charles E. Wright[1]; [1]University of California, Irvine, Cognitive Sciences* – INTRO: We document dramatic, between-observer differences in the interaction effects of hue and spatial frequency (SF) on equiluminance settings derived from the minimum motion method. METHOD: We estimate equiluminant settings separately for a saturated red and green to a fixed neutral gray within annular square-wave grating stimulus. Estimations for each color condition are also made in 5 "low-SF" and 10 "high-SF" cycles/deg. visual angle displays. RESULTS: Observers fall on a continuum between two extreme data patterns: in one extreme, when the stimulus is low-SF, a green needs to be made much lower in photometric luminance (L) to be perceived as equiluminant to gray than when the stimulus is high-SF (LLow-LHigh=-diff). In the other extreme, the reverse pattern holds: the equiluminant green settings for low-SF stimuli have higher L than for high-SF stimuli (LLow-LHigh=+diff). Most strikingly, whichever pattern an observer produces for green, is likely to reverse for red: e.g., an observer producing a -diff for green tends to produce a +diff for red, though the magnitudes are similar. A slight high-SF bias makes observers toward the distribution's center produce two small +diffs. The results for all observers (N=20) fall on a linear locus between these extremes ($r=-.9$, $p<.0001$). CONCLUSION: We speculate that the interaction between hue and spatial frequency may reflect an observer's l:m cone ratio. The variation across observers may then reflect difference in this ratio. If this speculation is confirmed, the tests we have developed could provide a simple, psychophysical method of estimating l:m cone ratios.

H80

SPATIAL ATTENTION LIMITS THE SPEED OF BINOCULAR RIVALRY *Chris Paffen[1], Ignace Hooge[1]; [1]Experimental Psychology & Helmholtz Institute, Utrecht University, Utrecht, the Netherlands* – When the eyes are presented with images containing interocular conflict, an observer typically reports perceiving only one of the images at a time. This phenomenon is called binocular rivalry. During binocular rivalry, the percept continuously alternates between each of the images. Paffen and Alais (2006) recently showed that drawing away attention from rival

images by means of a secondary task reduced the number of alternations reported. Their finding suggests that the number of alternations is highest when attention is fully available for reporting them. Based on this, we hypothesized that increasing the number of rival targets does not increase the number of alternations. If attention plays no role in tracking alternations of multiple targets, increasing the number targets will increase the number of alternations. A display contained 1, 2 or 3 rival targets. Targets were placed in a circular arrangement around the fixation point, and consisted of Gabors with orthogonal orientations for the two eyes. Observers were instructed to press a button whenever a perceptual alternation was perceived. The number of alternations reported increased only slightly with increasing number of rival targets. Control experiments ruled out the possibility that an inability to report alternations occurring at high frequency was responsible for the small increase in the number of alternations. The results suggest that attention plays an important role in the speed at which alternations occur. When spatial attention needs to be distributed over multiple targets, fewer alternations per target occur.

H81

LEFT VERSUS RIGHT VISUAL FIELD ASYMMETRY IN TEXTURE DENSITY JUDGMENTS *Jennifer Corbett[1], Jason Fischer[1], Thomas Harp[1], David Whitney[1]; [1]Center for Mind and Brain & Psychology at UC Davis* – Performance in a texture discrimination task is impaired in central versus parafoveal areas, due to the increased resolution of foveal vision (a Central Performance Drop, CPD; Kehrer, 1987). Here we examined whether texture discrimination is subject to performance asymmetries not attributable to such differences in resolution. Specifically, we investigated whether texture discrimination differs between the left and right visual fields, both of which contain information from each. Observers determined the number of dots in a texture display presented in the upper right, upper left, lower right, or lower left quadrant of the visual field. Judgments of texture density were superior in the left versus right visual field, but similar across the upper and lower visual fields. This asymmetry suggests that each hemisphere may contribute independently to the perception of texture.

Perceptual processes: Multisensory processing

H82

VIEW-INDEPENDENCE OF VISUO-HAPTIC OBJECT REPRESENTATIONS *Simon Lacey[1], Marisa Pappas[1], Alexandra Kreps[1], Kevin Lee[1], K. Sathian[1,2,3,4]; [1]Emory University School of Medicine, Neurology, Atlanta, GA, [2]Emory University School of Medicine, Rehabilitation Medicine, Atlanta, GA, [3]Emory University School of Medicine, Psychology, Atlanta, GA, [4]Rehabilitation R&D Center of Excellence, Atlanta VAMC, Decatur, GA* – We previously showed that cross-modal recognition of unfamiliar objects is view-independent, in contrast to view-dependence within-modally, in both vision and haptics. Does the view-independent, bisensory representation underlying cross-modal recognition arise from integration of unisensory, view-dependent representations or intermediate, unisensory but view-independent representations? Two psychophysical experiments sought to distinguish between these alternative models. In both experiments, participants began from baseline, within-modal, view-dependence for object recognition in both vision and haptics. The first experiment induced within-modal view-dependence by perceptual learning, which was completely and symmetrically transferred cross-modally: visual view-independence acquired through visual learning also resulted in haptic view-independence and vice versa. In the second experiment, both visual and haptic view-dependence were transformed to view-independence by either haptic-visual or visual-haptic cross-modal learning. We conclude that cross-modal view-independence fits with a model in which unisensory view-dependent representations are directly integrated into a bisensory, view-independent representation, rather than being gated by unisensory, view-independent representations.

H83

AUDIOVISUAL INTEGRATION ENHANCES ILLUSORY FILLING-IN OF SPEECH *Antoine J. Shahin[1], Lee M. Miller[1,2]; [1]University of California, Center for Mind and Brain, Davis, California, [2]University of California, Neurobiology, Physiology and Behavior, Davis, California* – Phonemic restoration occurs when speech is perceived to be continuous through noisy interruptions, even when the speech signal is artificially removed from the interrupted epochs. This temporal filling-in illusion helps maintain robust comprehension in adverse environments and illustrates how contextual knowledge through the auditory modality (e.g. acoustic, lexical) can improve perception. This study investigated how audio-visual speech affects phonemic restoration. We hypothesized that audiovisual integration of speech should improve phonemic restoration, allowing the perceived continuity to span longer temporal gaps. Subjects listened to tri-syllabic words with a portion of each word replaced by white noise while watching lip-movement that was either congruent, temporally reversed (incongruent), or static. For each word, subjects judged whether the utterance sounded continuous or interrupted, where a "continuous" response indicated an illusory percept. Results showed that illusory filling-in of longer white noise durations (longer missing segments) occurred when the mouth movement was congruent with the spoken word compared to the other conditions, with no differences occurring between the static and incongruent conditions. Thus, phonemic restoration is enhanced when applying prior knowledge through multisensory integration.

H84

WHEN PHOTISMS HELP AND WHEN THEY HURT - THE IMPACT OF COLOUR INCONGRUENCY ON OBJECT SUBSTITUTION MASKING IN GRAPHEME-COLOUR SYNAESTHETES *Jutta Peterburs[1], Michelle Jarick[2], Mike Dixon[2]; [1]Ruhr-University Bochum, Germany, Institute of Cognitive Neuroscience, Neuropsychology, [2]University of Waterloo, Psychology, Ontario, Canada* – Grapheme-colour synaesthesia is a fascinating condition whereby black graphemes elicit colour experiences. Research has shown that synaesthetic colours (photisms) can directly influence the perception of externally presented digits and enhance a synaesthete's performance on visual masking tasks. Currently, research is lacking experiments that show both superior and inferior performance of synaesthetes relative to control participants in order to rule out motivational factors and experimenter expectation as possible explanations for performance differences between these groups. We tested four grapheme-colour synaesthetes (projectors) and 21 non-synaesthetic control participants with an object substitution masking paradigm involving achromatic (black), congruently and incongruently coloured target digits (with respect to a given synaesthete's photisms) to show such a double-dissociation. While control participants exhibited object substitution across all conditions, this effect was alleviated for synaesthetes for achromatic targets, indicating that the synaesthetes benefitted from their photisms. On trials with incongruently coloured targets, however, the synaesthetes' performances were reduced (relative to performance on the achromatic condition), suggesting that their photisms provided a source of interference. Hence, motivational factors and experimenter expectation cannot account for performance differences observed between control participants and synaesthetes. The results furthermore indicate that externally perceived colour might be able to activate digit-related information, corroborating recent findings of bidirectionality of grapheme-colour synaethesia in some projector synaesthetes.

H85

ELECTROPHYSIOLOGICAL CORRELATES OF AUDIO-VISUAL INTEGRATION OF SPOKEN WORDS IN TYPICAL DEVELOPMENT AND AUTISM SPECTRUM DISORDER *Odette Megnin[1], Atlanta Flitton[1], Catherine Jones[1], Michelle de Haan[1], Tony Charman[1], Torsten Baldeweg[1]; [1]UCL Institute of Child Health* – The present study examines electrophysiological (ERP) correlates of audio-visual (AV) integration of spoken words in 19 typically developing adolescents and 14 adolescents with autism spectrum disorder (ASD). There are a number of reasons why we might expect to see differences in an autistic population, including (but not limited to) findings of atypical unimodal auditory processing (e.g. Bomba & Pang, 2004), atypical unimodal visual processing, particularly with regards to face processing (e.g. McPartland et al, 2004), and multi-sensory processing differences (e.g. Bebko et al, 2006; Magnée et al, 2008). In a previous ERP study examining AV integration of speech in typical adults we found a speeding up and attenuation of the auditory N1 component and a shorter latency and increased amplitude auditory P2 component with AV speech stimuli and these effects were specific to an AV condition with informative or predictive lip movements. An additional novel finding of that study was that the N1 attenuation correlated with an earlier increased fronto-polar negativity (FPN) raising the possibility of a top-down modulation effect. Preliminary results of the present study suggest that in both autism and typical development, participants fall into subgroups with only approximately half showing the adult pattern of audio-visual integration. Amongst those showing the FPN and N1 attenuation effects, there are also differences between the autism and typically developing adolescents, suggesting that AV integration may change across development and also that the process may be different in ASD.

H86

INDUCED AND EVOKED SEX DIFFERENCES IN EEG MEASURES OF A PERCEPTION/ACTION MATCHING SYSTEM *Jonathan Silas[1], Joe Levy[1], Maria Nielsen[1], Lance Slade[1], Amanda Holmes[1,2]; [1]Roehampton University, [2]Birkbeck College* – Recent EEG research is said to support the involvement of a perception/action matching system (P/AMS) in social cognition. Induced decreases in 'mu' power, during performance and observation, index activation of a P/AMS system (Cochin et al., 1999). Evoked event related potentials (ERPs) indexing motor activity have also been demonstrated during the observation of movement, linking ERPs to a P/AMS (Kilner et al., 2008; van Schie et al., 2008). To date, only modulation of induced activity has been studied in relating a P/AMS to social cognition (Bernier et al., 2007; Oberman, et al., 2005). We recorded 128-channel EEG from male and female participants while they observed and performed simple movements. Participants also completed several questionnaires pertaining to aspects of social cognition, such as empathy and systemising traits (IRI, EQ, SQ-R). Females showed stronger mu attenuation during observation (but not performance) of an action, and males showed increased mean amplitude in motor-related ERPs for both performance and observation of an action. However, neither induced nor evoked activity was associated with social cognition psychometrics. Our results suggest that both evoked and induced components of the EEG are modulated by sex differences in a P/AMS. These results suggest that there may be two dissociable processes underlying a P/AMS. Furthermore, we argue that during the observation of simple movements, sociocognition does not modulate a P/AMS.

H87

THE SPREAD OF ATTENTION ACROSS MODALITIES AS A FUNCTION OF AUDIO-VISUAL TEMPORAL ASYNCHRONY *Sarah E. Donohue[1], Maria A. Pavlova[1], Kenneth C. Roberts[1], Tineke Grent-'t-Jong[1], Marty G. Woldorff[1]; [1]Center for Cognitive Neuroscience, Duke University* – A fundamental task in daily life is the accurate perception and integration of information from multiple modalities. This can be done in a robust and reliable manner by using cues from space and time, with stimuli more proximal in space and/or time more likely to be integrated. Further, it has been shown that attention to stimuli in one modality (vision) can spread to irrelevant but synchronous stimuli in another modality (audition), even when they arise from different locations, an effect reflected by a late frontal ERP negativity and enhanced fMRI activity in auditory cortex (Busse et al., 2005). Here, we investigated such attentional spread when the irrelevant auditory event was either simultaneous with the visual, delayed by 100 ms (inside the temporal window of integration), or delayed by 300 ms (outside the window). EEG was recorded from 18 participants, and time-locked averages were obtained for each of the delay conditions. When the irrelevant auditory stimulus was synchronous with the attended visual event, the late frontal negativity was enhanced, replicating Busse et al. (2005). When the auditory stimulus was delayed by 100 ms, this late negative wave was slightly attenuated relative to the simultaneous condition and shifted in time by 100 ms. When the auditory stimulus was delayed by 300 ms, the late negative wave was substantially attenuated and shifted by 300 ms. These results suggest that attention can only spread effectively between visual and auditory stimulus events when they occur sufficiently close in time, presumably thereby facilitating appropriate multisensory integration.

H88

BRAIN ACTIVATION DURING OBSERVATION OF SOCIAL INTERACTION BETWEEN HUMANS OR DOGS *Miiamaaria Kujala[1], Riitta Hari[1]; [1]Brain Research Unit, Low Temperature Laboratory, and Advanced Magnetic Imaging Centre, Helsinki University of Technology, Finland* – We aimed to find out how brain activations differ when subjects observe interaction between humans or between dogs, and whether expertise on dog behavior affects the results. Brain activity of 37 healthy subjects (19 experts and 18 non-experts in dog behavior; half of all female) was recorded with 3-T fMRI. The subjects viewed color photos where humans and dogs were either alone (ALONE), friendly interacting with a conspecific (INTER), or facing away from a conspecific (AWAY). Altogether 280 stimuli were presented in 25-s blocks (10 stimuli per block, 2.5 s each). Analysis of variance revealed significant effects of interaction level (INTER, AWAY, ALONE) in the brain's "social circuitry", including the posterior superior temporal sulcus (pSTS), posterior cingulate cortex, posterior intraparietal sulcus, temporal poles, and fusiform gyri bilaterally. Species (HUMAN, DOG) had an effect bilaterally in the pSTS, posterior cingulate cortex, posterior intraparietal sulcus, hippocampi, and amygdalae. In both groups, amygdala was activated more strongly to interacting humans than dogs. The effect of expertise was marked in the hippocampi, which responded more strongly to dogs than humans in experts. Moreover, the right lateral occipital cortex (rLOC) responded similarly to interaction of humans and of dogs in experts, but only to interaction of humans in control subjects. To conclude, interaction between humans or between dogs activated the viewer's social brain circuitry similarly, with some species-dependent emphasis. Dog expertise modulated activity in the memory-linked hippocampus and in the LOC associated with object (or body) recognition.

Perceptual Processes: Multisensory Processing

H89

VISUAL MODULATION OF SOMATIC PAIN USING OPTICAL MEANS *Eric Altschuler[1,2], Paul McGeoch[2], V. S. Ramachandran[2]; [1]UMDNJ, PM&R, [2]UCSD, Center for Brain and Cognition* – We have shown using a simple optical trick (mirror visual feedback (MVF)) that visual input can powerfully modulate somatic pain in a clinically useful manner: Phantom limbs are often reported to be fixed in a painfully awkward position. We had patients view the refection of the normal hand optically superimposed on the phantom via a parasagittally placed regular plane mirror. Moving the real arm made the phantom APPEAR to move and reduced the pain in the phantomóthe first demonstration of

visual modulation of somatic pain. Ourselves and others have found that MVF shows promise in treating complex regional pain syndrome, anesthesia dolorosa, hemiparesis following stroke and hand dysfunction in orthopaedic patients. McCabe and colleagues and Moseley and colleagues found a perception of change and change of temperature during MVF. Gawande noted use of MVF in a patient after brain tumor surgery with an arm that felt painfully "swollen, and found that ensuing shrinkage of the arm also shrank the somatic pain! In normal subjects we noted that viewing one's hand through a minifying Fresnel lens caused the hand to feel shrunken and alienated from one's body image (Sci Am Mind 18 (4), 16-19 (2007)). We used this procedure on a patient who had painful severe neuropathic leg pain. Remarkably, optical shrinkage of the foot and its optical alienation caused a corresponding shrinkage of associated pain. Taken collectively these results demonstrate powerful modulation of somatic pain using visual feedback observations that dissolve conventional barriers between vision, pain and skin.

Perceptual processes: Multisensory processing

H90

MISMATCH NEGATIVITY REVEALS EARLY AUDIOVISUAL INTEGRATION OF VISUAL LETTERS AND AUDITORY LETTER NAMES *Allison J.D. Andres[1], Janis E. Oram Cardy[1], Marc F. Joanisse[1,2]; [1]School of Communication Sciences and Disorders, The University of Western Ontario, [2]The University of Western Ontario, Psychology* – Reading involves integrating visual stimuli (letters) with known auditory categories (phonemes). Prior studies have used electrophysiology and neuroimaging to examine the temporal and cortical mechanisms of audiovisual integration, however it remains unclear at what stage in perception this process actually occurs. In particular, there is significant debate whether stimuli are integrated during primary sensory processing, or following independent processing in their respective sensory cortices. In this study we recorded event-related potentials (ERPs) in 22 adult participants in response to visual letters presented simultaneously with auditory letter names. A key novelty of this study was that auditory stimuli were presented in an unattended fashion, using the mismatch negativity (MMN) paradigm, simultaneously with a visual letter identification task. It was hypothesized that if audiovisual integration occurs at an early point in sensory processing, we should observe modulations to MMN amplitude when the attended visual stimulus was congruous with the auditory stimulus (i.e., seeing "E" and hearing 'ee') compared to when it was not (seeing "E" and hearing 'oh'). As expected, we observed significant MMNs for auditory oddball stimuli, at around 200 ms post stimulus onset. However we also observed that the magnitude of this effect was greater in congruent trials. A similar effect was also found for the P300 component. The data suggest that audiovisual integration of letters does occur concurrently with primary sensory processing.

H91

AUDIO-VISUAL SYNCHRONY ENHANCES WORKING MEMORY UPDATE: AN EVENT-RELATED POTENTIAL (ERP) STUDY *Natalya Kaganovich[1,2], George Hollich[2], Christine Weber-Fox[1]; [1]Purdue University, Speech, Language, and Hearing Sciences, [2]Purdue University, Psychological Sciences* – Multisensory representation plays an important role in learning and memory. Behavioral studies in infants show the importance of audio-visual synchrony for perceptual learning (Bahrick & Lickliter, 2000) and speech stream segregation (Hollich, Newman, & Jusczyk, 2005). In adults, memory formation is also enhanced by multisensory stimuli (Shams & Seitz, 2008). However, the facilitative effect of audio-visual synchrony on working memory has not been fully investigated. We hypothesized that a detection of change from audio-visually synchronous contexts will be easier compared to detection of change from asynchronous ones even when the degree of change is identical. We employed an oddball paradigm with audio-visual stimuli (a 1000 Hz tone and a lighted circle, 50 ms in duration). The onsets of the two stimuli were either synchronous or separated by 400 ms in standards. They were always offset by 200 ms in deviants. The physical change from standard to deviant was thus identical across conditions (200 ms). Two modality sequences were used: audio-visual and visual-auditory. Behavioral measures of sensitivity to change (d') were combined with electrophysiological measures. We compared ERPs in response to the same deviant stimulus when it was preceded by either a synchronous or an asynchronous standard. We found no differences in early sensory components. However, regardless of the order of modalities, targets preceded by audio-visually synchronous standards elicited a significantly larger P300 component compared to targets preceded by asynchronous standards. These findings indicate that multi-modal synchrony may enhance working memory update processes as indexed by the P300.

H92

SENSORIMOTOR NETWORKS: PREFERENTIAL RELATIONSHIPS BETWEEN AUDITORY REGIONS AND MOTOR MOUTH CORTEX *Jonathan Power[1], Alexander Cohen[1], Fran Miezin[1], Bradley Schlaggar[1], Steve Petersen[1]; [1]Washington University, Neurology and Psychology, Saint Louis* – Humans are proficient, relative to other species, in linguistic communication and object manipulation. These proficiencies may require optimized networks subserving specific sensorimotor combinations, such as audition/speech production and vision/hand movement. Recently developed analytical methods, utilizing functional connectivity MRI (fcMRI) to examine network relationships between brain regions, could reveal such optimizations. To investigate these putative networks, we examined 22 fMRI studies involving 523 subjects performing myriad tasks all involving combinations of auditory or visual input with speech or finger-pressing responses. Ninety-three regions of interest (ROIs) were defined based on activation in these tasks, and timecourses for each of these ROIs were derived from concatenated resting-state fcMRI data from 40 adults. A 93x93 correlation matrix of correlations between each ROI's timecourse with all other ROI timecourses was used to construct a network, which was then subjected to community detection analysis using edge removal (Girvan & Newman, 2002) and modularity optimization (Newman, 2006). Both methods revealed communities within the network. Notably, regions of sensorimotor cortex representing "mouth" and "finger" clustered in separate communities. The mouth regions were closely related to several temporal (including auditory) and subcortical regions, while the finger regions were more closely related to multiple frontal and parietal regions, which then linked to occipital regions. These specific sensorimotor network relationships are consistent with human specializations underlying language and object manipulation, respectively. The extent to which these relationships represent specializations existing at birth versus the result of years of conjoint activation could be examined through developmental studies.

H93

ENHANCED CROSS-MODAL PROCESSING IN SYNESTHESIA *David Brang[1], Lisa E Williams[1], Vilayanur S Ramachandran[1]; [1]University of CA, San Diego* – Synesthesia is a heritable trait in which a sensory stimulus presented in one modality evokes a sensation in a different modality. Recent research has suggested that neurotransmitter imbalances and excess neural connections mediate these synesthetic experiences. Crucially, this over-connectivity occurs not only between the sensory cortices engaged for a particular synesthete's associations, but also within parietal structures, known to be critical in binding the senses together in normals. In typical individuals, there are a number of perceptual effects that highlight the integration of sensory information from multiple modalities. Given that the proposed overconnectivity in synesthesia occurs in brain areas thought to mediate multisensory integration in typical individuals, we hypothesized that general cross-modal integration may also be enhanced in synesthetes. To test this idea, we ran 9 grapheme-color synesthetes on two classic cross-modal tasks utilizing interactions between

the visual and auditory domains - the Shams double-flash illusion, and intersensory facilitation of reaction time. On these tasks, synesthetes' accuracy and reaction times differed significantly from those of control subjects, reflecting an overall increase in cross-modal processing in synesthetes. As none of our subjects experienced auditory synesthetic concurrents, these findings reflect generalized differences in cross-modal processing between groups. These results support, for the first time, that part of the synesthesia phenotype is an extreme form of normal cross-modal integration, as well as the notion that the overconnectivity in synesthesia is diffusely expressed. Subsequently, these results allow generalization of other findings from synesthesia research, to aid in the understanding of cross-modal processing in all individuals.

H94

THE UNIVERSALITY OF SENSORY ANALOGIES: A STUDY WITH THE HIMBA TRIBE OF NAMIBIA *Catherine Mulvenna[1,2]; [1]University College London, [2]University of California, Los Angeles* – Crossmodal correspondences are an example of basic higher-level cognition. It is a seemingly natural process to align properties of two different sensory modalities (such as frequency/pitch with reflectance/lightness) resulting in relative analogies such as 'high pitch=strong light', and vice versa. This phenomenon spans several dimensions including reflectance, luminance, curvature, intensity and frequency. It has long been demonstrated that cognitive effects of these correspondences include facilitation/interference in speed and accuracy of identifying a stimulus that is presented with relatively corresponding/non-corresponding stimulus. However, little is understood about whether this phenomenon is relative (to culture, language) or universal. Here, 45 members of the semi-nomadic Himba tribes of Kaokoland, northwest Namibia, carried out an audio-visual matching task. This tribe historically live remote from the developing culture of the rest of the country, speaks an ancient tribal language with no written component, and has minimal exposure to modern African or Western music. Participants heard randomized sequences of high and low pitches and made a binary forced choice decision between light and dark images based on what 'goes best with the sound.' Auditory stimuli varied in familiarity to the tribes-people: high, medium and low, represented by human voice, cello, computer-generated beeps. A local interpreter acting as the naïve instructor enabled a double-blind design, and minimized implicit information being communicated to participants. For all stimuli, the tribes-people followed the analogy of 'high pitch=high light.' This supports universal over relativist theories of sensory analogies, and hard-wired 'basic correspondences' in sensory processing.

H95

MODULATIONS OF EARLY VISUAL EVOKED POTENTIAL IN THE PROFOUNDLY DEAF *Davide Bottari[1], Anne Caclin[2], Marie-Hélèn Giard[2], Francesco Pavani[1,3]; [1]University of Trento, Cognitive Science and Education, Italy, [2]INSERM U821, Lyon, France , [3]Centro Mente e Cervello, University of Trento, Italy* – Behavioural studies have revealed enhanced reactivity to visual events in the deaf. Here we examined the electrophysiological response to visual stimuli in deaf and hearing controls during a speeded simple-detection task. After the appearance of a warning-signal (500ms), a visual target was randomly presented with either a short (500ms) or long ISI (1800ms), at central (3°) or peripheral (8°) locations with respect to fixation. Behaviourally, deaf were faster than hearing controls, particularly for targets appearing at the short ISI. In addition, controls responded more slowly for peripheral than central targets, whereas this difference did not emerged for the deaf. The ERPs revealed activation at occipito-parietal sites in the deaf, before any visual stimulation. Moreover, the C1 component in response to the warning-signal peaked earlier in deaf than controls. Deaf also displayed prolonged and ampler visual analysis in the second phase of the P1 component, which in turn produced a delay of the N1 onset. While the P1 was ampler for central than peripheral targets in the controls, comparable P1 amplitude emerged in the deaf regardless of target location. Finally, the CNV preceding targets at short ISI had a larger amplitude range in deaf than controls. These results show quantitative and qualitative changes in very early visual-evoked potentials (C1, P1). Because modulation of the late P1 complex has been recently linked to exogenous attention capture, these findings point to a key role of this attention component in enhanced reactivity in the deaf.

Perceptual processes: Somatosensory processing

H96

SINISTRALS' UPPER HAND: EVIDENCE FOR HANDEDNESS DIFFERENCES IN THE REPRESENTATION OF BODY SPACE *Sylvia Hach[1], Simone Schuetz-Bosbach[1]; [1]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany* – A difference in the perception of extrapersonal space has been shown to exist between dextrals (right-handers) and sinistrals (left-handers). On the classical line bisection task, this difference is evident in a greater left bias for dextrals compared to sinistrals. Different modalities and regions of space can be affected. However, it has not yet been investigated whether a systematic bias also exists in the perception of personal or body space. We investigated this with the use of three tasks which assess different aspects of personal space in both an implicit and explicit way. The results showed that; (i) dextrals possess an asymmetric estimation of their body, while no such asymmetry was present for sinistrals, (ii) sinistrals display superior access to an overall spatial representation of their body and (iii) no handedness differences exist for an explicit measure of body representation. Possible mechanisms underlying the handedness differences shown for the implicit tasks are a stronger lateralisation or a greater activation imbalance for dextrals and/or greater access to right hemispheric functions such as an "up-to-date" body representation by sinistrals. In contrast to implicit tasks, explicit measures of how body space is represented may not be affected due to their relying on different processing mechanisms. These results are the first to describe handedness differences in the maintenance of and access to representations of the body in the neurologically normal population. Furthermore, they suggest that personal or body space is processed in a similar way to extrapersonal space and is affected by the same constraints.

H97

MODULATION OF ROLANDIC ALPHA AND BETA BAND ACTIVITY DURING VIBROTACTILE WORKING MEMORY REFLECTS DYNAMIC ADJUSTMENT OF SOMATOSENSORY CORTEX FUNCTION *Claudia Preuschhof[1,2], Ruth Schubert[3], Torsten Schubert[4], Hauke R. Heekeren[1,2]; [1]Max Planck Institute for Human Development, Berlin, Germany, [2]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, [3]Neurophysics Group, Charité - University Medicine Berlin, Campus Benjamin Franklin, Berlin, Germany, [4]General and Experimental Psychology, Ludwig-Maximilians University, München, Germany* – The role of the primary somatosensory cortex (S1) for vibrotactile working memory (WM) is still under debate. The rolandic alpha and beta rhythms indicate the activation level of S1. Using electroencephalography, we investigated the dynamics of the rolandic rhythms during the encoding and delay period of a vibrotactile WM task. Fourteen participants had to decide which of two sequentially presented vibrotactile stimuli had the higher frequency. We found enhanced rolandic alpha and beta power during the middle delay indicating functional inhibition of S1. In contrast, frontal and posterior alpha and beta power amplitudes were enhanced during the entire delay, which might be related to the functioning of a fronto-parietal attentional network involved in WM maintenance. During the early delay, high performers already exhibited maximum levels of alpha power whereas low performers reached maximum power only in the middle of the delay. This suggests that inconsistent findings regarding the role of S1 during the early delay are related to encoding efficiency. The most pronounced effect for

the rolandic rhythms was a reduction of baseline power in the pre-trial period indicating a tonic up-regulation of the contralateral S1 caused by sustained attention to the stimulated finger. The pattern of results suggests that S1 does not maintain the vibrotactile stimuli. However, the activation level of S1 seems to be dynamically adjusted to optimize task performance. In addition, there is a dissociation between the rolandic alpha and beta rhythms related to somtatomotor processing and fronto-posterior alpha and beta rhythms involved in top-down control.

H98

A PSYCHOMORPHOMETRIC INVESTIGATION OF THE HUMAN HAND *Matthew Longo[1], Patrick Haggard[1]; [1]Institute of Cognitive Neuroscience, University College London* – Morphometric techniques, involving the geometric analysis of landmark data, have become increasingly widespread in the biological sciences as tools for the analysis of biological shape. This method provides a precise, quantitative characterization of the veridical structure of a biological form, such as a body part like the human hand. Here, we apply this method to study the mental representation of a body part (the hand), by having participants point to where they believed landmarks on their (occluded) hand to be. These landmarks provide an implicit map of the structure underlying the mental representation of the hand, which can then be compared to the veridical structure of the participant's hand. Several systematic biases in the representation of the hand were observed, which corresponded to characteristic features of primary somatosensory representations. In contrast, when participants were asked to pick from a series of hand templates the one that most closely matched the shape of their own hand, such biases were not observed. This suggests that the implicit representation of the body is quite different from the explicit, conscious image we have of ourselves. This implicit body image observed here may reflect a representation nearer to the 'homuncular' representation of the body.

H99

MULTIPLE MEDIATORS OF EXPECTANCY EFFECTS ON PAIN PERCEPTION: INTERACTIONS AMONG HIGHER-ORDER BRAIN REGIONS AND PAIN MATRIX ACTIVITY *Lauren Atlas[1], Niall Bolger[1], Martin Lindquist[1], Tor Wager[1]; [1]Columbia University* – A wealth of cognitive neuroscience research suggests that expectations can have a powerful influence on perception across multiple sensory modalities. We focus here on expectancy effects in pain, a phenomenon of both basic and clinical interest. While studies have shown that expectancies modulate brain activity in frontal and limbic regions, the brain pathways that mediate expectancy effects on pain experience have not been examined. In this study, we use whole-brain mediation analysis to address whether: a)expectancies influence a core set of regions (the "pain matrix") thought to mediate pain; b)pain matrix activity mediates expectancy effects on pain reports; and c)frontal and limbic brain mediators influence pain through connections to the pain matrix, or through other mechanisms. Auditory cues elicited expectations for low or high noxious thermal stimulation. On a subset of trials, cues were followed by a single temperature calibrated to elicit moderate pain. Compared with low-pain cues, high-pain cues produced robust increases in reported pain ($p<.0001$) and activity throughout the pain matrix. Mediation analyses revealed that a subset of pain matrix regions (thalamus, anterior insula, dACC, and pons) formally mediated expectancy effects on pain reports. Other mediator regions included those supporting value-processing (putamen, ventral striatum, caudate) and cognitive control (DLPFC, DMPFC, pgACC). Some higher-order regions (e.g. ventral striatum) affected pain perception through connections to the pain matrix, while others (e.g. DMPFC) affected pain reports independently. These results contribute to a model of how brain systems involved in expectancy interact with pain-processing regions to create the pain experience.

H100

TEMPORAL COURSE IN TACTILE ENCODING: FROM A SOMATOTOPIC TO AN EXTERNAL FRAME OF REFERENCE *Elena Azañón[1,2,3], Matthew R. Longo[3], Salvador Soto-Faraco[1,2,4], Patrick Haggard[3]; [1]Departament de Psicologia Bàsica, Universitat de Barcelona, Spain, [2]Parc Científic de Barcelona, Universitat de Barcelona, Spain , [3]Insitute of Cognitive Neuroscience, University College London, UK, [4]Institució Catalana de Recerca i Estudis Avançats (ICREA), Spain* – Localizing and reacting to tactile events on our skin requires the coordination between primary somatotopic projections and an external representation of space. Given that the primary somatosensory cortex (SI) maps skin location independently of posture, the brain must re-align tactile coordinates in order to locate events in external space. Here we track the time course of how these externally-based representations are built. In the first study participants held their arms crossed and performed a discrimination task on lateralised visual targets presented near the hands, after receiving a tactile cue. During the first hundred milliseconds after the cue, reaction times to the lights were speeded up for anatomically congruent but spatially incongruent tactile cues. This pattern reversed after about two hundred milliseconds so that tactile cues produced a facilitation of targets presented at the same external location. From the time course of the cueing effects as well as the results of previous studies, we reasoned that some structures in the posterior parietal cortex may be critical for tactile remapping. Thus, in a second study participants held their arms in a vertical position and judged the elevation of a tap on their forearm with reference to a part of their head. Single-pulse TMS was applied, targeting the ventral intraparietal area, in order to disrupt tactile remapping processes. The results of both studies expose the temporal course in the encoding of tactile space, from a somatotopic frame of reference, reflecting the neural organization in SI, to the external representations prevailing in orienting behaviours.

H101

SERIAL AND PARALLEL PROCESSING OF VISUO-TACTILE INPUTS AS REVEALED USING MEG *Andrea Quintero[1], Kim Russo[1], Leighton Hinkley[2], Srikantan Nagajaran[2], Elizabeth Disbrow[1,2,3]; [1]Center for Neuroscience University of California Davis, [2]University of California, Radiology, San Francisco, [3]University of California, Neurology, Davis* – Manipulation of the world around us requires the interaction of inputs from somatic, visual and motor systems to make accurate judgments regarding the physical attributes of an object, the sensory context in which the object is located and the object's relation to some internal representation of the body. The temporal dynamics of these interactions are not fully understood. In this study, we examined the cortical temporal spatial spectral patterns of processing a simple combination of tactile and visual stimuli by measuring fluctuations in oscillatory activity using time-frequency optimized adaptive spatial filtering reconstructions of magnetoencephalography data. We used a 275 channel CTF omega 2000 whole head MEG system (VSM MedTech, Coquitlam, B.C., Canada) to compare whole-brain responses to right, left and bilateral stimulation of the second digit. Tactile stimuli were pneumatic air pulses (30psi, ISI 2sec +/- 200ms) presented simultaneously with either a continuous central red fixation point on a gray background or a reversing checkerboard synchronized to tactile stimulation. We collected 256 trials/condition using a sample rate of 1200Hz. Results indicate that combined tactile and visual inputs are processed by a network consisting of primary and secondary somatosensory cortex (S1 & S2), posterior parietal cortex (PPC) and pre-motor cortex (PMC). Activity in these regions overlapped in both time and frequency, with activation progressing from S1 (onset = 50ms) to S2 (onset = 175ms) and PP (onset = 150ms), followed by PM (onset = 225ms). This spatial-spectral-temporal processing pattern reflects the known connectivity of putatively homologous regions of macaque monkey cortex.

Poster Session I

Higher level cognition: Executive functions

I1

NEURAL EVIDENCE OF A ROLE FOR SPATIAL RESPONSE SELECTION IN THE LEARNING OF SPATIAL SEQUENCES *Hillary Schwarb[1], Nehal Patel[1], Carla J. Burrus[1], Eric H. Schumacher[1]; [1]Georgia Institute of Technology* – Despite two decades of behavioral research, considerable disagreement remains regarding the locus of the cognitive mechanisms (e.g., stimulus encoding, response selection or response production) responsible for the learning and expression of spatial sequences. Functional neuroimaging may offer valuable insights to this controversy. The cortical mechanisms underlying spatial response selection (i.e., right dorsal prefrontal, dorsal premotor and superior parietal cortices) are well known. These regions as well as supplementary motor area, striatum and the hippocampus have also been implicated in sequence learning. Such neural overlap suggests that spatial response selection may play an important role in spatial sequence learning. These cognitive mechanisms, however, have not been manipulated in the same experiment so the true extent of the overlap is unknown. The current study directly investigates the role of spatial response selection in sequence learning using the serial reaction time (SRT) task. Both spatial sequence learning and spatial response-selection difficulty were orthogonally manipulated to directly identify the neural overlap of these two cognitive mechanisms. Functional magnetic resonance imaging (fMRI) results demonstrate near complete overlap in all of the regions investigated (dorsal premotor, supplementary motor, superior parietal and striatum). Only right dorsal prefrontal cortex was selectively influenced by the response selection difficulty manipulation. The hippocampus was unresponsive to either manipulation. These findings emphasize the importance of spatial response selection for successful spatial sequence learning.

I3

ENHANCING GAMMA BAND POWER (36-44HZ) WITH NEUROFEEDBACK IMPROVES FEATURE BINDING FLEXIBILITY AND INTELLIGENCE *Andre Keizer[1,2], Maurice Verschoor, Roland Verment, Bernhard Hommel[1,2]; [1]Leiden University, Institute for Psychological Research, [2]Leiden Institute for Brain and Cognition* – Neural synchronization in the gamma band has been associated with feature binding and intelligence. Using neurofeedback, we aimed at changing the power of the gamma band and investigated whether these changes would influence behavioral measures of feature binding and intelligence. The results show that people are indeed able to alter the power in the gamma band if provided with neurofeedback. Moreover, the increase of gamma band power was related to a decrease of binding costs and an increase in intelligence, suggesting that the control of feature binding and intelligence share a common underlying mechanism.

I4

PREFRONTAL DOPAMINE LEVELS PREDICT TRANSIENT COMMITMENT TO ATTENTIONAL SET *Sean James Fallon[1], Caroline Williams-Grey[2], Adam Hampshire[1], Roger Barker[2], Adrian Owen[1]; [1]MRC Cognition and Brain Sciences Unit, Cambridge, [2]Cambridge Centre for Brain Repair, University of Cambridge* – Dopaminergic stimulation of the prefrontal cortex (PFC) contributes to numerous aspects of cognitive control. It has been suggested that dopamine facilitates the ability to form and sustain an attentional set. An attentional set is the top down segregation of certain features in the environment as either relevant or irrelevant. A single nucleotide polymorphism (val108/158met) in the gene that codes for the catechol O-methyltransferase (COMT) enzyme has been shown to lead to alterations in the levels of PFC dopamine. Individuals, who are homozygous for the met allele of the COMT gene, will have relatively higher levels of PFC dopamine compared to val homozygotes as a result of the differential ability of these two groups to inactivate dopamine. Here we present an fMRI study investigating the effect of this polymorphism on the ability to form and shift attentional sets on the basis of positive or negative feedback, in genotyped older adults and patients with Parkinson's Disease (PD). Differential levels of hypothesised prefrontal dopamine, as modulated by disease and COMT genotype, predicted the formation of attentional sets and increased haemodynamic response in the PFC, in a manner consistent with an inverted-U shape function. Specifically, there was an interaction between val158met and disease, in that healthy met homzygotes displayed greater levels of attentional set formation and BOLD activity in the right dorsolateral PFC, whilst for PD patients this pattern was reversed. We suggest that this apparent reversal of the COMT effect in PD is the result of dopaminergic medication in this patient group.

I5

AGING, EXECUTIVE FUNCTIONING AND SELF-REPORTED MEMORY STRATEGY USE *Badiâa Bouazzaoui[1], Michel Isingrini[1], Severine Fay[1], Lucie Angel[1], Sandrine Vanneste[1], David Clarys[1], Laurence Taconnat[1]; [1]UMR CNRS 6234 University François-Rabelais of Tours, France* – The purpose of this study was to investigate age differences in self-reported memory strategy use in relation to the executive functioning decline accompanying aging. A large sample (n = 315) from 21 to 90 years responded to a strategy use questionnaire (Metamemory in Adulthood instrument, Dixon and Hultsch, 1983) allowing to differentiate self-reported internal (e.g., rehearsal, imagery...) from external (e.g., making lists for shopping, keeping a calendar to writing down appointments) memory strategy use. Neuropsychological tests of executive functioning (WCST, Verbal fluency, Category exemplar generation), and fluid intelligence (Cattell cutlture fair test) were also administered. Results showed that (1) aging increases the use of external memory strategies when conversely it decreases the use of internal memory strategies, (2) executive functioning and self-report of strategy use were related, participants who reported to use more frequently internal strategies were those with high level of executive functioning whereas participants who reported using more frequently external strategies were those with low level of executive functioning, and (3) executive functioning accounted for a sizeable proportion of the age-related variance in strategy use, largely for internal strategies and moderately for external strategies. These findings highlighted that the relationship observed in previous studies between executive functions and laboratory memory strategy tasks can be extended to questionnaire self-rating memory strategy use. They also support the proposal that preserved executive functioning in old age appeared as a relevant protective factor of the capacity to implement self-initiated internal strategies in order to prevent age-related memory difficulties.

I6

IF AT FIRST YOU DON'T SUCCEED, TRY, TRY AGAIN: ERRORS INFLUENCE DECISION-MAKING IN A VOLUNTARY TASK SWITCHING PARADIGM *Joseph Orr[1], Wendelin Diab[1], Joshua Carp[1], Daniel Weissman[1]; [1]University of Michigan* – When performance monitoring processes detect that we are performing poorly at a task (e.g., making errors, experiencing high levels of response conflict, or responding more slowly than usual), they are thought to enhance the activation of that task's representation in working memory, thereby promoting better performance

in the next trial. However, distinguishing such enhancements from the priming of specific stimuli, responses, and stimulus-response associations has proven exceptionally difficult. To provide an unambiguous test of the task-set enhancement hypothesis, we assessed the performance of 32 healthy adults in a number Stroop version of the voluntary task switching paradigm. Critically, in each trial the decision about which task to perform (i.e., numerical or physical size comparison, indicated using one of two fingers on the left hand) utilized different stimulus-response associations than the subsequent decision about which of two digits was largest (indicated using one of two fingers on the right hand). Consistent with the task-set enhancement hypothesis, participants chose to repeat the same task (rather than switch to a different task) significantly more often after making an error, experiencing high levels of response conflict, or responding more slowly than usual. These findings provide novel, unambiguous support for the task-set enhancement hypothesis that cannot be explained by the priming of specific stimuli, responses, or stimulus-response associations. Moreover, they extend current models of cognitive control by revealing an important interaction between performance monitoring processes that promote optimal task performance and decision-making processes that choose one of several possible tasks to perform in the future.

I7

EEG PHASE SYNCHRONY REVEALS A MEDIAL-LATERAL FRONTAL COGNITIVE CONTROL NETWORK FOLLOWING ERRORS *James Cavanagh[1], Mike Cohen[1,2], John Allen[1]; [1]University of Arizona, [2]University of Amsterdam* – Error-related activity in the medial prefrontal cortex (mPFC) is thought to work in conjunction with lateral prefrontal cortex (lPFC) as a part of an action monitoring network, where errors signal the need for increased cognitive control. The neural mechanism by which this mPFC-lPFC interaction occurs remains unknown. We hypothesized that transient synchronous oscillations in the theta range reflect a mechanism by which these structures interact. To test this hypothesis, we extracted oscillatory phase and power from current-source-density-transformed electroencephalographic data recorded during a Flanker task. Theta power in the mPFC was diminished on the trial preceding an error and increased immediately following an error, consistent with predictions of an action monitoring system. These power dynamics appeared to take place over a response-related background of oscillatory theta phase coherence. Theta phase synchronization between FCz (mPFC) and F5/6 (lPFC) sites was robustly increased during error trials. The degree of mPFC-lPFC oscillatory synchronization predicted the degree of mPFC power on error trials, and both of these dynamics predicted the degree of post-error reaction time slowing. Oscillatory dynamics in the theta band may in part underlie a mechanism of communication between networks involved in action monitoring and cognitive control.

I8

DISSOCIATING FRONTAL AND PARIETAL CONTRIBUTIONS TO EXECUTIVE CONTROL *Chris Dodds[1], Sharon Morein-Zamir[1], Trevor Robbins[1]; [1]University of Cambridge, Experimental Psychology, UK* – A central debate in cognitive neuroscience concerns the extent to which the prefrontal and parietal cortices can be fractionated according to their differential involvement in specific executive control processes. On the one hand, compelling evidence has been presented for a high degree of functional localization within these regions. Studies have consistently shown that the ability to withhold a prepotent response is dependent on the integrity of the right inferior prefrontal cortex, whilst regions within the parietal cortex are involved in the flexible shifting and reorienting of attention. On the other hand, taken as a whole the functional neuroimaging literature shows a remarkably consistent pattern of activity in a frontoparietal network across a wide range of different cognitive demands. In the present study we investigated whether it was possible to dissociate frontal and parietal contributions to executive control within a single task. Twenty healthy participants completed a novel task while undergoing fMRI scanning. The task required subjects to perform two different executive functions - inhibition of a prepotent response and attentional shifting. We found that a network of frontal and parietal regions was commonly recruited during stop and shift trials. However, direct comparison of activation during stop and shift trials revealed highly localised activations in the right inferior frontal gyrus during response inhibition and in the left inferior parietal lobe during attentional shifting. These results show that process-specific responses in frontal and parietal regions can be distinguished from a more general pattern of frontoparietal recruitment across different cognitive demands.

I9

EXECUTIVE FUNCTIONING IN RECURRENT MAJOR DEPRESSION INVESTIGATED USING THE DELIS KAPLAN EXECUTIVE FUNCTION SYSTEM *Marit Schmid[1], Mari Strand[1,2], Guro Årdal[1], Åsa Hammar[1,2]; [1]University of Bergen, Biological and Medical Psychology, Norway, [2]Division of Psychiatry, Haukeland University Hospital, University of Bergen, Norway* – Executive functioning in Recurrent Major Depression investigated using the Delis Kaplan Executive Function System. Marit Schmid a, Mari Strand a,b , Guro Årdal a & Åsa Hammar a, b a Department of Biological and Medical Psychology, University of Bergen, Norway b Division of Psychiatry, Haukeland University Hospital, University of Bergen, Norway Abstract Focus on the association between Major Depressive Disorder (MDD) and cognitive functioning have increased over the last decade and several neuropsychological tests have been developed to assess cognitive functioning. The aim of the study was to examine Executive Function (EF) in patients with MDD using four tests (Verbal fluency, Color- Word Interference test, Trail making test, Tower) from the newly developed Delis Kaplan Executive Function System (D-KEFS). D-KEFS is the first set of EF tests designed to check for underlying causes of observed deficits. We expected that patients with recurrent MDD would show impairment on tests that measure EF, and that basic cognitive skills are spared. Executive Functioning (EF) was investigated in patients with a DSM-IV diagnosis of recurrent Major Depression (MDD), in the acute phase of illness. Twenty six MDD patients (age 17-55) with a Hamilton Depression Rating Scale (HDRS) score of > 20 were included in the study. Twenty five healthy control subjects were matched for age, gender, and education. The results demonstrate that the patient group showed a tendency towards lower performance on most measures of EF compared to the control group. Significant differences were found on tests measuring inhibition, switching, and category fluency. There were no differences between the two groups on measures of basic cognitive skills. In conclusion, patients show impairment on measures of EF, whilst basic cognitive skills are spared.

I10

AN INTERACTION BETWEEN PRIOR PROBABILITY AND VISUAL NOISE IN VISUAL CORTEX *Sarah Hillenbrand[1], Kathleen Hansen[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, NIMH* – In this study we sought to identify regions of cortical activation associated with the use of prior probability (PP) during perceptual decisions in noisy visual conditions. We hypothesized that, in noisy conditions, activity levels in visual cortex would increase with PP. To test this hypothesis, we acquired fMRI data while subjects performed a perceptual decision task (deciding whether abstract parametric shapes belonged to distribution A or B, where distribution A was on average smoother than distribution B). Subjects made decisions under two PP conditions (50/50, equal PP that each shape belonged to A or B, vs. 80/20, higher PP that each shape belonged to one of the two distributions) and two noise conditions (noise vs. no noise). Stimulus discriminability was manipulated in the noisy condition by using varying levels of noise to obscure the shapes, and in the noise-free condition by overlapping the shape distributions such that many shapes were somewhat or very ambiguous. In the noisy condition, cortex near LO (a location where selectivity for visually-presented shapes and objects has been observed) showed a significant interaction with increased activity at high PP and increased visual noise. In

the noise-free condition, this region did not show an analogous interaction between PP and ambiguity; thus, the observed interaction between PP and stimulus discriminability is specific to noisy visual conditions.

I11

COMMON AND DISTINCT PREFRONTAL REGIONS FOR SWITCHING BETWEEN TASK MAPPINGS, TASK RULES, AND TASK ORDERS *Christine Stelzel[1,2,3], Ulrike Basten[1,2,3], Christian Fiebach[1,2,3]; [1]University of Heidelberg, Psychology, Germany, [2]University of Heidelberg, Neuroradiology, Germany, [3]University of Heidelberg, Neurology, Germany* – Switching between task representations leads to performance costs (i) when different responses are assigned to identical stimuli ('task-mapping switch'), (ii) when the rules relating stimuli and responses change ('task-rule switch'), and (iii) when the order of two tasks in a dual-task situation changes ('task-order switch'). All types of switching have been associated with the lateral prefrontal cortex (lPFC). However, it is not known yet whether these switching processes involve common or distinct prefrontal regions. We tested the three switching processes within one fMRI session. Participants performed choice reactions on visually presented digits: smaller/greater five or odd/even decisions. In task-switch blocks, a cue indicated which task rule to perform in the following trial ('task-rule switch'). In dual-task blocks, both cues were presented with a delay and participants responded in the order of cue presentation to both stimuli ('task-order switch'). Cues appeared to the left or right of a fixation cross, indicating the response hand for the relevant tasks ('task-mapping switch'). Behaviorally, switching costs were present for all three manipulations. No brain regions were significantly active in the conjunction of all three switching contrasts. The left inferior frontal junction (IFJ) region was commonly activated by switching between task mappings and task rules but not by task-order switching which was related to the right IFJ. In addition to this left-right dissociation, task-rule switching and task-order switching commonly activated a region in the right anterior middle frontal gyrus, supporting a hierarchical lPFC view with more abstract control processes located in more anterior lPFC regions.

I12

EYE MOVEMENT CONTROL AS A PROBE OF IMPULSIVE DECISION MAKING *Robert Adam[1,2], Paul Bays[1,2], Masud Husain[1,2]; [1]Institute of Cognitive Neuroscience, [2]Institute of Neurology, University College London* – Why do some people dash across the street at the last minute or 'put the pedal to the metal' almost before the light goes green, while others are more cautious? Here we introduce a novel oculomotor task to examine decision making. In our task, a traffic (stop) light dictates when subjects should make a horizontal saccade as fast as possible in return for a hyperbolically decaying reward. Subjects are cued by the onset of an amber light to prepare to make a saccade when the light turns green. The duration of the amber signal is variable but randomly selected from a fixed distribution so that subjects build an expectation of the GO (green) signal. Under these circumstances some subjects generate anticipatory saccades in addition to the reactive distribution that follows GO onset. Disproportionately rewarding early saccades encourages subjects to behave 'impulsively', increasing anticipatory responses. Young participants (n=20) demonstrated increasing anticipatory behaviour with lengthening amber durations prior to the GO. Anticipations were rare, however, in older volunteers (n=20). We modelled the two types of behaviour - anticipatory and reactive - as two linear rise-to-threshold processes, one triggered by amber onset and the second by the GO stimulus. Using maximum likelihood estimation we found best fit values for the mean and variance of two recinormal saccade distributions: an early anticipatory process and a later reactive response. The findings show how eye movement control can be used as a quantitative probe of impulsivity, with few parameters required to generate a well fitting model.

I13

GLUCOSE ENHANCEMENT OF EVENT-RELATED POTENTIAL MARKERS ASSOCIATED WITH EPISODIC MEMORY AND EXECUTIVE FUNCTION *Louise Brown[1], Leigh Riby[2], Andrew Meikle; [1]The University of Edinburgh, Psychology, [2]Northumbria University, Division of Psychology* – The ingestion of a glucose containing drink has been shown to improve cognitive performance, particularly for episodic memory functioning. However, it remains unclear the extent to which task domain moderates the glucose enhancement effect. The aim of this research was to determine whether facilitation is restricted to known event-related potential (ERP) components related to episodic memory (i.e., left-parietal effect; recollection), or if frontal lobe functioning (i.e., central-frontal negativity; conflict monitoring) can also benefit. In a mixed design 35 participants were administered either 25g glucose dissolved in an organge-flavoured drink, or a placebo product (a matched saccharin drink). Blood glucose monitoring performed at the start, midpoint, and end of each session confirmed that blood glucose levels increased mid-session for the glucose group only. After consumption of the drink and a subsequent 15 minute delay period, two tasks traditionally associated with episodic memory (an old/new recognition task) and frontal lobe functioning (the Stroop task) were carried out in a counterbalanced order. Consistent with previous behavioural research, an analysis of the grand average ERPs revealed facilitation of the left-parietal episodic memory component. However, glucose also moderated the frontal ERP component related to conflict monitoring. These findings therefore support the idea that glucose impacts on neural mechanisms involved in episodic memory but, contrary to expectations, glucose was also found to facilitate frontal lobe function. These data are discussed in relation to recent fMRI data which also suggest that both the medial-temporal lobes and pre-frontal cortex are sensitive to the action of glucose.

I14

ARE SPECIFIC PREFRONTAL REGIONS NECESSARY FOR SELF-ORDERED SPATIAL WORKING MEMORY PERFORMANCE? EVIDENCE FROM A LESION STUDY *Ami Tsuchida[1], Lesley Fellows[1]; [1]Montreal Neurological Institute, McGill University* – Executive components of working memory, such as the ability to monitor information and implement effective strategy, are critical for goal-directed behaviour, and thought to depend on prefrontal cortex (PFC). The self-ordered spatial working memory (SWM) task has been widely used to investigate the neural substrates of such components across species. Lesion studies in rats and non-human primates have specifically implicated dorsolateral PFC in the successful performance of this task, and much of the neuroimaging work in humans has also emphasized a specific role for this area. However, there is no direct evidence for such specificity from neuropsychological studies in humans. The effect of damage to specific regions within PFC was examined by administering the SWM task to 36 subjects with focal frontal lobe damage, and 53 demographically-matched control subjects. Contributions of prefrontal sub-regions to task performance were tested with both region-of-interest and voxel-based lesion symptom mapping (VLSM) methods. Surprisingly, the group with lateral prefrontal damage was the least impaired among the patient groups: groups with dorsomedial or ventromedial damage made more errors, with the ventromedial group having notably poor performance. VLSM confirmed this pattern, indicating significant effects of damage to broad areas within medial prefrontal and orbitofrontal cortex, but not lateral PFC. The results suggest the executive processes tapped by the SWM depend on a network of prefrontal regions, rather than isolated contributions from dorsolateral PFC.

I15

CHANGES IN ERP COMPONENT AMPLITUDES REFLECT THE UPDATING OF VALUE FUNCTIONS IN A REINFORCEMENT LEARNING TASK *Olav Krigolson[1]; [1]University of British Columbia, Psychology* – In order to successfully optimize behaviour, we utilise feedback to modify the information on which we have base our decisions. The

error-related negativity (ERN), a component of the event-related brain potential (ERP), is thought to reflect a reinforcement learning prediction error elicited by feedback evaluation. To date, only a few studies have attempted to demonstrate that the ERN is actually followed by improvements in subsequent performance. In other words, if the ERN reflects a prediction error signal, then on trials following its occurrence there should be corresponding changes in the ERP which reflect the updating of the value functions used for response selection. In the present study, participants performed a two choice n-arm bandit gambling task. Within each block of trials, gambles were repeated so that participants could use the outcome of their initial response (win, loss) to improve response selection on subsequent trials. An analysis of feedback locked waveforms revealed a difference between initial win and loss trials in line with previous accounts of the ERN. Analysis of waveforms locked to stimulus presentation revealed no differences correlated with response selection on the initial trial. However, on subsequent trials, increases in lateralised ERP components were observed which predicted the subsequent response. In sum, the results of the present experiment support the hypothesis that the ERN reflects a prediction error. Further, the increases in lateralised ERP component amplitude observed here are indicative of a process in which the prediction error modifies value functions in order to improve future performance.

116

MECHANISMS FOR RETRIEVAL AND SELECTION DURING LANGUAGE PRODUCTION *Hannah Snyder[1], Natalie Hutchison[1], Yuko Munakata[1]; [1]University of Colorado Boulder, Psychology* – During language production, words must constantly be retrieved and selected for production in the face of multiple possible alternatives. There is broad consensus that our ability to respond in such underdetermined situations requires cognitive control and relies on left ventrolateral prefrontal cortex (VLPFC). However, there has been little investigation, or even speculation, as to specific mechanisms that may support retrieval and selection of responses. Regardless of whether separate areas of VLPFC support these processes (e.g Badre & Wagner, 2007), the specific mechanisms could be common or distinct. We present a biologically-plausible neural network model that implements a language-production task (verb generation). The model reproduces the effects of competition and association strength found in human participants, taking longer to produce a response when there are multiple competing responses, and when stimulus-response association strength is low. Recurrent connections in PFC appear to be essential both for resolving competition, and for boosting activation of weakly associated responses ('retrieval'), while k-winners-take-all inhibition is also essential for selection when competition is high. This model suggests that basic neural properties of PFC, together with synaptic weights established through Hebbian learning, may be sufficient to account for effects of both association strength and competition. In addition, the model predicts that participants with reduced neural inhibition should exhibit difficulty resolving competition. We confirm this prediction, demonstrating increased selection costs in participants high in trait anxiety (associated with poor GABAergic function). Implications for understanding cognitive control in both normal populations and those with anxiety disorders are discussed.

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TRAINING WORKING MEMORY AND VISUAL ATTENTION ON THE INTERNET *Gregory Kellett[1], Michael Scanlon[2], Kunal Sarkar[2], David Drescher[2], Mark Geisler[1]; [1]San Francisco State University, [2]Lumos Labs, Inc.* – Prior research has shown that cognitive abilities are adaptive and can be improved via targeted cognitive behavioral training methods; however, use of these methods is limited outside of the laboratory. We investigated the efficacy of a web-based cognitive training program which participants could complete at home, by measuring improvement of visual attention and working memory in healthy adults. Volunteer participants (mean age=54) were made up of 14 people receiving the treatment and 9 receiving the control (no treatment) condition, for a total of 23 participants. All participants were given initial cognitive assessments, a training (or control) intervention and then cognitive assessments again post-training. Both training and testing were conducted online at each participant's respective home. Trained subjects completed twenty-minute sessions of online cognitive exercise once daily for five weeks, while control participants received no training. Exercises consisted of one visual attention and three working memory tasks. Results and compliance data were captured online and saved to a secure server automatically. The trained group improved significantly ($p<0.01$) in measures of visual attention and working memory while the control group did not. Training reduced the average error in localization of transient and non-central visual stimuli while also improving performance on measures of spatial working memory. There were no significant performance shifts in the control group. These results provide evidence that web-based cognitive training can transfer to improvement on tests of working memory and visual attention, and indicate a practical method for home-based cognitive development.

118

DISSOCIATING OUTCOME EXPECTANCY (P300) AND ACCURACY (FRN) IN RELATION TO POST-ERROR SLOWING *Elena Núñez Castellar[1], Simone Kuehn[2,1], Wim Gevers[3], Wim Fias[1], Wim Notebaert[1]; [1]Ghent University, Belgium, [2]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, [3]Université Libre de Bruxelles, Belgium* – During the last years a growing number of studies have used event-related potentials (ERPs) to investigate the mechanisms underlying error processing. However, how these mechanisms are associated with behavioral adjustments, which follow the commission of an error, remains unclear. In the present study we investigate how the slowing down observed in the trial immediately following an error (post-error slowing) is linked to outcome expectations and error feedback. An adaptive four-choice reaction time task was used to manipulate outcome expectancy. Subjects performed the task in two conditions: 75% correct responses (expectancy for correct) and 35% correct responses (expectancy for error). Behaviorally, the results show post-error slowing in the 75%-correct condition and post-correct slowing in the 35%-correct condition, indicating that outcome expectancy mismatch is crucial for post-error slowing. Feedback-locked ERP analyses revealed Feedback Related Negativity (FRN) for errors irrespective of outcome expectancy and increased P300 amplitude for unexpected outcomes irrespective of accuracy. The results suggest that FRN is unrelated to the slowing after unexpected outcomes while the P300 is. The results support the hypothesis that post-error slowing is caused by attentional orienting to unexpected events.

119

RESOLUTION OF CONFLICT BY BILINGUALS AND MUSICIANS: EVIDENCE FROM ERP *Sylvain Moreno[1], Ellen Bialystok[1], Zofia Wodniecka[2], Claude Alain[3]; [1]York University, [2]Jagiellonian University, [3]Rotman Research Institute & University of Toronto* – Bilinguals and musicians have been shown to perform better than monolinguals in executive function tasks involving conflict (Bialystok, 2001; Costa et al., 2008; Bialystok & DePape, in press). For bilinguals, these findings have been attributed to their need to switch constantly between their two languages and inhibit interference from the other language. The recruitment of executive processes into language processing for bilinguals alters the development and efficiency of these processes for bilinguals. For musicians, these findings have been attributed to their training requirements which involve high levels of control, attention, and memorization, again involving executive processes. Here, we recorded ERPs in 42 young adults who were either English monolinguals, English-Hebrew bilinguals, or monolingual musicians while they performed a visual Go-Nogo task. This paradigm involved two different executive function processes: conflict detection and response inhibition mechanisms. Our hypothesis was to observe the effect of different life experiences on specific aspects of executive functioning. Bilingualism is based in language conflict and so should influence conflict detection processes and not response inhibition mecha-

nisms; musical training incorporates motor responses into the executive function system and so should modify response inhibition mechanisms, but their ear training should also influence conflict detection processes. Our results supported these hypotheses: Bilingualism influenced the N2 ERPs wave component related to conflict detection and musical training influenced N2 and P3 ERPs wave components related to conflict detection but also to response inhibition. The results are used to refine conceptions of the effect of experience on executive functioning.

I20

EEG AND FMRI IMAGING OF AN EXPERT MEDITATOR IN EIGHT JHANAS *Michael Hagerty[1,2], Julian Isaacs[2], Leigh Brasington, Larry Shupe[3], Eberhard Fetz[3], Steven Cramer[4]; [1]University of California, Davis, [2]Wellspring Institute, [3]University of Washington, [4]University of California, Irvine* – We report the first fMRI images and EEG recordings of an expert in the 8 advanced Buddhist meditations called jhanas, and test 5 hypotheses on how the jhanas differ from the closed-eye resting state in 8 different brain regions. We hypothesize simple changes in the brain regions responsible for each of the 5 principal experiential features of jhana states. These features are: (1) internal verbalizations fade, (2) external awareness dims, (3) the sense of personal boundaries is altered, (4) the experience of evaluations, goals, and "shoulds" diminishes, and (5) attention is highly focused on the object of meditation. The results strongly confirm reduced activity in the brain regions related to the first 3 hypotheses, with all 16 of the planned comparisons significant and in the predicted direction. With respect to Hypothesis 4, results are mixed, with all 4 predictions significantly confirmed in the alpha1 band, but all 4 disconfirmed in the theta band. However, fMRI shows reduced BOLD signal in predicted areas. Lastly, Hypothesis 5 was mostly confirmed, with 5 of the 6 planned comparisons in the predicted direction. The EEG spectra show strong, significant, and consistent differences in specific brain regions when the meditator is in a jhana state compared to normal resting consciousness, and the fMRI largely confirm these results, with higher BOLD signal only in executive areas. The strength of these effects appears to be larger than any other meditation discipline studied so far.

I21

AN ASSOCIATION BETWEEN MALADAPTIVE COPING AND INHIBITORY DEFICITS IN THE STROOP TASK: PAIN CATASTROPHIZING SCORES CORRELATE WITH INCONGRUENT COLOR NAMING TIMES *Kristin Janschewitz[1], Theresa Khoo[1], Barbara Knowlton[1]; [1]University of California, Los Angeles* – It has been demonstrated that persistent negative thinking and poor coping impact health. Since inhibition is normally needed to control thoughts and actions, inhibitory deficits may underlie emotion regulation deficits that contribute negatively to health. Specifically, catastrophizing interpretations about health-related information may contribute to the experience of distress in chronic physical disorders. In the current study, 23 undergraduate students completed a Stroop task in which they were asked to name the ink colors of words that denoted congruent or incongruent colors. Participants' scores on the Pain Catastrophizing Scale (PCS; Sullivan, Bishop & Pivik, 1995) were also obtained. It was found that PCS scores significantly positively correlated with naming times in the incongruent (p=.03) but not congruent conditions. These results suggest that deficits in relatively high-level (cognitive) inhibition for neutral material are associated with maladaptive coping styles in otherwise healthy participants. We suggest that basic cognitive control problems may factor into the experience of distress in clinical populations in which intrusive thoughts are considered characteristic of impaired emotion regulation. The current study is part of a larger effort to examine the relationship between cognitive control, emotion, and health outcomes.

I22

CARDIORESPIRATORY FITNESS MODERATES NEURAL MECHANISMS OF COGNITIVE CONTROL IN OLDER ADULTS *Ruchika Prakash[1], Michelle Voss[1], Kirk Erickson[2], Jason Lewis[1], Laura Chaddock[1], Katherine Morris[3], Shawna Doerksen[3], Amanda Szabo[3], Edward McAuley[3], Arthur Kramer[1]; [1]University of Illinois at Urbana-Champaign, Beckman Institute and Department of Psychology, [2]University of Pittsburgh, Psychology, [3]University of Illinois, Kinesiology and Community Health, Urbana-Champaign* – A growing body of literature provides evidence for the prophylactic influence of cardiorespiratory fitness on cognitive functioning of older adults. In here, we examined the neural mechanisms underlying such fitness benefits in the context of theories of healthy aging. Specifically, employing a modified version of the Stroop task, we questioned whether higher levels of cardiorespiratory fitness were associated with an increase in cortical regions responsible for imposing attentional control along with a concomitant up-regulation of task-relevant representations. To isolate regions of the ventral visual cortex involved in processing task-relevant attributes and task-irrelevant attributes, we presented our participants with localizer scans to identify areas of the brain that were sensitive to color processing and word processing and subsequently studied modulation of these regions as a function of the Stroop task. Higher fitness levels were associated with improved behavioral performance on the most demanding incongruent condition of the Stroop task. This was accompanied with an increase in the recruitment of prefrontal cortices in the most challenging condition for higher-fit individuals, providing evidence that cardiorespiratory fitness can act as a potential moderator of the age-related neural inflexibility demonstrated in previous studies. Consistent with models of selective attention, we found a modulation of both the task-relevant and task-irrelevant attributes relative to the baseline. However, only activation in the color-sensitive areas was associated with improved behavioral performance, but not with cardiorespiratory fitness. Our results thus provide insights for the differential mechanisms by which fitness has a favorable influence on cognitive control in older adults.

I23

LARGE-SCALE ASSESSMENT OF COGNITIVE PERFORMANCE AND PLASTICITY *Michael Scanlon[1], Gregory Kellett[1,2], Jacob Rothstein[1], Kunal Sarkar[1], David Drescher[1]; [1]Lumos Labs, [2]San Francisco State University* – An individual's cognitive performance can influence their living or working performance; and a wide range of health conditions can lead to impairments in cognitive ability. It may be possible, however, to improve human cognitive performance with appropriately directed training. We used the data saved by the web-based cognitive training application "Lumosity" to compare cognitive status and plasticity across demographics, and to construct a normalized scale that can be used for future testing. The Lumosity software saves the results of each neuropsychological test and training task completed by each user. Because Lumosity is a popular consumer product, the data is comprised of a diverse and large number of participants (>40,000 individuals), making it possible to assess demographic sub-populations with sufficient statistical power to detect subtle differences. We first established population normalized score distributions for each task. Using these norms, we measured participants' baseline abilities in areas including working memory, short-term memory, reaction time, and cognitive control, as well as real-world skills such as arithmetic computation and face-name memory. We found significant performance differences between age groups, and these differences depended on the particular cognitive function examined. Additionally, by observing changes in scores during and following training, we were able to compare cognitive plasticity at different ages and across different cognitive domains. The capability to efficiently evaluate cognitive status, alter it with appropriate treatments, and then assess changes from baseline has both academic and clinical importance, and this research suggests a viable method to achieve this capability.

I24

NEURAL CORRELATES OF AGE-RELATED DIFFERENCES IN EXECUTIVE FUNCTIONS AND MAGNITUDE PROCESSING *Chih-Mao Huang[1], Denise C. Park[2]; [1]University of Illinois, Psychology, Urbana-Champaign, [2]Center for Brain Health, University of Texas at Dallas* – There is increasing evidence that patterns of bilateral neural activation

that occur with age in frontal as well as parietal areas are functional and supportive of cognition in older adults and are a type of compensatory neural scaffolding (Park & Reuter-Lorenz, in press). In this fMRI study, we examined age differences in an executive control task where stimulus congruity was manipulated, using a numerical Stroop paradigm. Fifteen young and 13 old participants were instructed to decide which digit of a digit pair was either numerically (numerical comparison task) or physically (physical comparison task) larger. The physical size of digits and numerical distance between the digits were varied such that numerical and physical magnitude of digits could be congruent, neutral or incongruent with each other. Compared to young adults, older adults had a longer reaction time for both physical and numerical magnitude comparisons and also had a larger incongruency effect (incongruent vs. congruent trials). In addition, older adults, in contrast to young, showed bilateral recruitment in parietal and frontal areas, with a dissociation of task type from locus of bilaterality. For incongruous judgments of size magnitude, bilateral recruitment occurred in frontal areas, but for judgments of distance magnitude, the bilaterality occurred in parietal regions. The study provides evidence for highly specific compensatory recruitment for different executive processes involving the same physical stimuli, and is supportive of the Park and Reuter-Lorenz STAC (Scaffolding Theory of Cognitive Aging) model which makes specific predictions about the loci of compensatory recruitment with age.

I25

THE TIMING TO KNOW THE SIGNIFICANCE OF ERRORS MODULATES THE ERROR PROCESSING *Asuka Murata[1], Junichi Katayama[2]; [1]Graduate School of Education, Hokkaido University, [2]Faculty of Education, Hokkaido University* – Previous studies have demonstrated that the error-related negativity (ERN) reflects the mismatch between the representations of the goal and the outcome of our behavior. The goal of our behavior varies depending on the environment. As for time, there are different timings when we know the impact of our behavior. To investigate an effect of the timing to know the significance of errors on the ERN, an arrowhead version of flankers task was administered. Participants were instructed to press the left or right button in accordance with the direction of the central target. The first and second cues appeared approximately 2000 ms and 500 ms before the presentation of arrowheads, respectively. Either the first or second cue informed whether or not participants could gain monetary reward for correct in the present trial. Motivated trials, in which participants were shown the reward by the first or second cue, were categorized to long notice (LN) or short notice (SN) trial, and the rest was labeled as not motivated (NM) trial. Hit rates were higher for LN and SN than for NM trials, indicating that participants changed their strategy according to the motivational incentive regardless of the timing. All error trials elicited clear ERN. The ERN was larger for LM than for SN trials, indicating that the timing to know the significance of errors changed the degree of mismatch between the representations of goal and outcome. The finding suggests that the goal representation is modulated by temporal alterations of motivation for achieving the goal.

I26

EFFECT OF MOTOR IMAGERY ON BILATERAL TRANSFER, BEHAVIORAL AND NIRS EXPERIMENT *Kaoru Amemiya[1,2], Tomohiro Ishizu[2], Tomoaki Ayabe[3], Shozo Kojima[2]; [1]The University of Tokyo, Graduate School of Medicine , [2]Keio University, Faculty of letters , [3]National institute for physiological sciences, Sensory-Motor Integration* – The aim of this experiment was to investigate the imagery effect on the ipsilateral and transfer training and its correlating brain area using NIRS (Near Infrared Spectroscopy).?Using finger tapping paradigm, right handers were randomly distributed to physical training group, imagery training group or control group. Each group participants typed the predetarmined sequence physically or mentally, or counted numbers (control group) during NIRS recording. After each training sessions (5 session of 30 seconds), they were tested the old sequence and newly transfer sequence. The results showed that physical training led to the improvement of the old sequence. On the other hand, mental training led more transfer to the new sequence than did the physical training, as well as the improvement of the old sequence. The NIRS data revealed the imagery activated the supplementary motor area (SMA), as the same level at the physical execution. Although the activation level of the SMA correlated with the improvement of the physical training, there was significant correlation neither with the improvement nor with the transfer in the case of imagery training. This behavioral and NIRS experiment suggested the following hypotheses. One is that the imagery training is effective to achieve the abstract representation more than physical execution. The imagery training might activated the SMA differently from the case of the physical training. The last one is that the SMA might not be the predictive factor of the transfer.

I27

USE OF TWO-DIMENSIONAL SURFACE MAPPING TO DISSOCIATE TWO ADJACENT ACTIVATIONS IN RIGHT POSTERIOR INFERIOR PREFRONTAL CORTEX ASSOCIATED WITH DISSIMILAR FUNCTIONS *Satoshi Hirose[1], Junichi Chikazoe[1], Koji Jimura[1], Ken-ichiro Yamashita[1], Yasushi Miyashita[1], Seiki Konishi[1]; [1]The University of Tokyo School of Medicine, Physiology* – Response inhibition and negative feedback processing activate similar regions in the right posterior inferior frontal gyrus (pIFG). The locations of these regions were determined on the basis of group analysis of recruited subjects, but the subject groups differed between studies. It is unclear, therefore, whether these two cognitive requirements increased activity of a single common focus in the pIFG or they increased activity of two separate foci in the pIFG. In order to test these two possible patterns of functional organization of the pIFG, the present functional magnetic resonance imaging study employed the same subjects to perform the two tasks, one of which required response inhibition and the other required negative feedback processing. The region associated with response inhibition was calculated based on the anti-saccade task used in Chikazoe et al. (2007). On the other hand, the region associated with negative feedback processing was calculated based on the modified Wisconsin Card Sorting Task (Konishi et al., 2002). Because of the individual difference in sulcal structures, the pIFG activation in each subject was analyzed using two-dimensional surface mapping based on Caret (Van Essen et al. 2001). By comparing the coordinates of the two activations of individual subjects, it was revealed that the two regions were adjacent but separate, and that the region associated with response inhibition was located caudal to that associated with negative feedback processing. These results suggest that the right pIFG is functionally heterogeneous, and that the functional organization of subregions within the pIFG should be further investigated.

I28

PREFRONTAL BRAIN ACTIVATION DURING THE PROCESSING OF HIERARCHICAL SEQUENTIAL EVENTS *Jörg Bahlmann[1], Ricarda Schubotz[2], Jutta Mueller[1], Dirk Koester[3], Angela Friederici[1]; [1]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, [2]Max Planck Institute for Neurological Research, Cologne, Germany, [3]Leiden Institute for Brain and Cognition, and Leiden University, The Netherlands* – A number of studies exist that investigated sequence processing in serial reaction time tasks or artificial grammar tasks. However, little is known about higher order sequence processing (e.g., hierarchical organization of event sequences). Here, we manipulated the regularities within sequentially occurring, non-linguistic visual symbols by applying two types of prediction rules. In one rule (the adjacent dependency rule), the sequences consisted of alternating items from two different categories. In the second rule (the hierarchical dependency rule), a hierarchical structure was generated using the same set of item types. Thus, predictions about non-adjacent elements were required for the latter rule. Functional Magnetic Resonance Imaging (fMRI) was used to investigate the neural correlates of the application of the two prediction rules. We found that the hierar-

chical dependency rule correlated with activity in the pre-supplementary motor area, and the head of the caudate nucleus. In addition, in a hypothesis-driven ROI analysis in Broca's area (BA 44), we found a significantly higher hemodynamic response to the hierarchical dependency rule than to the adjacent dependency rule. These results suggest that this neural network supports hierarchical sequencing, possibly contributing to the integration of sequential elements into higher-order structural events. Importantly, the findings suggest that Broca's area is also engaged in hierarchical sequencing in domains other than language.

I29

NEURONAL REPRESENTATIONS OF GOAL PROXIMITY IN A MULTITRIAL REWARD SCHEDULE *Ruth M. Schmitt[1,2,3], Andrea Gaebel[1,2,3], Christian J. Fiebach[1,2,3]; [1]University of Heidelberg, Psychology, Germany, [2]University of Heidelberg, Neuroradiology, Germany, [3]University of Heidelberg, Neurology, Germany* – Goal-directed behavior is putatively influenced by motivational aspects of anticipated performance outcomes. However, in complex environments, these desired effects are typically not achieved immediately. Rather, several action steps are necessary to reach a predicted result. Recent monkey studies identified anterior cingulate (ACC) neurons that code the proximity to an anticipated reward. In humans, to our knowledge, evidence for such stepwise alterations of reward-related brain activity during a sequence of actions is still missing. We addressed this question in an fMRI study by integrating Knutson's Monetary Incentive Delay (MID) task into a multitrial reward schedule paradigm, using two different reward contingencies: in the delayed condition, participants received a large amount of money only after successful completion of 4 consecutive trials. In the immediate condition, a small amount of money was earned after every successful trial. A classical MID task was furthermore employed to localize reward anticipation signals in the striatum, rostral cingulate zone (RCZ) of the ACC, and dorsal premotor cortex (dPM). In the multitrial paradigm, all three regions exhibited a response profile sensitive to progress through the schedule. RCZ and dPM activation were additionally modulated by contingency condition, indicating that these areas encode proximity to actual goal attainment. These findings corroborate the assumption of a performance monitoring function of the ACC, suggesting that increased reward expectation signals the need for accordant adjustments in cognitive control. Differential dPM activation points towards an increased motivation in the delayed contingency condition resulting in augmented motor control as an expected result approaches.

I30

THE RELATIONSHIP BETWEEN WORKING MEMORY CAPACITY AND A NEURAL INDEX OF CONTROLLED RECOLLECTION *Rachael Elward[1], Edward Wilding[1]; [1]CUBRIC, School of Psychology, Cardiff University, UK* – It is widely assumed that control can be exerted over conscious recollection, and one possibility is that this occurs via inhibitory mechanisms. According to one account, inhibition is a resource demanding process and as such is linked to the availability of working memory capacity. In order to test this account, performance on the O-span test (an assessment of working memory capacity) was correlated with a neural index of the control of recollection derived from event-related potentials (ERPs). Participants studied a list of items and in a subsequent test phase responded on one key to new (unstudied) items and on another to studied items (targets). Some of the new items repeated, and participants responded to these 'non-targets' on the same key as for new items. ERPs were acquired during the test phases and the ERP measure of control over recollection was the difference between the size of the left-parietal ERP old/new effect for targets and for non-targets. This ERP old/new effect indexes recollection in a graded fashion, and larger parietal old/new effects for targets than for non-targets have been interpreted as an index of the degree to which control over the recollection of non-targets has been exerted. There was a significant positive relationship between O-span scores and the magnitude of this neural index of recollection control. This implies that the extent to which cognitive control resources (and possibly inhibition processes) are available influences the degree to which recollection of some kinds of information can be prioritised over others.

I31

DIFFERENTIAL EMOTIONAL AND COGNITIVE PROCESSES ELICITED BY CONFLICTS IN THE GO/NOGO AND THE SIMON TASK *Werner Sommer[1], Schacht Annekathrin[1]; [1]Humboldt-University, Berlin, Germany* – Conflicts have been suggested to require effortful processing and, therefore may be aversive (Botvinick, 2007). Two classical experimental paradigms, which are known to elicit cognitive conflicts, are the Go/NoGo task and the Simon task. Whereas the conflict in NoGo trials consists in the inhibition of a predominant response tendency, the Simon conflict is characterized by incompatible response activations. Nevertheless, similar monitoring processes have been claimed to be reflected in the N200 component of event-related potentials (ERPs) elicited in both tasks. In the present study, participants performed a Go/NoGo and Simon task in a within-subject design using the same type of stimuli, while ERPs, skin conductance responses (SCRs), pupil diameter, and activity of the facial Corrugator muscle were recorded. Whereas NoGo trials elicited reduced SCRs and pupillometric responses, but prolonged Corrugator activity as compared with Go trials, incompatible and compatible Simon trials were indistinguishable in these parameters. Furthermore, the conflict-sensitive N2 and P3 ERP-components in both paradigms were similar in amplitude strength, but showed significantly different scalp distributions indicating dissociable neural generator systems. The present findings suggest different emotional and cognitive processes to be involved in both types of cognitive conflicts, none being aversive. In addition, the N200 findings call into question claims of common monitoring systems for all kinds of cognitive conflicts.

I32

ARE AGE EFFECTS IN PERFORMANCE MONITORING MODULATED BY DECISION UNCERTAINTY? *Melanie Schreiber[1], Anne Weigand[1], Norbert Kathmann[1], Tanja Endrass[1]; [1]Humboldt Universität zu Berlin* – Event-related brain potential (ERP) studies identified the error related negativity (ERN/Ne) and the correct related negativity (CRN) to be related to performance monitoring. The CRN has previously been explained with decision uncertainty. Pailing and Segalowitz (2004) showed that ERN/Ne and CRN amplitude differences attenuated when subjects were highly uncertain. Since our previous study revealed pronounced differences between ERN/Ne and CRN amplitudes in younger adults, but not in older adults, our present study aims to investigate whether age effects on ERN/Ne and CRN amplitudes are related to higher decision uncertainty in older adults. Participants performed a visual discrimination task with four difficulty levels to assess decision uncertainty while recording event-related potentials. They were asked to discriminate the volume of two dots and to decide which of the two dots was larger. Subsequent response accuracy ratings allowed us to compare aware and unaware correct and incorrect reactions as well as trials classified as uncertain. Results indicate that ERN/Ne and CRN amplitudes were reduced in older compared to younger adults. Both groups showed attenuated ERN/Ne amplitudes, while CRN amplitudes increased with higher task difficulty. The percentage of uncertainty ratings was larger in younger compared to older adults. Further, the distribution of uncertainty ratings corresponded not to the course of the CRN in the different task conditions. Therefore, the present findings signal that age effects of ERN/Ne and CRN amplitudes seem not (only) to be due to decision uncertainty. Alternative explanations including age-related differences in strategic adjustments are discussed.

I33

THE LOCUS OF INTERFERENCE IN PRIMED INHIBITION: AN ERP STUDY *Jonne Oldenburg[1], Frederick Verbruggen[1], Sara Assecondi[2], Wim Fias[1]; [1]Ghent University, Ghent, Experimental Psychology, Belgium, [2]MEDISP-IBITECH-IBBT, Ghent University, Electronics and Information Systems, Ghent, Belgium* – Recently, it was found that if, in a stop signal task, participants successfully inhibit their response to a stimulus, response to a subsequent presentation of that same stimulus is slower than the response to a different stimulus (Verbruggen et al., 2008). This delay is thought to be due to conflict between go and stop processes both activated by the stimulus that was previously associated with inhibition but to which now a response has to be made. We use ERP to investigate the nature of this association. Specifically, we were interested in the locus of the interference between go and stop processes. To this end, we compared response locked and stimulus locked LRP waves of repetition trials at which a response had to be made (trial N) but which could have either an inhibition trial or a response trial preceding them (Trial N-1). Results showed a latency difference between conditions at trial N which was stimulus locked rather than response locked. Thus, interference at trial N does not act directly on motor execution, but seems to affect duration of pre-motoric processes.

I34

NEURAL MECHANISMS UNDERLYING RESOURCE DEPLETION OF EXECUTIVE CONTROL *Jonas Persson[1], Patricia Reuter-Lorenz[1]; [1]Stockholm University, [2]University of Michigan* – Executive control coordinates, prioritizes and selects task relevant behaviours especially under conditions of conflict and competition. Behavioural results indicate that control efficiency in a second task is diminished when control demands are high in a first task immediately preceding it in time. This suggests that executive control is a finite resource that can be temporarily depleted. For example, performance on semantic retrieval with high interference is impaired when preceded by a working memory task with high interference but not a working memory task with low interference (Persson et al., Neuropsychologia, 2007). Here, we use fMRI to elucidate the mechanisms associated with resource depletion or "selective fatigue" of executive control. Participants, randomly assigned to the Depletion group or the Non-depletion Control group, completed a pre-test and post-test verb generation task that included a measure of interference resolution. Between pre- and post-test, the Depletion group performed item-recognition with recent probes (high interference), whereas the Controls performed item-recognition without recent probes (low interference). These groups differed neither in pre-test verb generation performance nor pre-test activations, including left inferior frontal gyrus (IFG) and temporal regions. After their respective item recognition tasks, the groups differed on verb generation behaviorally and neurally. The Depletion group performed less efficiently, showed reduced activation in left IFG, and increased recruitment in right IFG compared to Controls. Selective depletion of executive control results in reduced performance, reduced recruitment of task-specific regions, along with homologous increases activation that may relate to compensation. These results have implications for process-specific transfer and training.

I35

A CHRONOMETRIC ANALYSIS OF COGNITION IN DEPRESSION *Marc Berman[1], Derek Nee[2,1], Patricia Deldin[1], Melynda Casement[1], Hyang Sook Kim[1], Susanne Jaeggi[1,3], Martin Buschkuehl[1,3], Courtney Behnke[1], Patrick Bissett[4,1], John Jonides[1]; [1]The University of Michigan, Psychology, [2]Indiana University, Psychology, [3]University of Bern, Psychology, [4]Yale University, Psychology* – Major Depressive Disorder has been characterized by an inability to remove negative information from mind. This inability may be a driver of rumination, a process by which negative thoughts are recycled recursively and lead to worsened affect. Here we explore both the ability to remove negative information from mind with a directed forgetting paradigm, and spontaneous rumination as associated with major depressive disorder. We find that participants with depression have more difficultly removing negative information from short-term memory and also have a long-term memory recall bias for negative information compared to age-matched controls who show the opposite pattern of results. In addition to these behavioral effects, we find neural differences between the two groups at the time of encoding, maintenance, and response selection. These differences include increased left Ventrolateral Prefrontal Cortex activation for controls vs. depressed and activation differences in the Amygdala and Parahippocampus as a function of stimulus valence (positive or negative) and Group (Control or Depressed). Lastly, we find that participants with depression, but not controls, activate a neural circuit involved in episodic retrieval and prospective memory during blank time intervals during our study, which may be the neural signature of spontaneous depressive rumination.

I36

THE RELATIONSHIP BETWEEN PERFORMANCE VARIABILITY AND DEGREE OF SELF-REPORTED COGNITIVE DIFFICULTIES IN TRAUMATIC BRAIN INJURY PATIENTS *Paula M. McLaughlin[1], Susan J. E. Murtha[1], Donald T. Stuss[2,3], Kelly J. Murphy[4]; [1]York University, Psychology, [2]Rotman Research Institute, Baycrest Centre, [3]University of Toronto, Psychology and Medicine (Neurology, Rehabilitation Sciences), [4]Baycrest Centre, Psychology* – Traumatic brain injury (TBI) is associated with increased variability on cognitive testing and behavioral changes. We investigated whether self-reported cognitive difficulties were related to variability in TBI patients using the verbal fluency (word-generation) paradigm. Verbal fluency is considered a test of executive cognition because it requires initiation, self-monitoring, cognitive flexibility, strategic search and sustained effort. We examined dispersion (individual variability within a task) and consistency in performance (individual variability between two test sessions) on verbal fluency to letter (phonemic) and category (semantic) cues in 16 TBI patients and 16 matched controls. Participants also completed the cognitive failures questionnaire (CFQ), a measure of everyday slips in attention, and the dysexecutive questionnaire (DEX), a measure of behavioral difficulties related to executive functioning (e.g., impulsivity, distractibility and poor decision making). Performance variability was compared between groups and correlated with CFQ and DEX scores. Relative to control participants, TBI patients exhibited greater dispersion, but comparable consistency in verbal fluency performance. The TBI participants also reported more cognitive slips on the CFQ, though overall scores on the DEX were comparable to controls. Correlation analyses revealed TBI patients who showed greater dispersion on phonemic fluency trials also report more cognitive difficulties on the CFQ and DEX. There were no significant correlations involving the control group. Phonemic fluency typically requires more frequent switching between subcategories of words as compared to semantic fluency. The correlation findings indicate variability in cognitive flexibility on objective testing may be related to increased functional difficulties in everyday tasks requiring executive cognitive control.

I37

EFFECTIVE CONNECTIVITY EVIDENCE FOR A RELATIONSHIP BETWEEN SPATIAL RESPONSE SELECTION AND SPATIAL SEQUENCE LEARNING *Temilade Adelore[1], Hilary Schwarb[1], Eric H. Schumacher[1]; [1]Gerogia Institute of Technology* – Behavioral and neuroimaging research has demonstrated that spatial response selection plays an important role in spatial sequence learning (Schwarb & Schumacher, in press). Univariate analyses of orthogonal manipulations of both response-selection difficulty and sequence structure revealed significant activity in bilateral dorsal premotor cortex (dPMC), bilateral superior parietal cortex (SPC), supplementary motor area (SMA) and the right dorsal prefrontal cortex (dPFC). Univariate analyses of these data reveal that both spatial sequence learning and spatial response selection are mediated by dPMC, SPC and SMA; while response selection alone is mediated by right dPFC. Multivariate analyses of these data, however, may provide further understanding of the interaction between these two

cognitive processes. Here we use dynamic causal modeling (DCM) to analyze the effective connectivity in the regions identified above. DCM and Bayes factors provide a means to test and compare hypothesized models that outline the various regions and their interactions with each other and the experimental conditions. These models are developed using both anatomical and functional evidence of connections between regions-of-interest. Model fit comparisons allow us to determine which model best explains the functional data, and provide insight into the nature of processing in the frontal-parietal network controlling goal-directed behavior.

I38

TESTING HIERARCHICAL INTERACTIONS IN FRONTAL CORTEX DURING COGNITIVE CONTROL *Nicole M. Long[1], David Badre[1]; [1]Brown University* – The frontal lobes broadly support cognitive control, which refers to our ability to control our behavior based on internal representations of goals, plans, and context. Understanding the functional organization of the frontal cortex remains a fundamental goal for cognitive neuroscience. We used functional magnetic resonance imaging to test the hypothesis that regions along the rostro-caudal axis of frontal cortex are arranged hierarchically with respect to one another, such that more posterior regions are subordinate to anterior regions during selection of a response. Within a hierarchically organized system, superordinate processors will influence subordinate processors but not vice versa. In our experiment, subjects made a decision about task to perform (task selection), and then a decision about which response to make given the task being performed (response selection). We manipulated demands on task selection by varying the number of alternative tasks (one or two). We manipulated demands on response selection by arranging for more frequent encounters with certain response cues during a pre-test training phase. Those stimuli encountered more often during training are better learned and so should elicit faster responses relative to less frequently encountered items. Crossing selection level (response/task) with frequency (more/less) permitted a probe of whether changes in the ease of selection at a lower level (response) affects the ease of selection at the higher level (task). Initial results appear broadly consistent with asymmetric hierarchical interactions between adjacent regions of frontal cortex.

I39

SHARED CONTROL MECHANISMS OF CONFLICT ADAPTATION AND SWITCHING IN THE INTRA-PARIETAL SULCUS *Derek Nee[1,2], Joshua Brown[1]; [1]Indiana University, [2]University of Michigan* – Previous research has demonstrated that when faced with conflicting demands, control processes up-regulate relevant information in order to facilitate performance. In other situations, control processes are involved in switching between different tasks. Hence, on the one hand, cognitive control involves reinforcing the present task, whereas on the other hand, cognitive control involves switching between tasks. It is unclear whether distinct neural substrates are involved in both reinforcing and flexible control, or whether a single collection of neural regions is involved in both. We investigated this issue using a Stroop-like task where subjects were required to switch between stimulus dimensions. Replicating previous results, when stimulus dimensions conflicted (incongruent trials), subjects demonstrated improved performance on subsequent incongruent trials (conflict adaptation). This performance enhancement was accompanied by increased activation in lateral prefrontal cortex (LPFC) and the intra-parietal sulcus (IPS), as well as increased activation in posterior regions representing the currently relevant stimulus dimension (e.g. fusiform face area (FFA)). Switching between stimulus dimensions also recruited the IPS, and activation in posterior representational cortices reflected the locus of the subjects' attention. Using multi-voxel pattern analysis (MVPA), we demonstrated that the IPS distinguished the relevant task dimensions even when no univariate signal differences were present. These results suggest that the IPS acts as the focus of attention, highlighting relevant information in the face of conflict, and switching among different sources of information when flexible control is required.

I40

AGE-ASSOCIATED DIFFERENCES BETWEEN HIGH AND LOW PERFORMERS IN EFFICIENCY OF WORKING MEMORY PROCESSING *Kirk R Daffner[1], Jenna L Riis[2], Hyemi Chong[3], Scott M McGinnis[1], Phillip J Holcomb[4], Xue Sun[1], Elise Tarbi[1]; [1]Neurology, Brigham and Women's Hospital, Harvard Medical School, [2]Johns Hopkins Bloomberg School of Public Health, [3]University of Texas Southwestern Medical School, [4]Tufts University, Psychology* – We investigated age-related differences in efficiency of neural processing between high and low performers on a working memory (WM) task. Event-related potentials were recorded in 23 young (mean age 23) and 18 old (mean age 73) subjects, matched for education and IQ, on a visual n-back WM paradigm with 3 levels of difficulty (0-back, 1-back, 2-back). Each age group was divided into high and low performers based on 2-back task accuracy. P3 amplitude served as an index of processing resources allocated to updating WM. Although high and low performers in both age groups did not differ in accuracy on the 0-back and 1-back tasks, high performers generated a much smaller P3 to n-back targets, suggesting that they manage relatively easy working memory demands more efficiently than age-matched low performers. As the WM demands increased under the 2-back condition, high, but not low performers, appropriated additional resources, as measured by P3 amplitude. This resulted in high performers having greater accuracy than low performers. Despite an augmentation in P3 amplitude, across young subjects, high performers still generated a smaller P3 to 2-back targets than low performers. In contrast, across old subjects, high performers now generated a larger P3 to 2-back targets than low performers. These results suggest that among old subjects, high performers meet the requirements of the 2-back condition by allocating more resources than low performers, a pattern that we anticipate finding in young subjects under WM conditions that are even more demanding.

I41

INVESTIGATING CONTROL MECHANISMS WITHIN AND BETWEEN MODALITY WITH A TEMPORAL FLANKER TASK *Erin Lightman[1], Hillary Schwarb[1], Eliot Hazeltine[2], Nehal Patel[1], Eric Schumacher[1]; [1]Georgia Institute of Technology, [2]University of Iowa* – The architecture of executive control is uncertain. Some theorists suggest that it is mediated by an amodal central executive mechanism (e.g., Baddeley, 1986; 1996), whereas others propose a set of independent control mechanisms (e.g., Miller & Cohen, 2001). In a series of behavioral and fMRI experiments, we investigated whether control mechanisms are unitary or independent by examining conflict adaptation within and between stimulus modalities. We used a modified flanker task, in which the target and flanker stimuli differed in time rather than space, making it accessible for both visual and auditory stimuli. As in a traditional flanker task, larger congruency effects were observed after compatible trials than after incompatible trials. However, this sequential effect only occurred when modality remained constant between the consecutive trials. Participants showed no adaptive control when the stimulus modality switched, even when the stimulus modalities used identical stimulus-response (SR) mappings. These data suggest that sequential effects are restricted to an input modality; that a set of independent mechanisms mediate executive control; and that modalities rather than SR mappings constrain conflict resolution. The neural implications of separate modality-specific executive control mechanisms were investigated using fMRI.

I42

RISK-TAKING IN A GAMBLING TASK INCREASES OSCILLATORY THETA-BAND ACTIVITY IN RIGHT MEDIAL FRONTAL CORTEX *Greg Christie[1], Andrew Butcher[1], Matthew Tata[1]; [1]University of Lethbridge* – When participants in a gambling game receive feedback as to whether they won or lost, a stereotypical series of neural responses can be observed in the electroencephalogram (EEG) and the stimulus-locked Event-Related Potential (ERP). These include the Feed-

back-Related Mediofrontal Negativity (FRN), the feedback-related P300, and increases in induced theta-band (4 - 7 Hz) power over frontal scalp. This study used a modified version of the Iowa Gambling Task to investigate how risk modifies these responses. We found the FRN was not modulated by the riskiness of a bet, but both the P300 and induced theta-band activity were of greater amplitude following high-risk/high-reward bets relative to low-risk/low-reward bets. Using a bilateral Beamformer approach, we localized this induced theta-band activity to partially overlapping sources in right medial frontal cortex, possibly including Anterior Cingulate.

I43

EXECUTIVE FUNCTION AND PAIN RELY ON SHARED ATTENTIONAL RESOURCES *Jason Buhle[1], Tor D. Wager[1]; [1]Columbia University* – It is widely assumed that distraction reduces pain. Similarly, it is assumed that pain distracts from concurrent, unrelated mental processing, reducing performance on difficult tasks. Taken together, these assumptions suggest a shared resources model for pain processing and cognitive executive functions. However, experimental tests of this model have yielded mixed results, leading to the recent proposal of alternative models in which pain and cognitive processes are relatively independent. We tested these contrasting positions using a novel concurrent pain and executive working memory paradigm. Both task difficulty and three levels of pain were individually calibrated for each participant. Participants reported less pain during working memory performance than during a visually matched control condition. Conversely, increasing levels of heat incrementally reduced task performance. We next used mediation analysis to test whether trial-by-trial fluctuations in pain predicted performance decrements within a given temperature. The effects of increasing levels of heat on task performance were completely mediated by subjective pain reports. In addition, causal effects analysis supported the existence of independent causal effects of both pain on performance and performance on pain. Taken together, these findings argue for shared resources between pain processing and executive working memory. Future studies could use this paradigm to understand more precisely which components of executive function are integral to pain processing.

I44

THE NEURAL BASES OF MESSAGE PROPAGATION *Emily Falk[1], Sylvia Morelli[1], Locke Welborn[1], Karl Dambacher[1], Matthew Lieberman[1]; [1]UCLA* – Information exchange between individuals is at the heart of social interaction, and can result in the spread of important attitudes and behaviors (e.g. health behaviors, product trends, political attitudes). Research suggests that individuals are more likely to pass information to similar than to dissimilar others, however, the mechanisms that support the decision about which information to pass on have not been investigated. Recent studies have, however, explored the neural bases of understanding the mind of others; considering the contents of another individual's thoughts and intentions from a general "theory of mind" and considering their psychological characteristics is associated with activity in dorsomedial prefrontal cortex (DMPFC), while self-reflective processing and mentalizing about similar others is associated with activity in medial prefrontal cortex (MPFC). Here we present the results of two studies in which we explore the decision to pass information to a close other (study1) and a more distant other (study2). Results indicate that passing information on (relative to not passing information on) to both close others and more distant others is associated with increased activity in MPFC. Passing information on to distant others (relative to not passing information on) is further associated with activity in DMPFC. Thus, we find a common neural mechanism relating decisions to pass information on to both close and distant others, as well as a component that may be more specific to the effortful process of mentalizing about less familiar others in the context of deciding which information is worthy of social exchange.

I45

STRATEGIC MODULATION OF DECISION-MAKING UNDER RISK *Tal Yarkoni[1], Todd Braver[1]; [1]Washington University in St. Louis* – When making decisions involving risk, people often deviate markedly from the predictions of normative choice models, and show a systematic tendency to minimize risk rather than maximizing expected value (EV). This bias is widely attributed to a tendency to assign greater emotional weight to negative prospects relative to positive prospects. However, it remains unclear to what extent such emotional responses are controllable and subject to strategic modulation. In the present study, participants were scanned with fMRI while engaging in a standard gambling paradigm involving repeated choice between two probabilistic rewards (e.g., 70% of 400 vs. 30% of 1000). We experimentally manipulated the manner in which rewards were computed as well as the nature of the feedback participants received. Results provided strong evidence that strategy choice is a critical determinant of decision-making under risk. Behaviorally, participants consistently maximized EV under some reward schedules while exhibiting robust risk aversion under others. Moreover, these differences persisted even when participants received no feedback about the outcome of their choices and stimuli were perceptually identical in all conditions. FMRI analyses identified qualitatively different patterns of activation associated with different decision-making strategies. Specifically, EV maximization strategies were associated with increased activation in frontoparietal regions implicated in numerical computation and visuospatial manipulation, whereas probability-maximizing heuristics were associated with increased activation in dorsal ACC and anterior insula when participants made risky choices. Collectively, these results suggest that risk aversion is a strategy-dependent phenomenon that can often be eliminated with little difficulty given appropriate environmental cues.

I46

NEURAL CORRELATES OF LOCAL AND GLOBAL EXPECTATIONS: A TEST OF THE JANUS MODEL *Joseph Dien[1], Aminda OHare'[2]; [1]University of Louisville, [2]University of Kansas* – A core feature of the Janus model of hemispheric lateralization (Dien, 2008) is the hypothesis that the left hemisphere focuses on making specific predictions about future events (local expectations) whereas the right hemisphere focuses on using base rates from past events to detect and respond to unexpected events (global expectations). In a key test of the Janus model, neural correlates of local and global expectations were examined. It has been noted in past event-related potential (ERP) studies that the P300 component following violations of sequences appears more frontally than the classic P300 seen in oddball paradigms (Jentzsch & Sommer, 2001; Kotchoubey, et al., 1997; Squires, et al., 1976). It was hypothesized that this distinction reflects the elicitation of local versus global expectancies. Participants (n=21) completed a visual oddball task and a visual sequence task, with colored circles as stimuli, while ERPs were recorded from a high-density, 128 channel system. In the sequence task red and green circles appeared equally. As hypothesized, one ERP component was more sensitive to local expectations and another was more sensitive to global expectations. Crucially, the local expectancy component was clearly left-lateralized and the global expectancy component was clearly right-lateralized, yielding positive support for the Janus Model.

I47

RELATIONSHIP BETWEEN INDIVIDUAL DIFFERENCES IN RISK-TAKING AND CORTICAL ACTIVATION DURING A DECEPTION TASK: AN FMRI STUDY *Michelle C. Phillips[1], Scott W. Meek[1], Laura Bradshaw-Baucom[1], Jennifer M. C. Vendemia[1]; [1]University of South Carolina* – The goal was to examine the relationship of individual differences in decision-making and risk-taking to brain activation during a task where one switched between truthful and deceptive responding. Undergraduates (M =20.7 years) completed a sentence verification task with two stimuli and were randomly assigned to one of two deception per-

centage conditions: 50% (n=19) or 80% (n=21). BOLD responses were measured in an event-related design during truthful and deceptive responses. Decision-making and risk-taking were assessed with the Cambridge Gambling Task. Results revealed greater activation in regions of the left inferior and middle prefrontal cortex (BA 47,10) during deceptive responses (p<.001) in the 50% condition. In the 50% condition, deceptive responses were associated with greater activation in regions of the left inferior and superior parietal cortex (BA 40,7) (p=.0356), while in the 80% condition, truthful responses were associated with greater activation in right temporal and parietal lobes (BA 37,39,7) (p=.000613). Activation in regions of the prefrontal cortex (BA 10) was also greater during truthful responses (p=.038) in the 80% condition. Frontal activation in the 50% condition points to the role of workload while activation to infrequent truthful stimuli in the 80% condition points to the role of salience. The measure of decision-making (M=.941, SE=.009) was associated with individual differences in limbic system activation during deceptive responding (p=.0213). The measure of risk-taking (M=.573, SE=.012) was associated with differences in limbic system activation during truthful responding (p=.0419). These results point to a role for individual differences in response uncertainty during the task.

I48

DISRUPTED FUNCTIONAL CONNECTIVITY DURING WORKING MEMORY PERFORMANCE IN INDIVIDUALS WITH PREFRONTAL DYSFUNCTION RELATED TO PHENYLKETONURIA *Shawn Christ[1], Amanda Moffitt[1], Dawn Peck[1]; [1]University of Missouri* – Phenylketonuria (PKU) is rare genetic disorder characterized by an inability to metabolize phenylalanine, a common amino acid and precursor of tyrosine and dopamine. Prior research indicates that the prefrontal cortex (PFC) is particularly susceptible to dysregulation of dopamine. Also, past studies have documented white abnormalities in individuals with PKU. In the present study, we utilized functional magnetic resonance imaging (fMRI) to evaluate potential PKU-related differences in functional connectivity between PFC and more distal brain regions during performance of a working memory task which relies heavily on PFC. Six individuals with early-treated PKU (mean age = 18.3 years) and six neurologically intact individuals (mean age = 18.4 years) were imaged while performing a 2-back working memory task. To evaluate functional connectivity, the correlation in activity between brain regions during task performance was calculated. Analysis of z-transformed data revealed significantly decreased connectivity ($p < .05$ corrected) among PFC regions (e.g., anterior cingulate, inferior frontal gyrus) as well as between PFC and other brain regions (e.g., inferior parietal lobule) in individuals with PKU as compared to their control counterparts. Taken together with prior behavioral findings, the present results provide converging evidence of prefrontal dysfunction in individuals with early-treated PKU. Results are discussed within the context of our current understanding of PKU, PFC, and working memory.

I49

REWARD-DEPENDENT MODULATION OF WORKING MEMORY IN LATERAL PREFRONTAL CORTEX *Jon Wallis[1,2], Steven Kennerley[1,2]; [1]University of California at Berkeley, Psychology, [2]Helen Wills Neuroscience Institute, University of California at Berkeley* – Despite much research implicating lateral prefrontal cortex (PFC) in the process of spatial working memory, it is still unclear how this representation contributes to executive control and goal-directed behavior. One possibility is that PFC integrates reward information with spatial working memory to construct a reward map that can guide behavior towards rewarding stimuli in our environment. Past studies investigating this focused on dorsolateral PFC, but this area only weakly connects with areas processing reward. Ventrolateral PFC has better connections in this regard. Thus, we contrasted the functional properties of single neurons in ventrolateral and dorsolateral PFC as two subjects performed a task that required them to hold spatial information in working memory under different expectancies of reward for correct performance. We balanced the order of presentation of spatial and reward information so we could assess the neuronal encoding of the two pieces of information independently and conjointly. Neurons in ventrolateral PFC encoded both spatial and reward information earlier, stronger and in a more sustained manner than neurons in dorsolateral PFC. In addition, when reward increased spatial selectivity, behavioral performance improved, whereas when reward decreased spatial selectivity, behavioral performance worsened. This pattern of integration is consistent with a role for ventrolateral PFC in attentional control. Our results provide further neurophysiological evidence that the cortex above and below the principal sulcus of the macaque is functionally distinct, and are consistent with the notion that ventrolateral PFC serves as a sensory gateway into PFC, ensuring the maintenance of task relevant information across delays.

I50

NEURONS IN THE FRONTAL LOBE ENCODE THE VALUE OF MULTIPLE DECISION VARIABLES *Steven Kennerley[1], Antonio Lara[1], Jonathan Wallis[1,2]; [1]Helen Wills Neuroscience Institute-UC Berkeley, [2]UC Berkeley, Psychology* – Damage to the frontal lobe, particularly to anterior cingulate cortex (ACC), lateral prefrontal cortex (LPFC) and orbital frontal cortex (OFC), impairs decision-making in a variety of contexts. A possible explanation for these impairments is that neurons here represent decision value across multiple decision variables. To explore how these areas contribute to decision-making, we trained two rhesus macaques (Macaca mulatta) to make choices between pictures associated with different values varied along three physically different valuation scales. Each picture was associated with a specific probability of obtaining a fixed amount of juice (probability trials), a specific amount of juice (payoff trials) or a specific number of lever presses required to obtain a fixed amount of juice (cost trials). We simultaneously recorded the activity of 610 neurons (257 from LPFC, 213 from ACC and 140 from OFC) while subjects made choices based on these three decision variables. The most prevalent selectivity was in ACC, where 84% of the neurons encoded value for at least one decision variable, followed by OFC (56%) and LPFC (49%). Neurons that encoded multiple decision variables were more common in ACC (57%) and OFC (30%) than in LPFC (19%). Time-course analyses revealed that decision value was encoded ~200ms before the upcoming motor response. Our results indicate that many frontal neurons encode an abstract value signal in the sense that choice value is encoded irrespective of the physical manner in which value is manipulated. The encoding of value across multiple decision variables by ACC emphasizes its role in efficient decision-making.

Motor control

I51

ANTERIOR CINGULATE CORTEX ENCODES ACTION-OUTCOME ASSOCIATIONS IN WORKING MEMORY *Chung-Hay Luk[1], Jonathan Wallis[1]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley* – In a dynamic environment an action that satisfies a particular goal can often change. Hence, to select the most appropriate action, it becomes necessary to actively update remembered contingencies between actions and outcomes (AO associations). Two regions implicated in action selection are lateral prefrontal cortex (LPFC) and anterior cingulate cortex (ACC). While both regions connect to motor areas, only ACC receives strong inputs from areas processing reward, placing it in a better anatomical position to control outcome-guided action. To examine this, we trained a monkey to perform a task that required him to monitor AO contingencies on a trial-by-trial basis. The monkey performed two sequential movements, separated by a delay, each of which was rewarded with a specific juice (apple, orange or quinine) and then had to repeat the movement that was previously paired with his preferred juice. Thus, during the first delay, the monkey had to remember both the movement he made as well as the juice he received. We recorded the activity of

77 LPFC neurons and 84 ACC neurons during the performance of the task. In ACC, 24% of the neurons encoded which movement the monkey had made and 33% of the neurons encoded what juice the monkey had received. In contrast, in LPFC 40% of the neurons encoded the movement and 13% encoded the juice. These findings support the hypothesis that ACC rather than LPFC is important for the control of outcome-guided action.

I52

TRANSFER OF MOTOR MOVEMENTS *Sien Hu[1], Charles Wright[1]; [1]University of California, Irvine* – Transfer of motor learning was investigated in a series of experiments using 4 different motor tasks that make different demands on the motor system and motor-learning mechanisms: Experiment 1 studied transfer of explicitly-learned, short, spatially defined, discrete movement sequences; Experiment 2 studied transfer of explicitly-learned, long, spatially defined, discrete movement sequences; Experiment 3 studied transfer of implicitly-learned regularities of long, spatially defined, discrete movement sequences; Experiment 4 studied transfer of explicitly-learned, long movement trajectories, defined in both space and time. Results suggest that, first of all, participants were able to transfer the learned, effector-independent knowledge in all experiments. Second, the degree of transfer was altered by differences in tasks but not by differences in the learning mechanism, i.e. implicit vs. explicit learning. Tasks that emphasized spatial knowledge had better transfer to the left side of the body contralateral to the spatial representation in the right hemisphere; the task that emphasized statistical regularities, generated from a finite-state grammar network, had better transfer to the right side of the body contralateral to the grammatical processing in the left hemisphere. Finally, acquisition of effector-specific knowledge also depended on tasks. In the task using simple sequences, participants optimized motoric coordination with the learned effector which created interference when they transferred to a different effector on the same side of the body. This motoric coordination also dominated cognitive strategies that could only be transferred to homologous body parts. In the tasks using long sequences or trajectories, the dominance of the motoric coordination was reduced.

I53

EVIDENCE FOR A LATERALIZED CONTINGENT NEGATIVE VARIATION DURING MANUAL BUT NOT MENTAL MOTOR PRACTICE *Sean Guillory[1], C. Chad Woodruff[2], Erica Wohldmann[3]; [1]Texas State University-San Marcos, [2]Northern Arizona University, [3]California State University-Northridge* – In the current study, we used event-related potentials (ERP) in an attempt to determine whether manual and mental practice can be dissociated electrophysiologically, as would be predicted from the work of Wohldmann, Healy, and Bourne (2007, 2008). More specifically, the results of Wohldmann et al. (2008) suggested that mental practice leads to the development and strengthening of an effector-independent mental representation, whereas physical practice leads to the development and strengthening of an effector-dependent representation. The present experiment examined an ERP component known as the Contingent Negative Variation (CNV) while subjects performed the data entry task used by Wohldmann et al. (2007, 2008). The CNV is taken to reflect cognitive and motor expectations of an upcoming stimulus (e.g. Brunia & van Boxtel, 2001). We hypothesized that the CNV would show significant laterality effects during an expectancy period for manual practice reflecting effector-dependence while no such laterality would be evident for mental practice, reflecting effector-independence. Consistent with our hypothesis, we found that CNV amplitudes showed hemispheric asymmetry under conditions of manual but not mental practice. Specifically, CNV amplitude was greater over the left hemisphere (electrode C3) than the right hemisphere (electrode C4) for manual practice, yet no hemispheric differences in CNV amplitude obtained for the mental practice condition. These results provide support for the claim made by Wohldmann et al. (2008) that motor representations established by mental practice do not include effector-dependent information.

I54

THE ROLE OF THE SUPERIOR TEMPORAL SULCUS AND THE MIRROR NEURON SYSTEM IN IMITATION *Pascal Molenberghs[1], Christopher Brander[1], Jason Mattingley[1], Ross Cunnington[1]; [1]The University of Queensland, Queensland Brain Institute & School of Psychology* – It has been suggested that the mirror neuron system is on the basis of imitation but the relative contributions of different brain regions involved in imitating actions is still a matter of debate. To investigate the role of the mirror neuron system in imitation we used fMRI to examine patterns of neural activity under four different conditions: passive observation of a pantomimed action (e.g., hammering a nail); (2) imitatation of an observed action; (3) execution of an action in response to a word cue; and (4) self-selected execution of an action. A network of cortical areas, including the left supramarginal gyrus, left superior parietal lobule, left dorsal premotor area and bilateral superior temporal sulcus (STS), was significantly active across all four conditions. Crucially, within this network the STS bilaterally was the only region in which activity was significantly greater for action imitation than for the passive observation and execution conditions. Our results suggest that the STS does not only respond passively to biological motion but actively maps visual representation with motor responses during imitation.

I55

DOES THE MIRROR SYSTEM INFLUENCE THE PERCEPTION OF OBJECT PROPERTIES? *Maurizio Gentilucci[1], Giovanna Cristina Campione[1], Riccardo Dalla Volta[1], Claudio Secchi[1], Ivilin Stoianov[1]; [1]Dipartimento di Neuroscienze University of Parma, Parma, Italy* – Can the implicit imitation, due to activity of the mirror system, influence the estimation of object intrinsic properties? Participants observed different types of grasp presented by video-clips showing an arm reaching-grasping either a small or a large sphere, using both a power and precision grasp. After the presentation, participants reproduced the sphere size, but the type of reproduction varied in the five experiments. In experiment 1 they opened their index finger and thumb, in experiment 2 they enlarged their index and middle fingers, similarly to a cutting pantomime, and in experiment 3 they opened their mouth; that is. the participants used the same effector and executed a movement similar to the grasp in experiment 1, used the same effector and executed a movement different from the grasp in experiment 2, and used a different effector and executed a movement similar to the grasp in experiment 3. In experiments 1 and 3 the kinematics of the reproduction was mainly influenced by the type-of-grasp observation; specifically object size was overestimated and underestimated after observation of power grasp and precision grasp, respectively, according to the fact that the power and precision grasps are used to interact with large and small objects, respectively. In experiments 4 and 5, in which the type of reproduction did not require any fingers' use nor had any relation with the grasp, the type of grasp did not affect the reproduction. The results of the present study suggest that the mirror system influences the perception of target properties.

I56

ACTION PREPARATION HELPS AND HINDERS PERCEPTION OF ACTION *Clare Press[1,2], Cecilia Heyes[2,3], Martin Eimer[1]; [1]Birkbeck College, University of London, [2]University College London, [3]University of Oxford* – Several theories of the mechanisms linking action and perception require that the links are bidirectional, but there is a lack of consensus on the effects that action has on perception. We investigated this by measuring visual event-related brain potentials to observed hand actions while participants prepared responses that were spatially compatible (e.g. both were on the left side of the body) or incompatible, and action type compatible (e.g. both were finger taps) or incompatible, with observed actions. An early enhanced processing of spatially compatible stimuli was observed, which is likely due to spatial attention. This was followed by an attenuation of processing for both spatially and action type compatible stimuli, likely to be driven by efference copy signals that attenuate

processing of predicted sensory consequences of actions. Attenuation was not response-modality specific; it was found when participants prepared manual and vocal responses, in line with the hypothesis that action control is hierarchically organised. These results indicate that spatial attention and forward model mechanisms have opposite, but temporally distinct, effects on perception. This hypothesis can explain the inconsistency of recent findings on action-perception links, and thereby supports the view that sensorimotor links are bidirectional. Such effects of action on perception are likely to be crucial, not only for the control of our own actions, but also in sociocultural interaction; allowing us to predict the reactions of others to our own actions.

I57

MOTOR CORTEX ACTIVATION PRIOR TO ACTION OBSERVATION DEPENDS ON THE TASK-INDUCED SOCIAL RELATIONSHIP BETWEEN ACTOR AND OBSERVER *Dimitrios Kourtis[1], Natalie Sebanz[1], Günther Knoblich[1]; [1]Donders Institute for Brain, Cognition and Behavior, Centre for Cognition, Radboud University, Nijmegen, The Netherlands* – Neurophysiological studies suggest that in joint action tasks, one represents the action of one's partner, even prior to a prompted response. Interestingly, motor areas are activated during action observation and action anticipation in a qualitatively similar way as during motor execution. Our aim was to determine whether there are differences in motor activation when people anticipate observing an action performed by an interaction partner compared to an action performed by a person whom they never interact with. Electroencephalograms were recorded simultaneously from two persons sitting in front of a table facing each other ("partners"), while a third person ("outsider") was sitting at right angles with them. A small object was placed in the middle of the table, on top of which visual stimuli were projected, consisting of a cue, instructing the participant(s) to prepare an action, followed 1sec later by a go/no-go signal (go: 83.3% probability). "Partners" had either to swiftly lift the object and place it back or alternatively to pass it to their "partner". The "outsider" was only performing the lifting action individually. Pre-movement motor cortex activation, reflected in the Contingent Negative Variation (CNV) and the beta Event Related Desynchronization (ERD) amplitudes, was similar when participants prepared to act or anticipated to observe their "partner"'s action. Importantly, both CNV and beta ERD amplitudes were significantly smaller when anticipating the "outsider's action. This suggests that pre-movement motor cortex activation depends on the "social" relationship between two persons established through the frequency of interaction and/or the actors' spatial arrangement.

I58

INTERHEMISPHERIC INTERACTION IN SIMPLE RESPONSE TIME: A COMBINED FUNCTIONAL- AND DIFFUSION-TENSOR IMAGING STUDY *Matthew Roser[1], Jon Fulford[2], Abdelmalek Benattayallah[2]; [1]School of Psychology, University of Plymouth, [2]MR Research Centre, Peninsula Medical School, Exeter* – Behavioral studies suggest that the speeding of reaction times to bilateral-redundant targets relative to unilateral targets (the redundant-targets effect or RTE) involves the hemispheric interaction of response preparation processes. Studies of patients who have undergone partial callosotomy suggest that the posterior corpus callosum, connecting occipital cortices, mediates the size of the redundancy gain. To examine which callosal channels support the RTE, diffusion-tensor weighted (DTI) images, and functional images, were acquired for a group of 34 neurologically-normal subjects who performed a simple-response task. DTI data were analyzed using Tract-based Spatial Statistics (TBSS). Results showed that individual differences in redundancy gain were associated with variation in fractional anisotropy in distinct callosal regions and with the degree of functional activation in regions processing visual information and motor responses. These results suggest that structural connectivity in the brain mediates individual differences in rapid responding to visual stimulation.

I59

CORTICAL EXCITABILITY BETWEEN DOMINANT AND NON-DOMINANT HEMISPHERES IN HEALTHY ADULTS *Matthew Malcolm[1], Wen-Pin Chang[2]; [1]Colorado State University, [2]University of Indianapolis* – Neurological studies demonstrate a hemispheric asymmetry in the primary motor cortex (MI). The dominant MI acquires larger and more richly connected neural representations for movement than the non-dominant MI. One factor that could impact the neuron recruitment for movement is cortical excitability. However, a paucity of studies investigates whether hemispheric asymmetry will result in different cortical excitability between two hemispheres. The purpose, therefore, of this study was to determine any difference in the cortical excitability, indexed by recruitment curve (RC), between the two hemispheres in healthy adults with right-hand dominance using transcranial magnetic stimulation (TMS). Ten right-handed healthy volunteers (age= 23.5±3.1) without any neurological and psychiatric disorders participated in this study. We provided magnetic stimulation over both left and right MIs and recorded the electromyographic (EMG) activity over the first dorsal interosseous (FDI) and extensor digitorum communis (EDC) muscles in both left and right upper limbs. The results revealed that there was no difference in motor evoked potential (MEP) between left and right FDI. Similarly, there was no difference in the MEP between left and right EDC. The RC slope, obtained from the MEP, revealed no difference between left and right FDI as well as no difference between left and right EDC. Our results did not support the hypothesis that the dominant MI may have stronger cortical excitability than non-dominant MI. Our results indicate that the baseline cortical excitability between two MIs could be similar.

I60

AN INVESTIGATION OF BRAIN MECHANISMS UNDERLYING PARALLEL PROGRAMMING OF SACCADE SEQUENCES *Yanbo Hu[1], Robin Walker[1], Andrew T. Smith[1]; [1]Royal Holloway, University of London* – This event-related fMRI study investigated the brain mechanisms underlying parallel programming of saccade sequences. Participants made either a single saccade or a sequence of two saccades. There were four conditions: (i) a single voluntary saccade (a symbolic cue elicited the saccade) (SV), (ii) a single stimulus-elicited (reflexive) saccade (SR), (iii) a two-step (parallel programming) saccade condition in which advance knowledge of the second saccade target location was provided prior to stimulus onset (PP), and (iv) a two-step saccade condition without advance knowledge of the second target location (SP - serial programming condition). Behavioural measures were obtained outside the scanner and showed a significant latency reduction of the second saccade in the parallel programming condition compared to the serial programming condition. Fifteen subjects were then tested on the paradigm in an event-related functional imaging study using a 3-Tesla scanner. A region of interest analysis was carried out using MarsBaR-0.14 and SPM. Activity was observed during the response preparation period bilaterally in the frontal eye fields (FEFs) and parietal eye fields (PEFs). This was greater in the two-step parallel programming condition, relative to the two-step serial programming condition. Activity was seen in the supplementary eye field (SEF) (left only) when contrasting the two-step conditions with the single-step condition, but not when contrasting the parallel and serial two-step conditions. The findings support a role of the FEF and PEF, but not the SEF, in the parallel programming of saccade sequences.

I61

DIRECTIONAL TUNING IN HUMAN MOTOR CORTEX *Chris Cowper-Smith[1], Esther Lau[2], Eskes Gail[1,3], McMullen Patricia[1], Carl Helmick[3], Schmidt Matthias[3,4,5], Kirby Lee[6], David Westwood[1,2,3], Chris Cowper-Smith, Chris Cowper-Smith; [1]Dalhousie University, Psychology and Neuroscience,[2]University of Hong Kong , Psychology, [3]Dalhousie University, Psychiatry, [4]Dalhousie University, Radiology, [5]IWK Health Centre, Diagnostic Imaging, [6]Dalhousie University, Physical Medicine and Rehabilitation* – Here we explore Georgopoulos' (1986) model of movement direction coding in human motor cortex using an fMRI adaptation design. Based on evidence

from monkey neurophysiology showing that motor neurons in the primary motor cortex (M1) exhibit preferred direction tuning curves where neural activity is strongest in the preferred direction and weakest for movements 180 degrees opposite, we examined the blood oxygen-level dependent (BOLD) response as a function of the directional similarity of repeated arm movements. In separate 18-second blocks, participants responded to arrows presented at fixation by making repeated joystick movements that called for movements that were offset by 0, ±90, or 180 degrees. Drawing on the logic of fMRI adaptation, if there are distinct regions in motor cortex with directional tuning preferences, then over the time course of each block, we should find a reduction of BOLD signal that is proportional to the degree of offset between successive reaching movements. That is, we predicted the greatest reduction of BOLD signal when repeated movements were made in the same direction relative to blocks of movements that were offset by ±90 or 180 degrees. Our results demonstrate adaptation of the motor system in M1, pre-motor cortex (PMC), and cerebellum during the 0° condition relative to the ±90° and 180° conditions. Interestingly, the results do not show adaptation of the ±90° relative to the 180° condition. The similarity of activation in the ±90° and 180° conditions is consistent with narrow (i.e. less than 90°) directional tuning curves in motor cortex.

I62

FACTORS MEDIATING MOTOR CORTICAL REPRESENTATIONS *Jessica Bernard[1], Rachael Seidler[1,2,3,4]; [1]University of Michigan, Psychology, [2]University of Michigan, Division of Kinesiology, [3]University of Michigan, Neuroscience Program, [4]University of Michigan, Institute of Gerontology* – The somatotopic organization of the primary motor cortex (M1) is subject to changes due to a variety of factors including practice, experience, age, and disease. Another variable that has been suggested to mediate motor cortical representations is an individual's handedness (Volkmann et al., 1998). This study sought to clarify relationships between handedness, interhemispheric communication, and the organization of M1 representations. We used a TMS motor mapping procedure (Sparing et al., 2008) to investigate motor cortical representations. Additionally, subjects completed several different handedness evaluations and the Poffenberger Paradigm (Poffenberger, 1912) to assess interhemispheric communication. Results indicate that less strongly handed individuals have faster interhemispheric transfer times (IHTT; $p<.05$) and more symmetrical motor cortical representations ($p<.05$). We also found that those with faster IHTT show more ipsilateral motor activity ($p=.06$). These data indicate that experiential factors result in differences in motor cortical representations that are related to degree of handedness, and presumably hand use. Furthermore, these results extend correlational findings from the fMRI literature showing more symmetrical motor cortical activation in less strongly handed individuals (Dassonville et al., 1997). Additional data collection and analyses are ongoing.

I63

TASK SHARING WITH INTENTIONAL VS. UNINTENTIONAL AGENTS *Silke Atmaca[1], Antje Hollaender[1], Dorit Wenke[1], Wolfgang Prinz; [1]Max Planck Institute for Human Cognitive and Brain Sciences* – The present study investigated environmental conditions eliciting or hampering task sharing in a turn taking paradigm. More specifically, collecting both behavioral and EEG data, we examined how the 'nature' of a co-actor (intentional vs. unintentional agent) influences effects of task sharing. Pairs of participants performed a go-nogo Flanker task (Eriksen & Eriksen, 1974) in response to target letters arbitrarily linked to two responses. Each participant was assigned to one response key and a distinctive set of targets. The results of this 'joint condition' differed from results of participants performing the same go-nogo task on their own (individual condition). In a third condition, we tested whether the co-actor's actions needed to be intentional in order to evoke task sharing effects. That is, we compared the joint condition with a passive movement condition in which the co-actor's finger was pulled down by an automatic key, controlled by a computer. The results of this 'unintentional condition' also significantly differed from results of the joint condition, indicating that taking turns with an unintentional agent resembles a situation where one is acting in isolation (individual condition). We understand the type of task sharing effects described in this study as a forward system, anticipating other agents' future actions and thereby extending the temporal limits of ones own action planning. Considering the present results, we conclude that task sharing mechanisms are only applied when the acting individual can attribute intentionality to a co-actor's actions.

I64

MOTOR INITIATION AND INHIBITION : A MAGNETOENCEPHALOGRAPHY STUDY *Kimberly Russo[1], Leighton Hinkley[2], Andrea Quintero[1], Karen Sigvardt[1], Srikantan Nagarajan[2], Elizabeth Disbrow[1,2]; [1]UC Davis, [2]UC San Francisco* – We investigated response initiation and inhibition, two subprocess of motor planning. Subjects were shown a visual cue followed by a response target that instructed them to respond with a right, left, or bilateral button press. A mismatch between the cue and the target would either require the subject to activate a previously uncued response (uncued initiation) or suppress a prepared movement (response inhibition). We investigated the cortical response to initiation and inhibition by measuring fluctuations in oscillatory activity using time-frequency optimized adaptive spatial filtering reconstructions of magnetoencephalography (MEG) data. For uncued initiation, we observed activity in the left middle frontal gyrus (MFG) at 37.5 ms following the target, then the right and left posterior parietal cortex (PPC) at 287.5 ms and 387.5 ms respectively. In contrast, inhibition resulted in activity in the right MFG at 112.5 ms post target, followed by activity in the left and right superior temporal gyrus (STG) at 562.5 and 612.5 ms respectively, and activity in the precuneus at 632.5 ms. In initiation, the left MFG is known to play a role in establishing a task set, and PPC has been implicated in rapid activation of an uncued response (Aron et al., 2004; Gaveau et al., 2008). Inhibition results are consistent with a right cortical network responsive to unexpected stimuli (Corbetta et al. 2000; 2002; Arrington et al. 2000), which includes the right STG, MFG, and precuneus. The right MFG and precuneus have also been shown to be involved in inhibition of finger movement (Brass, 2001).

I65

IS INHIBITION INVOLVED IN THE STOP-SIGNAL AND GO/NO-GO TASKS? *Chelan Weaver[1], Michael Anderson[1]; [1]University of St. Andrews* – Stop-signal and go/no-go paradigms have been used extensively to measure the ability to stop motor responses across myriad populations and species. Although both tasks clearly quantify aspects of stopping performance, it is unclear to what degree they share common processes or neural substrates. Further, it has not been shown that either task necessitates inhibitory control as defined by cognitive psychologists, in which stopping is accomplished by attenuating the response itself. To ascertain the involvement of inhibition in these paradigms, each was adapted to incorporate the independent probe method, a technique developed to isolate the aftereffects of inhibition from other sources of memory impairment. In the current work, novel stimuli were used to elicit recently-stopped motor responses, enabling the measurement of performance decrements localized to responses. This revealed a dissociation between the two types of motor-stopping. Robust aftereffects of inhibition were found in the adapted stop-signal task, but no evidence of inhibition was found in the adapted go/no-go task, suggesting that inhibitory control is recruited for revoking actions, but might not be utilized to prevent movements. These results provide a novel measure of inhibitory control in motor-stopping, measuring the functional consequences of inhibition rather than stopping speed or error rate.

I66

NEURAL CORRELATES OF MULTI-STEP ACTION PLANNING *Mattia Marangon[1,2], Stephane Jacobs[1,2], Scott Frey[1,2]; [1]University of Oregon, [2]University of Oregon, Psychology, Lewis Center of Neuroimaging* – The way we grasp objects (e.g., over- vs. under-hand) depends on sensory information concerning the state of the body (e.g., posture) and the target object (e.g., location, orientation, form), as well as prediction of forthcoming task demands (e.g., intended rotation of the target object). This ability to predict the consequences of our own multi-step actions relies on the use of internal models and reflects the temporally-extended nature of internal action representations (Johnson-Frey et al., 2004). Previous work showed that a parieto-frontal circuit is involved in the transformation of sensory information into a motor plan for grasping (Johnson et al., 2002). Are these same circuits involved in grip selection decisions influenced by predicted demands of a forthcoming object rotation? Event-related fMRI was used to ask this question in 15 healthy, right-handed adults. Participants were asked to select the most comfortable way (over- vs. underhand) to grasp a handle using either hand with the intention of rotating it in a cued direction or to only grasp the handle. Even if movement execution was not required, grip preferences were significantly affected by the predicted demands of handle rotation. Preparation for an imagined anticipatory grip selection activates the same parieto-frontal networks involved in both the rotation and no-rotation conditions. Specifically, brain regions involved are bilateral dorsal premotor cortex (dPMC), bilateral intraparietal sulcus (IPS) and cerebellum. Further, fMRI data suggest that prediction of these demands is accomplished in the very same neural structures as grip selection based on available sensory information.

I67

THE ROLE OF SOCIAL COGNITION IN CONTROLLING SHARED REPRESENTATIONS OF ACTION *Stephanie Spengler[1], D. Yves von Cramon[2,4], Marcel Brass[2,3]; [1]Max Planck Insitute for Human Cognitive and Brain Sciences, Independent Junior Research Group Body and Self, Leipzig, Germany, [2]Max Planck Insitute for Human Cognitive and Brain Sciences, Cognitive Neurology, Leipzig, Germany, [3]Ghent University, Experimental Psychology, Ghent, Belgium, [4]Max Planck Institute for Neurological Research, Cologne, Germany* – In this neuroimaging study we argue that the control of shared representations of action shares common underlying computational mechanisms (the capacity for self-other differentiation and building of intentional states) with social cognitive abilities such as mentalizing and agency processing. Recent research showed that action observation leads to the automatic activation of the corresponding motor representation in the observer, constituting a 'shared representational system' for observed and executed action. However, this raises the fundamental question about the functional mechanisms underlying the control and distinction of shared representations. Brain imaging suggests that control of shared representations, indexed by the ability to control automatic imitative responses, activates anterior-fronto-median-cortex (aFMC) and temporo-parietal-junction (TPJ). Crucially, these regions are also consistently implicated in social-cognitive processing suggesting that the control of shared representations involves similar functional processes. In a within-subject, functional magnetic resonance imaging (fMRI) study, we directly tested whether the control of shared representations activates overlapping brain circuits with social-cognitive processes. As predicted, commonly activated regions occurred selectively in aFMC and TPJ. Controlling imitation recruited a region in aFMC, overlapping with activations during mentalizing and self-referential thoughts. In the TPJ an area overlapped between imitative control, mentalizing and agency processing. Individual ability for controlling imitation was further related to behavioral and neural correlates of mentalizing. Our findings support the idea of shared key processes, including the ability for representing one's own or others' intentions and for differentiating between self- and other-related actions or perspectives.

I68

ATTENTION AND THE READINESS FOR VOLUNTARY ACTION *Ross Cunnington[1], Julie Keegel[1], Marta Bortoletto[1]; [1]The University of Queensland, School of Psychology and Queensland Brain Institute, Brisbane, Australia* – Voluntary action is preceded by a readiness potential, a slowly increasing negative potential arising from activity of premotor and supplementary motor areas. Recent studies have suggested that attention directed towards the intention to initiate action selectively increases activity of the pre-supplementary motor area during voluntary action. The readiness potential, however, is generally thought to represent motor processes that are specifically related to the action to be produced, and the influence of more general attentional or motivational factors has rarely been examined. In this study, we examined the effect of attention on the readiness potential within a paradigm that focused participants' attention on their intentional decision to initiate action. We manipulated the degree to which participants could allocate attention to the voluntary movement task by giving a secondary working memory n-back task at high and low levels of attentional load. 64-channel EEG was recorded from 16 participants as they performed voluntary finger movements and judged their times of intentions within a standard Libet paradigm. The readiness potential amplitude was significantly reduced under conditions of high attentional load, when attentional resources available for the voluntary movement task were limited. Crucially, this effect was evident even in the earliest component of premovement activity, up to 1000 ms prior to movement. Results suggest that neural activity contributing to the early readiness potential represents cognitive processes that are dependent on attention, possibly including the intentional decision of the time to initiate action.

I69

ATTENTION TO TIMING AND SEQUENCING MODULATES ACTIVITY ASSOCIATED WITH THE PREPARATION FOR ACTION *Marta Bortoletto[1], Ross Cunnington[1]; [1]The University of Queensland, School of Psychology and Queensland Brain Institute, Brisbane, Australia* – Voluntary actions are preceded by cortical activity for 1-2 seconds, as indicated by the Readiness Potential (RP). The function of this long lasting activity is still poorly understood, whether it is related to preparation of single movements and movement order in a sequence or to processing of timing for movement initiation. The aim of this study is to directly compare RP and cortical activity related to movements with complex sequencing demands and movements with complex timing demands. 18 participants took part in the study. They were asked to perform self-paced sequences of 6 consecutive movements and to interpose intervals of a few seconds between sequences. The task involved three conditions in which participants paid attention to movement order in the sequence, to timing of sequence initiation or they performed simple sequences with low demands. 64 channels ERPs and fMRI were recorded. A second experiment was run to verify attentional demand and difficulty in each condition. Both attention to timing of sequence initiation and attention to sequencing induced a change in the brain activity during movement preparation. With complex timing, greater activity was found in the right prefrontal cortex and ERPs increased during the early part of RP. With complex sequencing, greater activity was found in parietal and premotor areas and activity increased only during the late RP. Therefore processes related to organising the content of actions and deciding the time to initiate actions arise from different brain regions and contribute to different times during the preparation and readiness for action.

I70

AN FMRI STUDY ON SENSORIMOTOR AND MOTORSENSORY CONTRIBUTIONS TO SPEECH PRODUCTION *Pascale Tremblay[1,2], Vincent Gracco[1,2,3]; [1]School of Communication Sciences and Disorders, McGill University, Montreal, Canada, [2]Center for Research on Language, Mind and Brain, [3]Haskins Laboratories, New Haven, CT* – The control of a wide range of human motor behaviors rely on both feedforward and feedback control schemes. Because of the inherent delays and potential instability in

the feedback loop, it has been suggested that the motor system may use feedforward projections to predict the consequences of motor actions. Specifically, it has been suggested that cortical signals are projected in parallel to brainstem motor nuclei and cortical sensory regions, the latter acting as an "efference copy" command. The sensory area most often associated with speech production, both as a target for a motor to sensory discharge and as a sensorimotor interface area, is a portion of the temporal cortex in and around the planum temporale (PT). For overt speech production, evidence for this mechanism is indirect and limited. The purpose of the present study was to examine, using fMRI, the extent to which speech production uses predictive, feedforward (motor to sensory) and reactive, feedback (sensory) processes during speech and non-speech oral sensorimotor actions. Results suggest that, if present, feedforward (motor to sensory) projections are minimal, and that feedback processes are predominately responsible for activation in PT. Moreover, the feedback is mostly from the auditory rather than the somatosensory system. The significance of these results is discussed in the context of feedback and feedforward motor control mechanisms and the potential role of sensory and motor systems in speech production and perception.

I71

NEURAL EFFECTS OF MOBILITY TRAINING IN STROKE PATIENTS *Julie A. Conder[1], Stacy L. Fritz[2], Debra E. Krotish[3], Gordon C. Baylis[1]; [1]University of South Carolina, Psychology, [2]University of South Carolina, Exercise Science,[3]University of South Carolina, Division of Geriatrics* – This study used functional magnetic resonance imaging (fMRI) to explore the neural effects of a novel mobility therapy on stroke patients. Although many strokes result in death, there are over 3.5 million stroke survivors in the United States alone who experience disability caused by cell death from stroke. Intensive Mobility Training (IMT) is a novel method of challenging rehabilitation therapy that attempts to "retrain" intact neurons. IMT includes repetitive motion of the affected side of the body with a focus on gait training, range of motion, and balance. It is an intensive therapy that requires three hours of therapy each day for ten consecutive days. Participants performed three mobility tasks while in the scanner, which were designed to elicit neural activity related to movement of the affected lower extremity and the affected hand. Participants were required to perform flexion, extension and grip movements in response to visual cues indicating whether the left or right side should be moved. Two scanning sessions were conducted to capture neural activation before and after IMT. Scans included functional imaging during the mobility tasks and diffusion tensor imaging during rest. Results from functional scans indicate that intact regions of the brain may show differential activation as a result of the 10-day IMT treatment, and that these changes may be reflected in physical mobility gains.

I72

DEFICITS IN TARGET SELECTION FOR REACHING MOVEMENTS AFTER SUPERIOR COLLICULUS INACTIVATION *Joo-Hyun Song[1], Robert D. Rafal[2], Robert M. McPeek[1]; [1]The Smith-Kettlewell Eye Research Institute, [2]Bangor University* – The primate superior colliculus (SC) is important for the execution of saccadic eye movements, but recent evidence suggests that it also plays a role in the higher-level process of target selection for saccadic and pursuit eye movements, as well as in covert attention shifts. Thus, we speculated that SC activity may participate in a generalized salience map used for target selection for a variety of purposes. Consistent with this, we have found that in a task in which monkeys must reach to a target among distractors, SC activity discriminates the target of the reaching movement even when no eye movement is made. To determine if this SC activity plays a causal role in reach target selection, we tested the effects of temporary focal SC inactivation on monkeys' performance in two reach target selection tasks. In one task, a target was followed after a variable SOA by a distactor, and monkeys were rewarded for reaching to the target. In the second task, two potential targets were shown and a cue at the fovea indicated which was the target. Monkeys were required to maintain eye fixation throughout each trial. In both tasks, after SC inactivation, when the target appeared in the inactivated part of the visual field, monkeys made more reaching errors to the distractor. In contrast, monkeys were unimpaired when the target was presented without distractors. These results establish that, in addition to its role in saccades, the SC plays a causal role in target selection for reaching movements.

I73

NEURAL CORRELATES OF TARGET SELECTION FOR REACHING MOVEMENTS IN SUPERIOR COLLICULUS *Robert M McPeek[1], Joo-Hyun Song[1]; [1]The Smith-Kettlewell Eye Research Institute* – The primate superior colliculus (SC) has long been regarded as a structure important for the execution of saccadic eye movements. However, recent studies have suggested that the SC also plays a role in the higher-level process of target selection. Specifically, SC activity is correlated with the selection of targets for saccadic and pursuit eye movements, as well as with covert shifts of attention. We speculated that the SC may contribute to a generalized salience map which is used to select targets not only for eye movements and attention, but also for other visually-guided actions such as reaching movements. To test this hypothesis, we recorded the activity of isolated intermediate-layer SC neurons in monkeys trained to perform a reach target selection task. The monkeys were rewarded for maintaining fixation and reaching to touch an odd-colored target presented in an array of distractors. Even though no eye movements were made in this task, SC activity robustly signaled the goal of the reaching movement. Many SC neurons discriminated the target before the onset of the reach, and this activity typically persisted throughout the trial, consistent with SC involvement in target selection for reaching movements. On the other hand, SC activity was poorly correlated with the detailed kinematics of the movements, suggesting that it is not involved in the low-level control of reaching movements. Overall, the pattern of results is consistent with SC involvement in a generalized salience map used for visually-guided actions and attention.

I74

COMPARING OVERT AND COVERT MOVEMENT WITH MAGNETOENCEPHALOGRAPHY *Xing Tian[1], David Poeppel[1]; [1]University of Maryland* – What neural structures are active during real movement versus motor imagery is debated. Furthermore, the functional roles and temporal response profile of cortical regions engaged in overt versus imagined movement remain unclear. We ran two magnetoencephalography (MEG) experiments to pursue both questions. In the first experiment, participants were asked to either press or imagine pressing a button using the right thumb, immediately after a tone cue. The activation pattern in execution of thumb movement appeared above contra-lateral primary motor cortex (M1), whereas the topographic map in the imagery task was different, including more frontal areas, approximately in supplementary motor area (SMA) and premotor area (PM), and more posterior fields, approximately in parietal cortex. To monitor the motor preparation process, in the second experiment, a sequence of three tones with constant interstimulus interval of 1s was presented to participants, who were asked to either press or imagine pressing a button when the fourth tone was predicted to onset. This experiment replicated the observation that the activity pattern over M1 was only presented in motor execution. Moreover, activity approximately around SMA was activated in the overt task around 200ms before the actual movement. These results support the hypothesis that a subset of neural systems engaged in real movement is active during motor imagery. Moreover, SMA appears to be involved in both movement imagery and motor preparation. These results suggest that activation in SMA might serve as an indicator before real movement for brain-computer interface applications.

I75

FRONTAL AND PARIETAL CORTEX DECIDE WHERE TO LOOK *Kyeong-Jin Tark[1], Clayton Curtis[1]; [1]Psychology & Neural Science, New York University* – Neurons in the frontal and parietal cortex are thought to transform incoming visual signals into saccade goals, a pro-

cess known as target or saccade selection. Here, we used fMRI to test the degree to which those areas are involved when non-visual information is used for selection. First, we asked if the same portions of the frontal and parietal cortex that are active during visual-guided saccades are also active during saccades made to the locations of sounds. Second, we compared the activity when subjects made externally-guided (i.e., visual/auditory) and internally-guided saccades. We scanned subjects while they made saccades to one of four differently colored dots. Selection was based on a visual cue (i.e., one of the dots blinked), an auditory cue (i.e., a white noise burst was emitted at one of the dot's location), or a semantic cue (i.e., the color of one of the dot's was spoken). We found that activity in the superior parietal lobule and inferior frontal gyrus was greater during aurally-guided and semantically-guided saccades compared to a visually-guided saccades. Moreover, we found robust responses in frontal and parietal cortex, in the putative frontal eye field and lateral intraparietal areas, but these responses did not differ according to the type of information used to guide saccades. Therefore, prioritized maps of space formed by the activity of populations of neurons in frontal and parietal cortex that are thought to guide where we look may be agnostic about what led to the priority.

I76

PREPARING TO STOP SELECTIVELY IS REFLECTED IN REDUCED CORTICOSPINAL EXCITABILITY *Michael Claffey[1], Frederick Verbruggen[2], Adam Aron[1]; [1]University of California, Psychology, San Diego, [2]University of Ghent, Psychology, Belgium* – Behavioral studies show that participants can selectively stop responses if given foreknowledge of which response to stop. Foreknowledge may be effective because it generates proactive inhibitory control over a response representation. If so, this should be reflected in reductions in corticospinal excitability after the foreknowledge instruction. To test this, we delivered transcranial magnetic stimulation to the left motor cortex and recorded motor evoked potentials (MEPs) from the right hand while participants performed a modified stop-signal task. On each trial, a cue was presented ('maybe stop left', MSL, 'maybe stop right', MSR or 'maybe stop XXX', MSX), followed 2 seconds later by a Go stimulus requiring simultaneous responses with both hands. On a minority of trials a stop signal was presented, requiring participants to stop one initiated hand but not the other - something for which they could prepare in MSL and MSR conditions, but not the MSX condition. Magnetic stimuli were delivered 1200, 1500 and 1800 ms post-cue. An ANOVA performed on MEPs from the right hand showed a marginally significant effect of cue ($F(2,12)=3.51$, $p=0.063$), with corticospinal excitability least for MSR, more for MSX and greatest for MSL. Behavioral performance was similar in MSL and MSR conditions. The muscle of interest was equally at rest in all conditions prior to magnetic stimulation (mean RMS 0.004 mV.s, SD = 0.001). We interpret the smaller MEPs in the foreknowledge period for the MSR condition as evidence of proactive inhibitory control when the right hand may need to be subsequently stopped.

I77

MOTOR ABNORMALITIES IN ADHD ADULTS *Eve Valera[1,2], Jeremy Schmahmann[1], Thomas Zeffiro[3], Stephen Faraone[4], Thomas Spencer[1], Joseph Biederman[1], Larry Seidman[5]; [1]Harvard Medical School/Massachusetts General Hospital, [2]HST Athinoula A. Martinos Center for Biomedical Imaging, [3]Massachusetts General Hospital, [4]SUNY Upstate Medical University, [5]Harvard Medical School/Massachusetts Mental Health Center/Beth Israel Deacones Medical Center* – Attention-deficit/hyperactivity disorder (ADHD) is characterized by age inappropriate symptoms of inattention, and/or hyperactivity or impulsivity, and is estimated to affect approximately 5% of adults. Interestingly, a large number of ADHD individuals have been found to have motor abnormalities in both fine and gross motor tasks including, but not limited to, tapping, dynamic balance, handwriting, and manual dexterity skills. These difficulties have a detrimental impact on the lives of children with ADHD. Although there appears to be a growing literature for ADHD children, there do not appear to be any analogous reports regarding "fine or gross" motor assessment or coordination in ADHD adults. Thus, we used the International Cooperative Ataxia Rating Scale (ICARS) to provide an objective assessment of ataxia severity in 24 ADHD adults and 22 matched controls. The ICARS is a 100-point semiquantitative validated scale comprising 19 items in 4 subscales: posture and gait disturbances, limb/kinetic functions, speech disorders and oculomotor disorders. The ICARS provides an assessment and score of the clinical signs of the cerebellar motor syndrome. Subjects were judged on facets of walking, standing, sitting, coordinated limb movement, tracing a pattern, speech, and oculomotor abilities. ADHD adults showed significantly higher scores for the total ataxia scale as well as for the posture and gait disturbances and limb/kinetic functions subscales. These data show that motor abnormalities in ADHD persist into adulthood and can be detected by clinical examination of the cerebellar motor system. These data also provide additional evidence of cerebellar abnormalities in ADHD adults.

I78

A TRANSCRANIAL MAGNETIC STIMULATION STUDY OF BRAKING A MOTOR RESPONSE *Ian Greenhouse[1], Adam Aron[1], Frederick Verbruggen[2]; [1]University of California, Psychology, San Diego, [2]University of Ghent, Psychology, Belgium* – When people anticipate stopping a response, they slow their respondingósomething we refer to as 'braking.' We hypothesized that braking may be reflected in pro-active inhibition of the motor system. To test this, we delivered transcranial magnetic stimulation to the left motor cortex and recorded motor evoked potentials (MEPs) from the right hand while participants performed a stop-signal task. Participants were instructed to respond to a choice stimulus, but to withhold the response when the choice stimulus was followed by a stop signal. On each trial, a cue was presented ('maybe stop', MS, or 'no stop', NS), followed 1 second later by a choice stimulus. Stop signals only occurred on MS trials. Magnetic stimuli were delivered at baseline (before the cue), 600 ms post-cue, 800 ms post-cue and 80 ms post-choice-stimulus. RT for MS trials was significantly slower than NS trials ($t = 5.36$). MEP amplitude was significantly greater at all test times compared to baseline ($p < .01$). Importantly, there was no difference between MS and NS conditions. Pre-magnetic-stimulus EMG showed the muscle of interest was equally at rest in all conditions (mean RMS 0.003 mV, SD = 0.001). Thus, while participants use the 'maybe stop' cue to brake their responses, this braking effect is not reflected prior to response selection. We speculate that, in this version of a braking paradigm at least, the control cue is encoded at a purely cognitive level during the foreperiod, and braking of the motor system only occurs once a particular motor affordance exists.

I79

GENERALIZED CORTICAL MECHANISMS SERVING MOTOR SEQUENCE LEARNING *Leighton Hinkley[1], John Houde[2], Rebecca Webster[3], Anne Findlay[1], Nancy Byl[3], Srikantan Nagarajan[1]; [1]University of California, Radiology, San Francisco, [2]University of California, Otolaryngology, San Francisco, [3]University of California, Physical Therapy and Rehabilitation Science, San Francisco* – Implicit and explicit manual sequence learning is controlled by a well-defined network of brain regions that integrate motor and sensory information from the hand with cognitive parameters that generate associations between the movement elements (Ashe et al., 2006). The temporal dynamics and timing of activity between areas within this network have yet to be defined, and the extent to which functional modifications in this network generalize to other response modalities used to learn a motor sequence (e.g. vocal) is presently unclear. If movement sequences are encoded in a supramodal manner (Keele et al., 1995), learning a pattern with one body structure will result in performance improvements when repeating the sequence in an untrained effector and such transfer should remain symmetric. We examined changes in cortical activity that occur over the course of sequence learning using magnetoencephalography (MEG) while subjects performed a modified serial reaction time task (SRTT; Nissen & Bullemer,

1987). Data was acquired using a 275-channel whole-head biomagnetometer (CTF Systems, Vancouver BC) and analyzed in the time-frequency domain using Nutmeg (bil.ucsf.edu/nutmeg). Subjects were trained in the SRTT to learn an eight-step movement sequence in the manual (button press) and vocal (short vowels) response modalities. During movement sequence learning, we observed significant changes in beta (15-30Hz) and high-gamma (65-90Hz) power over the motor cortices as subjects implicitly learned the motor pattern. These findings expand upon the known role of the motor cortices in sequence learning by demonstrating that acquiring a movement sequence is associated with oscillatory changes over these areas.

Higher level cognition: Other

I80

WHERE IS "WHERE" IN THE BRAIN? *Ruth Seurinck[1], Wim Gevers[1,2], Simone Kühn[1,3], Filip Van Opstal[1], Wim Fias[1]; [1]Ghent University, Experimental Psychology, Faculty of Psychology and Educational Sciences, Ghent, Belgium, [2]Unité de Recherche en Neurosciences Cognitives (UNeSCog), Université Libre de Bruxelles (ULB), Brussels, Belgium, [3]Max Planck Institute for Human Cognitive and Brain Sciences, Cognitive Neurology, Leipzig, Germany* – Spatial information can be conveyed to our brain in two ways. First, directly as perceptual information (i.e. as a location in the physical world), and second, indirectly, in a symbolic way such as arrows, words etc. The current fMRI-study aimed to identify the commonalities and differences between the neural coding of perceptual and symbolic spatial information. Spatial and non-spatial information (i.c. color) was presented in a symbolic or a non-symbolic perceptual format. Sixteen male, right-handed and Dutch-speaking subjects performed a verbal semantic and non-symbolic perceptual same-different task. In the verbal conditions two words were sequentially represented. To ensure that subjects accessed the meanings of the words, the words always originated from different languages (French and English). The words were translations of either the spatial concepts "right" or "left" (spatial task), or the color names "purple" or "green" (non-spatial task). Subjects decided if the words had the same meaning. In the non-symbolic conditions two colored circles were sequentially presented with openings on the left or right side. Subjects decided either if the openings were on the same side (spatial task), or the circles had the same color (non-spatial task). Areas within bilateral posterior parietal cortex were more involved in processing of spatial information than non-spatial information, irrespective of stimulus format. The symbolic format additionally recruited inferior frontal gyrus, while the non-symbolic format relied more on lateral premotor and occipital cortex.

I81

SENSORIMOTOR FORWARD MODELS ACCOMMODATE DIFFERENT LEVELS OF PREDICTION SPECIFICITY *Andreja Bubic[1,3], D. Yves von Cramon[1,2], Ricarda I. Schubotz[1,2]; [1]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany, [2]Max Planck Institute for Neurological Research, Cologne, Germany, [3]University of Leipzig, Leipzig, Germany* – Prediction of external events relies on our motor system which is able to simulate the dynamics of our environment by developing internal representations of those events (i.e., forward models) and using them for prediction of incoming stimuli. Results from previous studies suggest that this process is subserved by a basic premotor-parietal network not only when subjects predict the exact identity of the upcoming stimulus, but also when they predict only one of its features. The present study investigates whether the involvement of this network is restricted only to the level of individual stimulus features or if it can generalize to a higher class of abstraction, namely a categorical one based on arbitrary rule-based conjunctions of those features. We directly compared the processing of external events of different specificity, namely perceptual sequences in which prediction of incoming stimuli could be made on the level of individual stimuli ("token") with those in which predictions were restricted to the level of stimulus categories ("type"). The obtained results confirm that prediction across different levels of abstraction is supported by the same premotor-parietal network without significant modulation of activation within any of its key regions. Furthermore, the processing of two sequence classes could be differentiated by the engagement of additional lateral prefrontal, occipital and posterior temporal regions supporting categorization in "type" sequences. These findings suggest that forward models in perception can be defined on a higher level of abstraction in contrast to those within the motor domain which require high degree of precision and accuracy.

I82

IMPLEMENTING INSTRUCTED STIMULUS RESPONSE ASSOCIATIONS: AN FMRI STUDY *Egbert Hartstra[1], Simone Kuhn[1,2], Marcel Brass[1]; [1]Ghent University, Experimental Psychology - Ghent Institute for Functional and Metabolic Imaging of the brain, Ghent, Belgium , [2]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany* – In everyday life our actions are often guided by verbal instructions. Usually we can implement such instructions immediately without trial and error learning. This raises the fundamental question how verbal instructions are transformed into efficient motor behavior? While we know a lot about the linguistic and the motor side of this problem, our understanding of the implementation process is rather poor. The aim of the current study was to gain deeper insights into this implementation of verbal instructions both on a neural and a cognitive level. To this end we devised an fMRI experiment in which participants were required to permanently learn and implement new stimulus response associations. Preliminary results suggest that a fronto-parietal network is involved in setting up S-R mappings from verbal instructions. Furthermore, we compared repeated exposure to verbal instructions without implementation with repeated implementation of the S-R mapping.

I83

SYNCHRONIZED TAPPING AS A MODEL OF MINIMAL SOCIAL INTERACTION *Ivana Konvalinka[1], Peter Vuust[1,2], Andreas Roepstorff[1,3], Chris D. Frith[1]; [1]Center of Functionally Integrative Neuroscience, University of Aarhus, [2]Royal Academy of Music, Aarhus, [3]Institute of Anthropology, Archeology and Linguistics, University of Aarhus* – Human beings have an extraordinary ability to synchronize their actions, goals, and intentions in order to accomplish goal-directed tasks. In order to study the dynamics and mechanisms involved in entrainment in social interaction, a finger tapping experiment was carried out, where pairs of subjects were asked to tap on their respective keyboards following an 8-beat stimulus sent through their headphones. The subjects were instructed to keep the given beat as well as synchronize with the 'other'. They were in scenarios where they could either hear themselves tapping, the other, or the computer metronome. Analysis of their inter-tap intervals (ITI) suggests that dyads are unable to achieve full synchrony but rather adopt oscillatory behaviour, such that each member attempts to lock in phase with the other, thereby error-correcting their tapping onsets in opposite directions. Windowed cross-correlograms showed that there was no leader/follower in the interactive condition, revealing high correlation in both lag +1 and -1, which suggested shared continuous adaptation to the other's output. A dynamical systems approach was taken to model this behaviour, using a system of two oscillators coupled in both phase and frequency, corresponding to phase and period error correction.

I84

COGNITIVE AND NEURAL FOUNDATIONS OF RELIGIOUS BELIEF *Dimitrios Kapogiannis[1], Aron Barbey[1], Michael Su[1], Giovanna Zamboni[1], Frank Krueger[1], Jordan Grafman[1]; [1]Cognitive Neuroscience Section, NINDS/NIH* – We propose an integrative cognitive neuroscience framework for understanding the cognitive and neural foundations of religious belief. We performed multidimensional scaling (MDS) analysis to ratings of dissimilarities between statements regarding religious beliefs, provided by 23 participants with varying degrees of religiosity. MDS

revealed three psychological dimensions of religious belief: God's perceived level of involvement, God's perceived emotion, and a continuum of doctrinal/experiential religious knowledge. We then performed functional magnetic resonance imaging to reveal the neural correlates of these dimensions. We scanned 40 demographically and religiosity-wise matched new participants. We discovered corresponding activation within networks processing Theory of Mind regarding intent and emotion, abstract semantics, episodic memory and imagery. Our results demonstrate, for the first time, that specific components of religious belief are mediated by well-known brain networks and support contemporary psychological theories that ground religious belief within evolutionary adaptive cognitive functions.

I85

LATERALISATION OF SELF-ESTEEM: AN INVESTIGATION USING A DICHOTICALLY PRESENTED AUDITORY ADAPTATION OF THE IMPLICIT ASSOCIATION TEST *Ryan McKay[1], Joanne Arciuli[2], Alikki Atkinson[3], Elaine Bennett[3], Elisabeth Pheils[3]; [1]Institute for Empirical Research in Economics, University of Zurich, [2]Faculty of Health Sciences, University of Sydney, [3]School of Social Sciences and Liberal Studies, Charles Sturt University* – Self-esteem is one of the most prominent and influential constructs in psychological science, yet very few neuropsychological/neuroscientific investigations have been undertaken in this area of research. The current study investigated the possibility of hemispheric lateralisation of self-esteem. By creating an auditory version of the Implicit Association Test (IAT) for self-esteem, we were able to present stimuli dichotically and thereby compare left- versus right-hemispheric measurements of self-esteem in 46 healthy adults. Although left- and right-hemispheric self-esteem measurements were correlated, within-participant analysis revealed that self-esteem levels (as reflected by IAT score) were significantly greater when elicited under right-ear dichotic presentation (reflecting left hemispheric processing). We interpret this asymmetry with reference to the approach-withdrawal model of emotion processing and suggest avenues for future research.

I86

CREATIVITY: THE OTHER WHITE MATTER *Robert Chavez[1], Arvind Caprihan[1], Shirley Smith[3,1], Alison Marshall[1], Ranee Barrow[1], Rachael Grazioplene[1], Rex Jung[1,2,3,4]; [1]Mind Research Network, [2]University of New Mexico, Neurosurgery, [3]University of New Mexico, Psychology, [4]University of New Mexico, Neurology* – A consensus definition of creativity refers to the production of something novel and useful within a given social context (Flaherty, 2005). The construct of creativity is comprised of numerous cognitive abilities, including convergent reasoning, divergent reasoning, focused attention, and insight, among others (Dietrich, 2007). The most researched of these, divergent reasoning (DR), refers to the capacity to produce multiple answers to a set problem (Guilford, 1957). Using diffusion tensor imaging (DTI) at 3 Tesla, we hypothesized that fractional anisotropy (FA) within association fiber tracts would relate to measures of DR. DTI and measures of creativity (Miller & Tal, 2007) were obtained from a cohort of 37 neurologically and psychiatrically healthy adults ranging in age from 18 to 29. Five independent judges rated creative products of each subject, with high inter-rater reliability (?= 0.89), from which a "Creativity IQ" (CIQ) was calculated. DTI data was processed using Tract-Based Spatial Statistics (Smith, et al. 2006) from which each subject's FA image was registered to a group "skeletonized" FA image. Applying a white matter atlas to obtain regions of interest, FA values were average across each voxel within each subject's particular fiber tract to calculate the mean FA of that tract. Using a partial correlation analysis controlling for age, we found mean FA within the left superior longitudinal fasciculus was related positively to CIQ (r= .38, p= .021). This report further demonstrates (Chavez et al., 2008) important relationships between white matter tract integrity and creativity in a cohort of healthy subjects.

I87

NEURAL RESPONSE TO FOOD CUES DURING HUNGER AND SATIATION IN HEALTHY-WEIGHT PARTICIPANTS *Anastasia Dimitropoulos[1], Jean Tkach[2,3]; [1]Case Western Reserve University, Psychology, [2]Case Western Reserve University, Radiology, [3]Case Western Reserve University, Case Center for Imaging Research* – Neural response to food cues differs as a function of hunger and satiety, yet the influence of food reward on hunger state may be critical to understanding mechanisms of overeating. The purpose of this research is to delineate differences in neural response to food stimuli of varying caloric value during fasting and satiation. Eleven lean adults (mean body mass index=22.37; 5 male) completed an fMRI block-design task with 3 conditions: high-calorie food (HI), low-calorie food (LO), and nonfood objects pre- and postmeal. In addition to T1-weighted and high-resolution 3D images, functional images were acquired on a 4.0T MR scanner (TR=1950, TE=22ms, flip angle=90). Group data sets were examined using GLM analysis contrasting the experimental conditions. Findings indicated greater activation to HI vs. LO during fasting in the orbitofrontal cortex (OFC), superior frontal gyrus, and amygdala ($p<.01$ corrected). Postmeal activations to HI vs. LO include the anterior cingulate and middle frontal gyrus ($p<.05$ corrected). Direct comparison of motivational salience (HI vs. LO) by hunger state (fasting vs. satiation) indicates greater activation in the OFC and amygdala to high-calorie foods during hunger. These results indicate increased activation in regions involved in food motivation, taste information processing and reward learning during hunger, when rewarding foods are most salient. These preliminary findings give insight into the effect of rewarding foods on the underlying neural mechanisms of food regulation during different hunger states. Understanding the effect of food reward during hunger and satiety may inform mechanisms of overeating and obesity in the general population.

I88

GENERAL VERSUS TASK-SPECIFIC ASSESSMENT OF ONE'S COGNITIVE ABILITIES. A MULTIDIMENSIONAL APPROACH OF THE METACOGNITIVE MONITORING *Audrey Perrotin[1], Amynta Hayenga[1], William Jagust[1,2]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, CA, [2]Lawrence Berkeley National Laboratory, Molecular Imaging and Neuroscience, Berkeley, CA* – Metacognitive monitoring encompasses two broad dimensions: assessment of one's general cognitive abilities (off-line monitoring), and assessment of one's performance at a cognitive task (on-line monitoring). Moreover, metacognitive judgments can also be assessed in terms of accuracy relative to actual performance. Objectives- (1) To explore processes underlying the two monitoring forms, by observing their association with depressive affect, and global and more specific cognitive processes (episodic memory and executive functioning). (2) To examine the relationships between the two monitoring forms. Method- Healthy older adults (192 subjects) were assessed on metacognitive measures: general memory self-reports (off-line monitoring), and judgment of performance after different cognitive tasks (on-line monitoring). Subjects were also tested on a depression measure, and on neuropsychological measures evaluating global cognition, memory and executive functioning. Results- Correlations revealed that both off- and on-line monitoring judgments were specifically related to the depression measure, whereas both accuracy indexes were related to the global cognition measure. Regression analyses showed that memory abilities were the main determinant for the off-line monitoring accuracy, and executive abilities the best predictor for the on-line monitoring accuracy. Strong correlations were observed between the off- and on-line monitoring measures. Conclusion- Whatever the monitoring form, it appeared that metacognitive judgments and accuracy may rely on distinct factors. The accuracy index may nevertheless depend on different cognitive processes according the monitoring form. Moreover, the overlap between off- and on-line monitoring supports the view of a general monitoring ability. These results are considered in light of neuroanatomical data.

I89

USING FUNCTIONAL CONNECTIVITY TO MAP CONCEPTUAL CIRCUITS IN THE BRAIN *W. Kyle Simmons[1], Mark Reddish[1], Alex Martin[1]; [1]Laboratory of Brain and Cognition, NIMH/NIH* – Thinking about people or tools elicits activity in distinct neural circuits. Evidence indicates that the constituent regions in these circuits represent properties that are salient in social- and tool-interactions. It remains unclear, however, whether the co-activation of regions within each circuit reflects accessing property-related information due to task demands, or their intrinsic connectivity. To address this question, we identified social- and tool-related activations in the posterior superior temporal sulcus and middle temporal gyrus respectively by scanning subjects while they learned facts about people and tools. Next we used the functionally localized regions as seeds in functional connectivity analyses of data collected while subjects engaged in a separate vigilance task scan. Importantly, regions within the social and tool-use networks maintained their connectivity with one another even though subjects were engaged in the vigilance task, and so were not thinking about people or tools. Thus, the social- and tool-property circuits identified in earlier research are not simply manifested during social or tool information processing tasks. Rather, they are "hard circuits" that are continuously present in the brain, irrespective of whether a person is thinking about others, or tools, at a given moment.

I90

THE DEFAULT NETWORK CONTRIBUTES TO INFERENCES ABOUT THOSE CLOSEST TO US *Fenna M. Krienen[1,2], Jessica R. Andrews-Hanna[1,2], Randy L. Buckner[1,2,3]; [1]Harvard University, Psychology, [2]Athinoula A. Martinos Center for Biomedical Imaging, Charlestown, MA, [3]Howard Hughes Medical Institute at Harvard University, Cambridge, MA* – The ability to consciously represent our own mental states and the mental states of other agents is one of the most intriguing human capacities (Frith & Frith, 2006). Many have noted the striking overlap of brain regions involved in social cognition and self-relevant mentation with regions comprising the "default network," a brain system that is found to be active during passive or "resting" task states (Gusnard and Raichle, 2001; Buckner et al, 2008; Schilbach et al., 2008). Here we investigate networks involved in mental state inference about others. "Others" varied on the dimension of familiarity (friends, strangers) as well as perceived similarity to the self, a dimension previously found to dissociate neural contributions to social inference (Mitchell et al, 2006). Healthy young adults (n = 28; 11 male) were scanned using fMRI while making inferences about targets' beliefs and preferences. Whole-brain analyses revealed dissociations between self, familiar, and unfamiliar others. Core default network regions were recruited when considering the self and familiar others. Making inferences about unfamiliar others resulted in an overall reduction in default network activation, with an increase in activation in additional regions. A region of interest analysis using default network regions derived from an independent dataset revealed that self and familiar others dissociated from unfamiliar others in a subset of regions, including posterior cingulate and medial prefrontal cortex. Our results suggest that the default network supports mentalizing about others in a manner sensitive to the target's relevance to the self.

I91

THE NEURAL CORRELATES OF VISUAL AND VERBAL COGNITIVE STYLES *David Kraemer[1], Lauren Rosenberg[1], Sharon Thompson-Schill[1]; [1]University of Pennsylvania* – Cognitive styles, thought to reflect an individual's preferred mode of processing information, are believed to affect the way individuals learn, recollect, and reason. However, little direct evidence currently exists to link cognitive styles to specific neural systems. In the present study, visual and verbal cognitive styles were measured both by objectively quantifiable tests of cognitive abilities and self-report measures of processing style preference. During fMRI scanning, participants took part in a novel task involving both word-based and picture-based feature matching conditions. Results demonstrate neural correlates of visual and verbal cognitive styles in brain areas that process visual and phonological information. Specifically, activity in a region that preferentially responded to viewing pictorial stimuli (R fusiform gyrus) correlated with self-reported Visualizer ratings. Likewise, activity in a phonology-related brain region (L supramarginal gyrus) correlated with self-reported Verbalizer ratings. These findings suggest that domain-specific cortical activity underlies processing in visual and verbal cognitive styles.

I92

OUT OF HAND: HOW EXPERIENCE AND RACE MODULATE NEURAL CORRELATES OF GESTURE OBSERVATION *Sook-Lei Liew[1,2], Lisa Aziz-Zadeh[1,2], Shihui Han[3]; [1]Brain and Creativity Institute, University of Southern California, [2]Division of Occupational Science and Occupational Therapy, USC, [3]Peking University, Psychology, China* – What are the neural correlates of gesture? How are they modulated by the race of the actor or by one's familiarity with the gesture? Recent neuroimaging findings suggest that gestures are processed in part by a mirror system that is active both when we observe and execute a given action. This system may be modulated by experience and beliefs about the other person. In this study, we used fMRI to examine the neural activation associated with observing both familiar and unfamiliar intransitive cultural gestures, such as a thumbs up or the word apple in American Sign Language. Due to the modulatory role of experience, we hypothesized that observing familiar gestures would generate distinct neural patterns from unfamiliar gestures in premotor and parietal regions important for action observation. Additionally, we asked whether physical similarity (i.e. same vs. different race) with the observed actor would affect activity in these regions. Eighteen Chinese participants viewed Chinese or Caucasian actors performing familiar or unfamiliar gestures while in the MR scanner. Our results suggest that while both familiar and unfamiliar gestures show activity in sensorimotor regions, familiar gestures activate areas associated with semantic processing (anterior temporal lobe) and emotional processing (insula), while unfamiliar gestures activate areas associated with action monitoring (superior parietal lobe, cerebellum). Additionally, we found a significant interaction between race of actor and familiarity of gesture, which suggests the importance of social context on simulation mechanisms and action understanding for Chinese subjects.

I93

IS NEURAL ENCODING OF RACE MANDATORY? AN ELECTROPHYSIOLOGICAL INVESTIGATION *Yina Ma[1], Shihui Han[1]; [1]Peking University, Psychology, China* – Previous behavioral studies suggest that, although race encoding is independent of task demands, it is not inevitable and can be erased by manipulating coalition. The current work investigated whether alliance-related social attitudes modulate neural encoding of race by recording event-related potentials (ERPs) to racial ingroup and outgroup faces in a face orientation identification task. We found that an early frontal negativity (N100) differentiated outgroup and ingroup faces of the models when they had behaved aggressively but not when they had behaved amicably towards the observer. Moreover, the N100 amplitude correlated with participants' attitudes toward the models. The long-latency ERP components (N200 and P300) differentiated outgroup and ingroup faces of the models only when they had behaved amicably towards the observer. The ERP results indicate that neural encoding of race depends on observers' alliance-related social attitudes rather than occurring mandatorily.

I94

NEURAL OSCILLATIONS IN ASSOCIATION WITH SELF-REFLEXIVE THINKING *Yan Mu[1], Shihui Han[1]; [1]Peking University, Psychology, China* – Previous behavioral studies indicate that self-related trait words are better remembered than those related to others. However, the neural mechanisms underlying this self-referential effect remain undefined. The current study explored whether the neural activity involved in encoding self-related trait may predict the individual differ-

ence in the self-referential effect during memory retrieval. The electroencephalogram (EEG) was recorded from 14 healthy adults while they made judgments of personality traits referenced to the self or to a public person. Subjects were given a memory test after the EEG recording session. To examine the relation between the non-phase-locked neural activity linked to encoding of self/other traits and the behavioral performances during the memory test, the time-frequency power of theta band (5-7Hz) and alpha band (8-13 Hz) neural activity was calculated within each 100-ms time window using Wavelet transform analysis method. We found that, relative to other-referential traits, self-referential traits induced reduced theta band power at 300-400ms but increased theta band power at 700-800ms. Alpha band (8-10Hz) power was stronger in the self- than other-referential conditions at 400-600ms. Moreover, we found that the frontal theta band activity at 700-800ms increased to negative than positive traits when referenced to the self. Most importantly, the frontal theta band activity at 700-800ms positively correlated with individuals' self-advantage in the recognition scores in the memory test. Our findings indicate that both theta and alpha neural oscillations differentiate the encoding of self- and other-referenced traits and theta band activity contributes to the individually differences in self-referential effect.

I96

THE EMOTIONAL EMBODIMENT DURING EXPERIENCING PROTAGONISTS' PHYSICAL ACTIVITIES IN NARRATIVE COMPREHENSION *Hidetsugu Komeda[1,2], Norihiro Sadato[1,3]; [1]National Institute for Physiological Sciences, [2]Japan Society for the Promotion of Science, [3]Japan Science and Technology Agency* – Readers construct mental representations associated with their experiential traces, such as motor and emotional representations in narrative comprehension. According to embodied cognition framework (Barsalou, 1999; Zwaan, 2004), understanding words about actions activates action-related brain areas. We used functional magnetic resonance imaging to test our hypothesis that reader's motor representation is activated when judging the increase of protagonists' physical activities. We constructed story-reading tasks, in which situation-sentences describing degree of protagonists' physical activities (low, middle, or high) were presented, followed by the target-sentences with high physical activities, with emotional valences (positive or negative). In high increasing stories about protagonist's physical activities, situation-sentences describe low activities and target-sentences do high activities. Low increasing stories starts from middle activities and result in high activities. Non-increasing stories are high activities consistently. Thus, the task was a 3 x 2 factorial design: the effect of degree of physical activities (high, low, and non-increase) and the effect of stories' emotional valences (positive vs. negative). The activation related to the target-sentence was positively correlated with the degree of increases in physical activities in the supplementary motor area, premotor cortex, primary motor area, dorsomedial prefrontal cortex, and supramarginal gyrus. As the supplementary motor and premotor cortex represents motor imaginary, they were activated in all stories about protagonists' physical activities. In the case of positive stories, medial orbitofrontal cortex and dorsomedial prefrontal cortex were activated. In conclusion, understanding protagonist's physical states activates reader's motor representation. In addition, medial orbitofrontal cortex is involved in the embodiment of emotions (Kringelbach, 2005).

I97

ACTION IDENTIFICATION: ITS NEURAL AND GENETIC CORRELATES *Abigail Marsh[1,2], Megan Kozak[3], Maggie Reid[2], Henry Yu[2], Daniel Wegner[4], R.J.R. Blair[2]; [1]Georgetown University, Psychology, [2]National Institute of Mental Health, Mood & Anxiety Program, [3]Pace University, Psychology, [4]Harvard University, Psychology* – Mentalization is the process by which an observer views a target as possessing higher cognitive faculties such as goals, intentions, and desires. The extent to which observers attribute these cognitive faculties to other actors can be assessed using action identification paradigms, in which observers select either mentalistic or mechanistic descriptions of targets' actions (Vallacher & Wegner, 1985). Although action identification overlaps conceptually with Theory of Mind, little is known about the neural or genetic correlates of action identification. We conducted an action identification paradigm with 15 healthy adults during fMRI scanning in a three-run event-related task. These adults completed the Autism Quotient scale upon completion of the task. We also assessed the relationship between action identification patterns and oxytocin receptor (OXTR) genotype in a separate group of adults. FMRI results revealed, consistent with prior findings, that mentalization was associated with higher level action identifications. The amygdala and extrastriate body area played a role in making higher level action identifications, particularly for more highly mentalized actors. Other structures involved in action identification included ventral premotor cortex, a region of the mirror neuron network, and the temporo-parietal junction. Autism Quotient results and genotyping results supported the link between action identification and Theory of Mind. A reduced tendency to make higher level identifications was associated with higher scores on the Autism Quotient and with the OXTR allele previously associated with autism. In conclusion, the current data provide evidence for neural and genetic correlates of action identification.

I98

COGNITIVE PROCESSES IN OLDER ADULTS: POTENTIAL IMPACT OF STRESS AND PHYSIOLOGICAL FUNCTIONING *Irina Fonareva[1,2], Daniel Zajdel[2], Megan Herting[1], Whitney McGee[1], Barry Oken[1,2]; [1]Oregon Health & Science University, Behavioral Neuroscience, [2]Oregon Health & Science University, Neurology* – The degree of cognitive deficits varies considerably among older adults, suggesting factors other than age might influence cognitive well-being. Stress level, sleep quality, and cardiovascular autonomic function, have been suggested as mediators of cognitive performance. We explored how these factors influence performance on tasks from different cognitive domains in a sample of older adults. Two groups of healthy seniors of both genders, caregivers for people with dementia and peers without caregiving responsibilities, completed cognitive battery including tests of episodic memory (Word Recall Task), processing speed (Attentional Network Task, ANT), and executive function (Stroop). Participants completed self-reports of stress level, sleep quality, and health status. Additionally, we objectively assessed sleep quality and autonomic physiologic measures including heart rate variability (HRV) using a novel ambulatory device allowing continuous recording of several EEG, ECG, and EOG channels for prolonged periods. Preliminary results revealed no differences in sleep quality parameters or HRV between the groups, but significantly increased self-perceived stress level in the caregiver group, $p=.002$. Using ANCOVA and controlling for age and stress level, we assessed differences in performance on the cognitive tasks between the groups. The analyses revealed that caregivers performed as well as controls on ANT but showed significantly more forgetting on the word recall task, $p < .03$, and made more errors during Stroop Color Interference test than controls, $p= .01$. Our results indicate that in older adults increased stress might mediate performance on critical cognitive domains such as episodic memory and executive function.

I99

AN FMRI STUDY OF SOCIAL COGNITION IN MEMBERS OF CONFLICT GROUPS *Emile Bruneau[1], Rebecca Saxe[1]; [1]MIT, Brain and Cognitive Sciences* – The majority of previous neuroimaging studies investigating cross-cultural social cognition have focused on groups that are not actively involved in conflict (e.g. Black and White Americans, Asians and White Americans). Psychological differences that may be contributing to inter-group conflicts around the world today, however, exist between groups that are both actively involved in conflict and not generally socialized to reconcile. To investigate differences in social cognition within individuals of conflict groups, we presented Arab, Israeli and control individuals with Arab and Israeli partisan statements about the Mid-

dle East, and control emotional/unreasonable and nonemotional/reasonable control statements unrelated to the Middle East. Subjects rated the 'reasonableness' of each statement during fMRI imaging. Random effects analysis revealed activation in the posterior cingulate/precuneus (PC) and dorsomedial prefrontal cortex (dmPFC) for unreasonable - reasonable control statements. Using these regions for ROI analysis of all subject groups, we found that activation in the dmPFC for Israeli partisan - Arab partisan statements correlated strongly with both individual response differences in 'reasonableness' of partisan statements and performance on an Israeli-Arab Implicit Association (IAT) test. PC activation was also significantly correlated with the difference in 'reasonableness' of partisan statements. These results suggest that discrete brain regions are involved in the processing of emotionally laden statements, and that these regions are called upon more when emotionally salient partisan statements from an antagonistic out-group are being considered, relative to in-group partisan statements.

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HUMAN BRAIN DYNAMICS ACCOMPANYING THE USE OF EGOCENTRIC AND ALLOCENTRIC REFERENCE FRAMES DURING SPATIAL NAVIGATION *Klaus Gramann[1], Julie Onton[1], Scott Makeig[1]; [1]Swartz Center for Comptational Neuroscience, UC San Diego* – To maintain spatial orientation during navigation, spatial information encountered from a first-person perspective is integrated into an egocentric reference frame. Concurrent development of an allocentric or map-like reference frame requires translation of this egocentric spatial information into a viewpoint-independent representation. We recorded high-density electroencephalographic (EEG) data during a virtual tunnel passage task in which near-equal numbers of subjects respond to a subsequent homing challenge in ways compatible with their predominant use of an egocentric or allocentric reference frame. Approaching and during tunnel turns, brain dynamics in temporal, parietal, and occipital cortex exhibited alpha band power decreases, while upper alpha and beta band power increased in somatomotor and theta band power increased in medial frontal cortex. Subjects responding in a way compatible with adoption of an egocentric reference frame exhibited stronger alpha blocking in or near right primary visual cortex, while subjects whose responses were compatible with maintenance of an allocentric reference frame exhibited stronger alpha blocking, implying more intense activation, in occipitotemporal, parietal, and retrosplenial cortical areas known to support visuospatial orienting. Differences in EEG dynamics associated with the use of distinct reference frames during path integration thus include early visual, visual motion, and parietal areas, with additional activation in or near retrosplenial cortex associated with translating egocentric and allocentric information into complementary reference frames. The results confirm and extend results of functional brain imaging studies and demonstrate use of EEG imaging to track brain dynamics during navigation.

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EEG DYNAMICS OF LEARNING IN SOCIAL CONTEXT *Ying Wu[1], Scott Makeig; [1]Swartz Center for Computational Neuroscience, UCSD* – Learning is both an individual and social process. This study investigates distributed EEG brain dynamics associated with the effects of social interaction on cognitive processes that are critical for learning. High density EEG (133 channels per subject) was recorded simultaneously from pairs of healthy adults as they played a computerized version of the card game, "Concentration," which involves finding matching pairs of hidden values by touching a card image in a grid displayed on a touch-sensitive screen. Players participated in four types of games: competitive, collaborative (versus the computer), and solo (playing or observing). Artifact-free EEG data were submitted to independent component analysis (ICA). Epochs were extracted from component activations time-locked to critical events, such as the appearance of a hidden card value. Event-related spectral perturbation (ERSP) transforms of each epoch were computed. In addition, a context vector was defined for each epoch to characterize socially and cognitively relevant features of the trial context, such as whether an uncovered hidden value yielded a matched or non-matching pair, whether it was selected by the player or partner, or whether it was selected in a competitive or collaborative game. Single-trial ERSPs and context vectors were combined, then concatenated, and then further decomposed by ICA into a set of independent context factors. We will discuss effects of social context (collaborative, competitive, and solo) on EEG dynamics accompanying performance and performance feedback during working memory and spatial learning.

1102

CAN IMAGINING OBSERVED BODY MOVEMENTS ENHANCE A NEUROMARKER OF SOCIAL COORDINATION: THE PHI COMPLEX? *Stanley Lunde[1], Anthony Carnevale Bonilla[2], Chloe Boyle[3], Mayra Estrada[3], Zachary Bogorad[3], Jennifer Torres[3], Raphael Bernier[4]; [1]Lanterman Developmental Center, Pomona, [2]University of California, Irvine, [3]California State Polytechnic University, Pomona, [4]University of Washington* – There is increasing evidence for a shared neural substrate (mirror neuron system) involving observed, imagined and executed motor activity. The "phi complex", a possible neural marker of human social coordination (Tognoli et al, 2007), purportedly interacts with the mirror neuron system and has been identified as two narrowband components oscillating in the 9-12 Hz range. This EEG study aimed to determine whether observing body movements can induce phi oscillations, whether imagining while observing might enhance phi, and the relation of phi with alpha and mu. Participants were presented forty 30s video clips of gross motor (swimming) and fine motor (piano playing) body movements as well as control video clips during 10 ~six minute blocks. They were instructed to imagine performing the movements during half of the trials. High-resolution spectral analysis (0.1 Hz steps) of electrical brain activity was necessary to detect the different spectral peaks of alpha, mu and phi. Phi is a lateralized centro-parietal component and thus was analyzed as the power difference between electrode pairs. As expected, both alpha and mu amplitudes decreased during the clips with body movements. Phi tended to increase. It was difficult to detect phi in a number of participants. Participants that played piano exhibited the largest phi, which was enhanced during their imagine condition. Elaborating the roles of mu and phi as components of the mirror neuron system may increase our understanding of social behavior and of neurodevelopmental disorders such as autism.

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NEURAL CORRELATES OF INCONGRUITY-RESOLUTION AND NONSENSE HUMOR *Andrea C. Samson[1], Christian F. Hempelmann[2], Oswald Huber[1], Stefan Zysset[3]; [1]University of Fribourg, Psychology, [2]Hakia, Inc., New York, NY, [3]NordicNeuroLab AS, Bergen, Norway* – Cognitive processes of humor comprehension and appreciation are influenced by stimulus characteristics. The resolvability of the incongruity is an important structural stimulus characteristic of humor as it correlates strongly with certain personality characteristics whether incongruity-resolution or nonsense humor is preferred. By means of functional magnetic resonance imaging the present paper analyzes the neural correlates of processing and appreciating incongruity-resolution and nonsense cartoons. In the processing of incongruity-resolution stimuli the incongruity of the joke is largely resolvable, whereas in nonsense stimuli it is only partially resolvable and more incongruity remains. 30 incongruity-resolution and 30 nonsense cartoons were presented to 17 participants in the scanner. The results revealed that the anterior medial prefrontal cortex, bilateral superior frontal gyrus and temporo-parietal junction (TPJ) show more activation during processing of incongruity-resolution than of nonsense cartoons. These differences indicate that processing of incongruity-resolution cartoons requires more integration of multi-sensory information and coherence building, as well as more mental manipulation and organization of information. In addition, less self-reference might be established in nonsense cartoons as it is more absurd and more often deals with impossible situations.

I104

POWER FUNCTIONS DESCRIBE DYSFUNCTIONS OF AN INTERNAL CLOCK *Elaine Wencil[1,2,3], H. Branch Coslett[1,2,4], Anjan Chatterjee[1,2,4]; [1]University of Pennsylvania, Center for Functional Neuroimaging, [2]University of Pennsylvania, Center for Cognitive Neuroscience, [3]University of Pennsylvania, Psychology, [4]University of Pennsylvania, Neurology* – Power function relationships describe normal psychophysical judgments of magnitude estimates, including duration judgments. Such functions can be used to quantify deficits precisely, exemplified by reduced exponents observed in neglect patients' judgments of spatial extent. Since similar networks have been implicated for spatial and temporal processing, we use power function analyses to test the hypothesis that damage to cortical regions such as posterior parietal cortex would impair temporal judgments. Changes in the pulse width within a putative clock mechanism would alter the constant and dysregulation of the accumulator would alter the exponent of these judgments. Sixteen patients with right middle cerebral artery distribution lesions performed a temporal production task. Each trial began with the presentation of a blue square containing a number ranging from 4-15. Participants indicated when the duration (in seconds) corresponding to that number had elapsed. Patients' performances were described by a range of functions; constants varied from 0.43-3.27 and exponents varied from 0.43-1.12. Voxel lesion symptom mapping revealed that changes in each component of these power functions had distinct anatomical correlates. Specifically, 1) a lesion in the posterior superior temporal gyrus correlated with increased constants; 2) lesions in posterior superior temporal and angular gyri correlated with decreased exponents and 3) lesions in posterior and anterior superior temporal, middle and inferior frontal and angular gyri correlated with increased variability. Damage to posterior superior temporal gyrus appears to disrupt the pulse width while damage to the posterior temporal and inferior parietal cortex appears to dysregulate the accumulator in interval timing.

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The Arts in Psychotherapy 77 (2022) 101872

Contents lists available at ScienceDirect

The Arts in Psychotherapy

journal homepage: www.elsevier.com/locate/artspsycho

Development of a music therapy micro-intervention for stress reduction

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ARTICLE INFO

Keywords:
Music therapy
Stress
Arousal
Micro-intervention
Literature Review
Delphi Method

ABSTRACT

Negative stress is a serious risk factor for the onset and progression of a wide range of physical illnesses and emotional problems. In the literature, an increasing examination of music therapy interventions for stress reduction over the past decade is seen, yet music therapy interventions for stress reduction have not been systematically developed and described. Moreover, there is a growing need for *micro-interventions*, which are defined as short-term interventions in which the therapist uses specific therapeutic techniques to work on a client's goals. In this study, a music therapy micro-intervention for stress reduction was developed based on both empirical and practice-based knowledge. First, the micro-intervention was described based on both findings from empirical studies ($N = 52$) focused on the effects of music therapy on stress reduction, and from a previously conducted focus group study focused on the perspectives of music therapists. Second, the Delphi technique was applied to collect feedback on the micro-intervention described, by surveying a panel of 16 music therapy experts. This procedure resulted in an improved description of the music therapy micro-intervention for stress reduction, including a receptive and an active intervention variant. Implications for clinical practice and recommendations for future research are discussed.

Introduction

The negative impact of stress can be a serious risk factor for the onset and progression of a wide range of physical and emotional problems (American Psychological Association [APA], 2017; Australian Psychological Society [APS], 2015). It is well known that music can provide relaxation and calmness, which ensures that music therapy interventions are increasingly used to reduce stress and enhance the well-being of clients across a variety of clinical populations (Agres et al., 2021; Bainbridge et al., 2020; Juslin & Västfjäll, 2008; de Witte et al., 2020). Several reviews show positive effects of music therapy interventions on stress reduction (e.g. Bradt, Dileo, Magill, & Teague, 2016; de Witte, da Silva Pinho et al., 2020; de Witte, Spruit et al., 2020; Landis-Shack, Heinz, & Bonn-Miller, 2017; Martin et al., 2018; Pelletier, 2004). However, no specific music therapy intervention for stress reduction has yet been systematically described or protocolized. From a scientific point of view, clear intervention descriptions are needed to further investigate what is effective in music therapy interventions (Hoffmann et al., 2014).

The impact of stress

In daily life, almost everyone experiences stress from time to time. In the short term, stress can lead to reduced concentration and difficulty learning new information (The American Institute of Stress, n.d.). Long-term stress can lead to psychopathology such as anxiety disorders, depression, addictions and burnout (Akin & Iskender, 2011; Pittman & Kridli, 2011; Wang, Wang, & Wang, 2019), as well as to health issues,

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https://doi.org/10.1016/j.aip.2021.101872
Received 25 June 2021; Received in revised form 10 November 2021; Accepted 27 November 2021
Available online 1 December 2021

such as high blood pressure, cardiovascular disease, insomnia and an increase or decrease in weight (Bally, Campbell, Chesnick, & Tranmer, 2003; Keech, Cole, Hagger, & Hamilton, 2020; Pittman & Kridli, 2011). To cope with stressors, millions of people around the world use tranquilizing medications, which are associated with numerous contraindications and negative side effects (e.g., Bandelow et al., 2015; Olfson, King, & Schoenbaum, 2015; Puetz, Youngstedt, & Herring, 2015). It is therefore important to develop and examine promising non-pharmacological interventions for the prevention and management of stress, such as experiential approaches which focus on the "here and now" while guided by a therapist through stress responses and real-time emotional regulation. Through safely structured active experiences, stress inducing situations can be co-navigated, and stress reducing strategies can be developed and/or practiced (de Witte, Bellemans, Tukker, & van Hooren, 2017; de Witte, da Silva Pinho et al., 2020).

Music therapy for stress reduction

Music therapists are specifically trained to use the unique qualities of music, also known as musical components, (e.g., melody, rhythm, tempo, dynamics, pitch) in the therapeutic relationship to work on the patient's treatment goals (Bruscia, 1987; de Witte, da Silva Pinho et al., 2020; Wheeler, 2015). During music therapy sessions, music therapists attune to the patient by adjusting the way of music-making as an *immediate response* to the client's needs (Aalbers et al., 2019; Magee, 2019). This can be related to the term "synchronization," meaning that the music therapist and the patient interact simultaneously and are regulated through time, yielding a similar expression in movement, matching pulse, rhythm, dynamics and/or melody (Aalbers et al., 2019; Bruscia, 1987; de Witte, da Silva Pinho et al., 2020; Schumacher & Calvet, 2008). For example, the music therapist may influence patients' perceived stress during musical improvisation by synchronizing with the patient's music-making, subsequently changing the musical expression by playing slower and less loudly (de Witte, da Silva Pinho et al., 2020). This specific form of patient-therapist attunement is commonly used in music therapy practice and refers to the so-called Iso Principle (e.g., Altshuler, 1948; Heiderscheit & Madson, 2015). The literature shows that the tempo and loudness are important for the experienced intensity of the music (Gabrielsson & Lindström, 2010), and music with a slow steady rhythm may provide stress reduction by altering inherent body rhythms, such as heart rate (Thaut & Hoemberg, 2014; Thaut, Kenyon, Schauer & McIntosh, 1999). Thus, the stress reducing effect of music therapy interventions can be explained by music itself as well as the continuous attunement of music by the music therapist to the individual needs of a patient.

There has been a rapid increase of research on the effects of music therapy on stress reduction. Results of a recent meta-analytic review (de Witte, da Silva Pinho et al., 2020), including 47 quantitative controlled studies, showed an overall medium-to-large effect of music therapy on stress-related outcomes ($d = 0.723$, [.51–0.94]). This is in line with previous reviews and meta-analyses, which show positive effects of music interventions on the reduction of stress or state-anxiety (Bradt & Dileo, 2014; Bradt, Dileo, & Shim, 2013; Bradt, Dileo, Grocke, & Magill, 2011; Bradt, Dileo, Potvin et al., 2013; Carr, Odell-Miller, & Priebe, 2013; de Witte, Spruit et al., 2020; Gold, Solli, Krüger, & Lie, 2009; Kamioka et al., 2014).

The need for music therapy micro-interventions

In music therapy literature, the term "intervention" may refer to both a specified therapeutic action and a process of intervening characterized by a structured and coherent collection of therapeutic actions (Aalbers et al., 2019; de Witte, Lindelauf et al., 2020). Music therapy interventions may thus vary from one single technique or action within a single music therapy session to therapy programs or protocols consisting of multiple therapy sessions. In the last decade, there has been a growing recognition that one-size-fits-all approaches to intervention may be suboptimal for the patient and healthcare system alike (Gauthier et al., 2017; Rush et al., 2004). Moreover, it is assumed that intervention effects are variable across patients both in magnitude and time (Cuijpers et al., 2012; Kessler et al., 2017). This argues for the need to develop more flexible and more widely applicable interventions in accordance with the patient's needs, such as micro-interventions. A music therapy micro-intervention can be regarded as a short part of a session in which the music therapist uses specific therapeutic techniques or steps to work on specific patient's goals (Hakvoort & van der Eng, 2020; Hakvoort, 2020). Despite the fact that micro-interventions are short-lived, they have been systematically described and follow a step-by-step approach based on both recent theoretical models as well as the latest scientific evidence.

The development of music therapy micro-interventions is important to music therapy practice, on the one hand because the way of intervening in micro-interventions is strongly linked to core components of music therapy, on the other hand because describing interventions helps to further develop the profession. As the level of a clients' perceived stress can differ from session to session, it is important that music therapists can respond directly to their clients' stress levels, at the time it is needed in the specific context of that moment. This fits well with the specific way of patient-therapist attunement widely used in music therapy and which can be seen as one of the main characteristics of music therapy. Therefore, short-term therapeutic interventions that align easily with the existing structure of the session or clients' musical preferences are particularly suitable. Describing micro-interventions may also stimulate transferability of valuable clinical practices which in turn may strengthen thinking about the relationship between clinical practice, theory, and research (Aigen, 1999; Smeijsters & Vink, 2006; Stige, 2015).

Purpose of the present study

In the literature, we have seen an increasing examination of music therapy for stress reduction in the last decade (de Witte, Spruit et al., 2020; de Witte, da Silva Pinho et al., 2020). In addition, there is a growing need for music therapists to be more explicit about their' tacit knowledge in order to create more transferability in the way they work on a client's stress relief (see also: de Witte, Lindelauf et al., 2020). Without these descriptions, music therapists face difficulties in reliably implementing interventions in their clinical practices and researchers can experience difficulties replicating studies (Hoffmann et al., 2014). By developing a micro-intervention in this context, we are in line with the recent developments in healthcare that emphasize the importance of short-term and flexible therapeutic interventions in general. In addition, the development of a micro-intervention is an important first step towards achieving more insight into which specific therapeutic factors lead to change, which is becoming increasingly important in the field of music therapy research (de Witte et al., 2021).

In order to provide a comprehensive analysis of music therapists' stress-reducing interventions, it is necessary to integrate the available practice-based knowledge. Published trials often demonstrate a lack of transparency in reporting detailed information on the content of the music therapy interventions (Aalbers et al., 2019; Robb, Carpenter, & Burns, 2011). This is also evident in the recent meta-analysis by de Witte, da Silva Pinho et al. (2020) in which the included studies mainly examined receptive (music listening) interventions, whereas in daily practice music therapists prefer to use active (music making) interventions to reduce their clients' stress (de Witte, Lindelauf et al., 2020). In addition, developing a music therapy micro-intervention through an iterative process aimed at integrating theory-based, evidence-based, and practice-based knowledge is consistent with how other creative arts therapy interventions have been successfully developed (e.g., Aalbers et al., 2019; Bellemans et al., 2018; Haeyen, van Hooren, Dehue, & Hutschemaekers, 2017). The main purpose of the present

study is therefore to provide a detailed description of a music therapy micro-intervention for stress reduction, which can be used directly by music therapists as well as provide a clear basis for future research.

Method

In this study, two developmental phases can be distinguished, namely, (a) describing the micro-intervention by analyzing and integrating the perspectives from both literature and clinical practice, and (b) consulting experts in the field of music therapy to reach consensus on the content and application of the micro-intervention developed. See Fig. 1 for the procedural diagram of the method of the current study.

Phase 1: the development of the micro-intervention

We used a recently developed format by Hakvoort and van der Eng (2020) to describe the micro-intervention as this was particularly designed for describing music therapy micro-interventions. The use of this format ensures a comprehensive and detailed description and encourages a grounded scientific rationale. The format consists of several sections that must be described, such as specification of the target group, treatment domains, function of music, requisites, therapeutic attitude, the scientific / theoretical foundation, and a stepwise description of the micro-intervention.

Describing the rationale

To describe a theoretical rationale for the use of the music therapy micro-intervention, we needed both to clearly understand the problem of stress as well as a framework for how music therapy leads to stress reduction. To make both the origins and consequences of stress more concrete, we searched for literature in common online databases.[2] To provide a theoretical framework on the relationship between music and stress, we mainly used the rationales of two recent meta-analytic reviews on the effects of music interventions and music therapy on stress-related outcomes (de Witte, Spruit et al., 2020; de Witte, da Silva Pinho et al., 2020). Both studies can therefore be regarded as providing key input to describing the scientific rationale for the micro-intervention. In addition, the introductory sections of the empirical studies on the effects of music interventions on stress included in the analysis of this study, were screened for additional theoretical background information.

Analyzing Intervention Descriptions based on Literature

The following step involved analyzing the *intervention descriptions* of 52 empirical studies examining the effects of music therapy interventions on stress-related outcomes to create a solid basis for the content of the micro-intervention. The majority of the studies ($n = 47$) correspond to those included in the recently performed meta-analysis by de Witte, da Silva Pinho et al. (2020). The primary aim of this earlier study was to demonstrate the overall effect of music therapy interventions on stress-related outcomes, in which a detailed analysis of the interventions examined was not taken into account. In this study, we therefore provide an in-depth analysis of particularly the *content* of the music therapy interventions examined. Five studies were initially excluded in the meta-analysis due to lack of quantitative data, however, we included them for the purpose of our study. The included studies concerned both clinical controlled trials (CCT) and randomized controlled trials (RCT) conducted in medical and mental health care settings, examining the effects of music therapy interventions on physiological and/or psychological stress-related outcomes. Only those studies in which a trained and qualified music therapist offered the intervention were selected. See De Witte, da Silva Pinho, et al. (2020) for more information about the applied search strategy and selection criteria; an overview of the characteristics of the 52 studies included in our study can be found in the Supplemental materials.

We then analyzed the extracted intervention descriptions using the coding principles of qualitative content analysis, which is frequently applied to answer questions such as what, why, and how, whereby the common patterns in the data were deduced using a consistent set of codes to organize text into identified categories of similar meanings (Cho & Lee, 2014; Moretti et al., 2011). To first gain more insights into how the initial data related to the particular sections of the format for the micro-interventions described by Hakvoort and van der Eng (2020), the open codes were grouped into “interventions and methods”, “non-musical interventions”, “preconditions”, “instruments and genres”, and “treatment goals”. Open codes either identical or very similar to each other were then grouped, such as “patient chooses song”, “patient selects songs” and “patient chooses music”. If a code could not be merged with others, we left it separate. This axial coding step led to the categorization of codes based on their overarching similarities to property levels (Corbin & Strauss, 2008).

Integrating practice-based data

After the analysis of intervention descriptions, the next step was the examination of practice-based knowledge, as outcome studies do not always reflect clinical practice in all its facets. For this purpose, we used an existing dataset of a previous qualitative study. The aim of this particular study was to gain insights into how music therapists reduce their clients’ stress, especially in people with mild intellectual disabilities. It consisted of three focus groups held in three different countries in which 13 music therapists participated (see de Witte, Lindelauf et al., 2020). The data from this study was transcribed and open coded by topic. The topic “interventions used within the music” proved particularly relevant for purposes of the present study. The open codes were extracted and then added to the initial categories that emerged from the analysis of the intervention descriptions from the literature.

Analysis of combined data

Due to the differing amounts of data, the categories consisting of either at least 4 codes from intervention descriptions from the empirical literature or at least 2 codes from the practice-based data were included as an *intervention component*. The categories formed by practice-based codes only were counted twice compared to those from the literature. Selective coding was then applied to create an integrated model in which those categories of intervention components could be linked to each other to interpret the steps of the micro-intervention (Charmaz, 2003). To minimize possible bias on the part of the researcher who analyzed the data, the entire process of data analysis was continuously monitored by two co-authors (SH and MDW) and decisions were made in consensus to ensure that the confirmability criteria were met.

Description of the micro-intervention

Based on the analyzes of the empirical literature and the qualitative data, the micro-intervention was described following Hakvoort and van der Eng (2020), consisting of a theoretical rationale, intervention goals, type of setting, treatment phase in which it can be applied, and contraindications. In order to further shape the specific intervention content, we used the integrated model of intervention components that emerged from data analysis. To establish consensus on the summarized narratives, we organized a final member check of a subgroup of the research team (MdW, AK, SvH).

[2] PubMed, PsycINFO, Web of Science, Wiley Online Library, ScienceDirect and Google Scholar

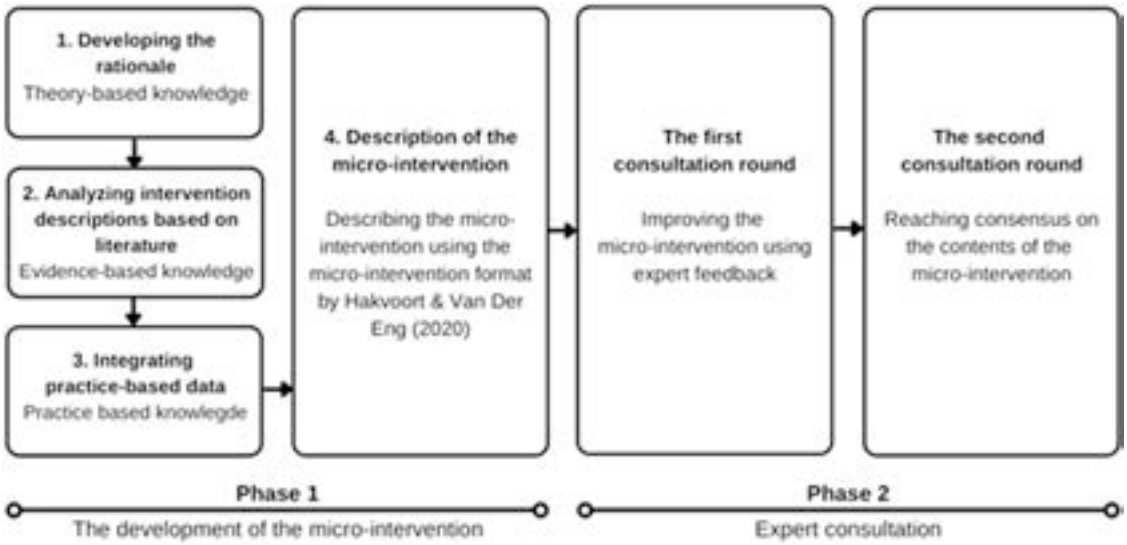

Fig. 1. Procedural diagram of the method.

Phase 2: expert consultation

In the second phase, the Delphi technique was applied in order to arrive at a group opinion by surveying a panel of experts, and to reach consensus through an iterative process of collecting feedback (Linstone & Turoff, 1975; McMillan et al., 2016; Skulmoski et al., 2007). As in other studies, we used a *modified* Delphi technique to better fit the objectives of the current study (Mullen, 2003; Wheeler et al., 2019). One of the modifications is that we did not use measures of central tendency and dispersion of the rankings by the respondents, which is usually reported in Delphi studies. Although the first consultation round collected individual rankings, the second round was sent by e-mail to check whether the adjustments made met respondents' expectations. Therefore, calculating central tendency and dispersion was not feasible in the present study (see also Wheeler et al., 2019). Another modification concerns the use of a structured questionnaire to obtain focused feedback from the respondents. Because the present study was designed to consult music therapists to strengthen the description of the micro-intervention, rather than to develop the intervention as a whole, a modified Delphi technique best suited our purposes.

Participants

Participants were sixteen music therapists and researchers in the field of music therapy. All had at least eight years of working experience as a music therapist. Six of them had already participated in one of the focus group interviews from our recent qualitative study (de Witte, Lindelauf et al., 2020). Ten participants were recruited through the international network of music therapists and researchers associated with Kenvak – a research center for arts therapies (www.kenvak.nl). Selected participants were located in four different countries, namely Belgium, Germany, the Netherlands and the United States. All participants gave informed consent and anonymity of the participants was ensured, both among the included participants and the researchers who analyzed the data.

The first consultation round

An online questionnaire[3] (available in Dutch and English) along with the described micro-intervention was sent to the experts. The questionnaire was focused on all sections of the described micro-intervention. For each topic, the level of agreement could be indicated with a four-point scale. In addition, the participants could add comments in each section, e.g. on reason of disagreements, new suggestions, and other feedback. In addition, the questionnaire included questions on the participants' professional background to gain more insights into their individual perspectives. The amount of agreement was calculated for each section. All suggestions and comments were listed in a file and analyzed by content. Then, every suggested change from the original micro-intervention description was discussed (MdW, AK, SvH) and decisions were made in consensus with each other. This procedure resulted in a renewed and improved description.

The second consultation round

For the second consultation round, the adapted version of the micro-intervention was sent again to the participants with a brief summary of the processed feedback and suggestions. They were asked to respond within two weeks if they disagreed with aspects of the new version of the micro-intervention.

Results

The first phase: the development of the micro-intervention

Describing the rationale

Identifying the problem of stress. In the short term, it is known that the negative impact of stress can lead to reduced concentration and difficulties when learning and memorizing new information (Schwabe & Wolf, 2010). As a result, working on treatment goals when the client is experiencing stress will be less effective and inefficient (de Witte, Lindelauf et al., 2020). It is therefore important to first reduce stress and tension so that the client is able to focus on the initial treatment goals. An overview of related health consequences of both long term and short term stress are described in the introduction of this study. A leaner narrative of this information is described in the format of the micro-intervention at "Specific domain that is targeted or treated" (see Table A.1 in Appendix).

Clarifying the stress-reducing effect of music interventions. Both music listening and music making/singing have been associated with a reduction of *physiological arousal* which increases during stress; this is

[3] The questionnaire can be requested from the first author.

visible in a reduction of cortisol levels or decrease in heart rate and blood pressure (e.g. Hodges, 2011; Koelsch et al., 2016; Kreutz, Murcia, & Bongard, 2012; Linnemann, Ditzen, Strahler, Doerr, & Nater, 2015; Nilsson, 2009). In addition, a large body of neuroimaging studies show that music can influence stress-related emotional states by modulating activity in brain structures, such as the *amygdala*, that are known to be involved in emotional processes (e.g. Blood & Zatorre, 2001; Hodges, 2011; Koelsch, 2015; Levitin, 2009; Moore, 2013; Zatorre, 2015). An increased dopamine activity in the mesolimbic reward brain system has been shown to be associated with feelings of happiness in response to listening to favorite/own-preferences music (e.g., Blood & Zatorre, 2001; Salimpoor et al., 2013; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011; Zatorre, 2015).

Plausible explanations for the positive effects of music interventions on stress, can also be sought in psychological and behavioral oriented scientific theories. Listening to pleasant music may have a positive influence on *emotional valence*, which can be explained by the degree of attraction that an individual feels towards a specific object or event (Jäncke, 2008; Juslin & Västfjäll, 2008). Music experienced as pleasant increases the intensity of emotional valence (the felt happiness), which has a stress-reducing effect (Jiang, Rickson, & Jiang, 2016; Rohner & Miller, 1980; Sandstrom & Russo, 2010; Witvliet & Vrana, 2007). Listening to music can also provide direct *distraction* from stressful feelings or thoughts (Bernatzky, Presch, Anderson, & Panksepp, 2011; Chanda & Levitin, 2013). Research that shows the benefits of music to distract people from aversive states is supported by short-term music interventions for acute stress reduction (de Witte, Spruit et al., 2020; Fancourt, Ockelford, & Belai, 2014; Linnemann et al., 2015). Lastly, music listening or music making together with others is also related to stress relief (Juslin, Liljeström et al., 2008). This can be explained by the fact that people synchronize with each other during music activities which evokes feelings of togetherness and social cohesion during the music experience (Boer & Abubakar, 2014; Linnemann, Strahler, & Nater, 2016). This in turn may be explained by the release of the neurotransmitters endorphin and oxytocin (e.g., Dunbar, Kaskatis, MacDonald, & Barra, 2012; Freeman, 2000; Tarr, Launay, & Dunbar, 2014; Weinstein, Launay, Pearce, Dunbar, & Stewart, 2016), which are positively associated with the defensive response to stress (e.g. Amir, Brown, & Amit, 1980; Dief, Sivukhina, & Jirikowski, 2018). A short narrative of these findings is presented in the format of the micro-intervention at "Function of music during the intervention" (see Table A.1 in the Appendix).

Analysis of the interventions from literature

Some of the included studies only offered limited descriptions of the examined intervention, whereas others offered detailed and rich intervention descriptions or even intervention protocols. However, each intervention description led to one or more open codes. Intervention descriptions showed both receptive interventions ($n = 22$), such as listening to live or pre-recorded music, as well as active interventions ($n = 10$), such as improvisation, playing existing songs, and songwriting. A combination of both receptive and active interventions was found in 20 of the intervention descriptions. In addition, in 20 of the studies, a complementary intervention/technique was offered along with music therapy, such as breathing exercises, muscle relaxation, and mindfulness exercises. In 38 intervention descriptions, the specific use of music (musical instruments or singing) was reported. Singing was mentioned in most studies ($n = 28$), followed by percussion instruments ($n = 21$), guitar ($n = 15$), and piano ($n = 10$). After the open coding step, categories were formed through axial coding by similar codes being grouped.

Integration of the practice-based data

Data-analysis of the focus groups indicated that the participating music therapists mainly use many active interventions (14 interventions) and few receptive interventions (one mentioned) for stress reduction. The active interventions included musical improvisation, playing existing music, songwriting, recording own music, and singing mantras or preferred songs. In addition, data showed that the following therapeutic techniques are most often used to reduce a client's stress: synchronization, pacing, structuring, increasing and decreasing dynamics and tempo, repeating themes, simple musical structures, and using familiar instruments and songs. The first coding step resulted in 33 categories and remaining single codes.

Analysis of the combined data

The final analysis resulted in a total of 14 categories of intervention components, which we present in order of the total number of codes counted: *music based on preferences* (10), *patient chooses song* (7), *expressing emotions* (5), *recording music* (4), *patient chooses intervention* (4), *therapist chooses intervention* (4), *verbal processing of emotions* (4), *using familiar songs* (4), *music based on emotional state* (4), *accelerating tempo* (4), *keeping appropriate physical distance* (4), *simplicity in harmony* (4), *slowing down tempo* (4), and *lower register* (4). These intervention components formed input for the further design of the micro-intervention.

Description of the micro-intervention

The next step was to describe the music therapy micro-intervention in detail. Information on the theoretical background of the problem of stress and the rationale for using music interventions to lower people's stress levels were added in the format for music therapy micro-interventions (Hakvoort and van der Eng, 2020). Then, the intervention goal, the target population and field, possible contra-indications, requisites, and specification of the setting, were supplemented. In order to remain as close as possible to the results of the data analysis, we described both an *active* and a *receptive* variant of the music therapy micro-intervention. This allows music therapists to choose the variant that best suits the client's needs and possibilities at that moment.

Because the micro-intervention is specifically designed to directly reduce the client's stress, i.e., in the music therapy session itself, the intervention goal was formulated as follows: "reducing tension and stress directly in the music therapy session". We consider the micro-intervention as transdiagnostic and therefore it does not only relate to the treatment of one specific condition or disorder. However, as research shows that some client populations are more vulnerable to stress, such as people with mild intellectual disabilities or those with impaired cognitive functions (e.g., Emerson, 2003; Scott & Havercamp, 2014), we expect that the music therapy micro-intervention might be particularly suitable for these client groups. Precisely because of this broad applicability and the fact that we developed two variants, there were no contra-indications. However, clients with severe autism, severe intellectual disabilities, or clients suffering from acute psychosis are expected to have difficulty participating because of their reduced ability to be in contact with the therapist. The main prerequisites for applying the micro-intervention include a sound-isolated room (especially in clinical settings), chairs for the client(s) and music therapist, access to a sufficient selection of musical instruments (active variant), and sheet music of the client's preferred music (receptive variant). Furthermore, the micro-intervention can be applied both individually and in groups. See the Appendix for more details of the abovementioned content of the micro-intervention.

All 14 intervention components were included in one of the micro-intervention variants (see Figs. 2 and 3). However, analysis showed that the intervention components "*patient chooses the intervention*" and "*therapist chooses the intervention*" appeared to contradict each other. If the client chooses the intervention, often used to appeal to client autonomy, it means that the therapist is not able to decide to use the micro-

Active variant:

1. The music therapist chooses to use the micro-intervention when the client indicates feeling stressed or tense, or when the therapist observes stress in the client [6]. The music therapist explains the micro-intervention and its purpose in clear language. The music therapist coordinates physical proximity in such a way that both the music therapist and the client have sufficient space, that there is a comfortable distance between them and that eye contact can be made [11].
2. The client and music therapist both choose an instrument [5] by which large dynamic variations can be made, such as a djembé, drum kit, piano or guitar. If this proves difficult, the therapist can suggest a number of instruments to choose from. If the music therapist chooses to use a harmonic instrument, the harmonies should be simple [12] and preferably played in the lower register [14].
3. The music tempo and dynamics are adjusted to the current stress level of the client [9]. Before proceeding with the micro-intervention, the music therapist checks whether the intensity of the music matches the client's current level of stress. If this is not the case, the music therapist adjusts the intensity based on observations and - when possible - instructions from the client.
4. If the music matches the client's stress level, the volume and music tempo will be increased evenly, such as when releasing/discharging [3, 10]. The client has a leading role in building up the music tempo and dynamics, and also determines when the intensity has reached a peak and can be reduced again [5]. The music therapist actively guides the client in this part of the intervention and helps to evenly bring the tempo back to 60-80 bpm and the dynamics to silence [13].
5. Afterwards, the music therapist and client discuss how the client experienced any tension during the intervention and how the stress has changed after the intervention [7].
6. The improvisation can be recorded and listened to [4] to reflect better, to indicate moments of tension and relaxation more easily, or to compare the intensity and course of the intervention in different sessions.

1. ~~Music based on preferences~~, 2. ~~Client chooses song~~, 3. Expressing emotion, 4. Recording music, 5. Client chooses intervention*, 6. Therapist chooses intervention, 7. Verbal processing of emotions, 8. ~~Using familiar song~~, 9. Music based on emotional state, 10. Accelerating tempo, 11. Keeping appropriate physical distance, 12. Simplicity in harmony, 13. Slowing down tempo, 14. Lower tonal register.

Techniques that have been crossed out do not apply in this variant.

Fig. 2. The active variant of the micro-intervention.

intervention. As music therapists use the micro-intervention precisely when it is needed to lower their client's stress levels, it is not possible to have the client choose the intervention themselves. However, to encourage client autonomy in another way, instead of letting them choose the intervention, we decided to offer them the choice of the song in the receptive variant and that they could take the lead role in the active variant by building up the music tempo and dynamics.

Receptive variant:

1. The music therapist chooses to use the micro-intervention when the client indicates feeling stressed or tense, or when the music therapist observes stress in the client [6]. The music therapist explains the micro-intervention and its purpose briefly. The music therapist coordinates physical proximity in such a way that both the music therapist and the client have sufficient space, that there is a comfortable distance between them and that it is easy to make eye contact [11].
2. The client chooses a song [1, 2, 5, 8]. If this proves difficult the music therapist can suggest a few songs or let the client choose from a song book. The music therapist plays the (if necessary simplified) chords [12] of this song on guitar or piano, preferably in the lower register [14]. The client is invited to listen.
3. The music tempo and dynamics are adjusted to the client's current stress level [9]. Before proceeding with the micro-intervention, the music therapist checks whether the intensity of the music matches the client's current level of stress. If this is not the case, the music therapist adjusts the intensity based on observations and - when possible - instructions from the client.
4. The music therapist can then choose to further increase the intensity of the music [10] and then decrease it, or to let the intensity be equal to the client's stress level and then gradually decrease the tempo to 60-80 bpm and the dynamics to silence [13].
5. Afterwards, the music therapist and client discuss how the client experienced any tension during the intervention and how the stress level has changed after the intervention [7].

1. Music based on preferences, 2. Client chooses song, 3. ~~Expressing emotion~~, 4. ~~Recording music~~, 5. Client chooses intervention*, 6. Therapist chooses intervention, 7. Verbal processing of emotions, 8. Using familiar song, 9. Music based on emotional state, 10. Accelerating tempo, 11. Keeping appropriate physical distance, 12. Simplicity in harmony, 13. Slowing down tempo, 14. Lower tonal register.

Techniques that have been crossed out do not apply in this variant.

Fig. 3. The receptive variant of the micro-intervention.

The second phase: expert consultation

The first consultation round

Analysis of the experts' feedback led to significant changes in the description of the micro-intervention.[4] Based on their suggestions, we added information, i.e. "voice" as one of the main instruments, allowing the client to experience the present stress before reducing it, specifying the therapeutic role and attitude with four functional domains, and the supporting role of the group when the micro-intervention is offered to just one of the group members. A note was added on contra-indications regarding clients suffering from trauma or anxiety disorders and on the function of the concepts "synchronizing" and "containing" which are related to stress reduction.

The second consultation round

The second round of consultation resulted in consensus among all experts, meaning that no further changes had to be made. The final description of the micro-intervention can be found in the Appendix.

Discussion

In our study, we systematically developed a music therapy micro-intervention aimed at stress reduction based on findings from theoretical and empirical studies as well as practice-based knowledge. The micro-intervention was developed for and evaluated by music therapists for use during the music therapy session when it is necessary to lower clients' stress levels. Although the micro-intervention does not relate only to the treatment of one specific condition or disorder and can be considered as broadly applicable, the literature indicates that some

[4] An overview of the feedback given can be requested from the first author.

client populations may benefit more due to their higher vulnerability to stress, such as people with mild intellectual disabilities (MID) or those with impaired cognitive functions (e.g., Emerson, 2003; Scott & Havercamp, 2014). For them, an experiential approach may be more appropriate than the cognitive approach (de Witte, Lindelauf et al., 2020; Didden et al., 2016). To our knowledge, this is the first study in which a music therapy micro-intervention has been systematically developed with the aim of direct stress reduction in the music therapy session.

Strengths and limitations of the present study

The way the micro-intervention was developed has several strengths. First, the systematic and comprehensive approach, which relied on data both from empirical studies as well as from clinical practice, resulted in a well-described micro-intervention. This approach has many similarities to the "Intervention Mapping" approach, a systematic method for the development, implementation, and evaluation of health interventions by constructing programs grounded both in theory and on empirical data (Bartholomew, Parcel, Kok, & Gottlieb, 2006). However, Intervention Mapping was originally designed to create larger or longer-term intervention and treatment programs (Bartholomew-Eldridge et al., 2016), and therefore does not fully align with the concept of micro-interventions, which are short-term interventions and can even be used as stand-alone techniques in existing treatment programs (de Witte, Lindelauf et al., 2020). Second, the inclusion of data derived from controlled outcomes studies (RCTs and CCTs: $N = 52$) offered a scientifically robust foundation for the core elements of the micro-intervention. This is relevant so that the basic claims made in the present study are clear (Aalbers et al., 2019; Crooke, Smyth, & McFerran, 2016). Moreover, the included outcome studies were derived from a recently conducted meta-analytic review (de Witte, da Silva Pinho et al., 2020) in which the inclusion criteria exactly matched the aims of this study. It can also be argued that this study strengthens the overall scientific basis of music therapy for stress reduction, as the previous meta-analysis looked primarily at effects using quantitative analyses, while in this study we qualitatively analyzed the content of the intervention, thus answering the *how* music therapeutic interventions can lead to stress reduction. Third, in the second phase of this study, the micro-intervention was submitted for consultation to music therapy experts from different countries in order to reach consensus in a collaborative process. Thus, thanks to this expert evaluation, the micro-intervention does not rely solely on pre-existing data. This strengthens its generalizability and makes it more plausible that the micro-intervention can be implemented easily in clinical practice.

Some limitations need to be noted. Through the years, several theoretical models have been developed to provide insights into the influence of music on stress. One of the most widely used models of the last decade involves models rooted in biological and neurological theories, so we also used these models to provide theoretical explanations of the relationship between stress and music. These models formed the basis of two earlier meta-analytical reviews of music interventions for stress reduction (de Witte, Spruit et al., 2020; de Witte, da Silva Pinho et al., 2020). However, we are aware that the general construct of stress integrates many scientific fields, in which both environmental, psychological, and biological/physical factors are interrelated within a comprehensive framework (Aldwin, 2007; Cohen, Janicki-Deverts, & Miller, 2007). In this sense, the strength of exclusively including intervention information from controlled outcome studies can be seen as a limitation; information on the content of interventions can also be obtained from less robust designs, such as case studies or one group designs. However, the importance of analyzing intervention content that demonstrates positive effects was paramount in our study. Related to the previous, the data from this large number of outcome studies mainly showed descriptions of receptive interventions, while the practice-based data almost exclusively showed active interventions. This may indicate a gap between what is applied in clinical practice and what is investigated in robust research designs (de Witte, Lindelauf et al., 2020). However, it may also be related to the context of a specific target group, such as clients with MID, who were central in the practice-based data. Because we wanted to stay as close as possible to the initial data, this led to the development of two different variants of the micro-intervention: the active and the receptive variant (see Figs. 2 and 3).

Recommendations for future research

Clear intervention descriptions are needed to further investigate what is effective in music therapy interventions (Hoffmann et al., 2014). Future research should focus on whether the developed music therapy micro-intervention for stress reduction does lead to stress reduction during the session. However, methods that can measure the direct effects of the micro-intervention on stress-related outcomes will be needed. Previous reviews of stress measures show that many researchers emphasize the importance of measuring stress outcomes related to both physiological arousal as well as to people's subjective experiences (Scott and Havercamp, 2014; de Witte, Spruit et al., 2020; de Witte et al., 2021).

As it is still unclear *how* and *why* music therapy interventions lead to certain outcomes such as stress reduction, more research on therapeutic factors[5] is needed to further develop music therapy micro-interventions. In our micro-intervention, *music tempo* can be seen as one of the most important elements, and therefore we expect it to be an important therapeutic factor leading to stress relief. This is in line with previous research showing that music tempo can be considered one of the most significant moderators of music-related arousal and relaxation effects (e.g., Bringman, Giesecke, Thörne, & Bringman, 2009; de Witte, Spruit et al., 2020). We therefore recommend that future research includes a secondary research question that focuses on therapeutic factors, such as the tempo of the music, in order to increase knowledge not only regarding efficacy, but also regarding what contributes to these effects.

Micro-interventions also allow researchers to conduct a *micro-analysis* of specific parts of the music therapy session (Lee, 2000; Wosch & Wigram, 2007). The most important questions are: "what exactly happened and why?". Through micro-analysis, therapy processes can be better understood or clarified, for example by analyzing the musical activity, social interaction, or nonmusical behavior of a short segment of a session (Wosch & Wigram, 2007). Micro-interventions are therefore highly suitable for pinpointing specific therapeutic factors that cannot be examined when testing over a larger period of time (de Witte et al., 2021).

Implications for clinical practice

Micro-interventions lend themselves well to music therapy practice because of their flexible character and the way in which the therapist can respond to the client's needs in the moment itself. By offering a musical frame, any musical expression produced by the client can be musically encouraged and responded to in a musical dialogue (e.g., Aigen, 2005; MacDonald, Kreutz, & Mitchell, 2013; Nordoff & Robbins, 1965). Most components of our developed micro-intervention are strongly related to certain therapeutic factors of music therapy, namely "musical dialogue" and "shared musical experiences". Other important therapeutic factors concern the structuring nature of music, such as tempo. A recent review shows that it is precisely these therapeutic factors that are often associated with positive change in music therapy (de Witte et al., 2021). In addition, the content of the micro-intervention is also in line with Bruscia's (1987) principles, who developed 64 musical

[5] Therapeutic factors are those factors identified by empirical studies that lead to therapeutic change and are associated with particular outcomes (Kazdin, 2009; Elliot, 2010).

improvisation techniques based on using the unique qualities of music to establish or influence the musical dialogue with the client; these still form the basis of global music therapy education. However, the concept of the micro-intervention provides more insights into (a) the needs and abilities of certain client populations that the intervention is focused on, (b) particular outcomes, (c) specific characteristics of the intervention, and (d) the underlying theoretical models that explain the relationship between music (therapy) and the targeted outcome. By describing this information, which is mainly subconsciously understood and applied by music therapists, it may stimulate them to strengthen the transferability of their clinical work and may provide more insights into the relationship between clinical practice, theory, and research (Aigen, 1999; Smeijsters & Vink, 2006; Stige, 2015).

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.aip.2021.101872.

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frontiers in
PSYCHOLOGY

ORIGINAL RESEARCH ARTICLE
published: 09 December 2010
doi: 10.3389/fpsyg.2010.00188

Effects of higher-order cognitive strategy training on gist-reasoning and fact-learning in adolescents

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Improving the reasoning skills of adolescents across the United States has become a major concern for educators and scientists who are dedicated to identifying evidence-based protocols to improve student outcome. This small sample randomized, control pilot study sought to determine the efficacy of higher-order cognitive training on gist-reasoning and fact-learning in an inner-city public middle school. The study compared gist-reasoning and fact-learning performances after training in a smaller sample when tested in Spanish, many of the students' native language, versus English. The 54 eighth grade students who participated in this pilot study were enroled in an urban middle school, predominantly from lower socio-economic status families, and were primarily of minority descent. The students were randomized into one of three groups, one that learned cognitive strategies promoting abstraction of meaning, a group that learned rote memory strategies, or a control group to ascertain the impact of each program on gist-reasoning and fact-learning from text-based information. We found that the students who had cognitive strategy instruction that entailed abstraction of meaning significantly improved their gist-reasoning and fact-learning ability. The students who learned rote memory strategies significantly improved their fact-learning scores from a text but not gist-reasoning ability. The control group showed no significant change in either gist-reasoning or fact-learning ability. A trend toward significant improvement in overall reading scores for the group that learned to abstract meaning as well as a significant correlation between gist-reasoning ability and the critical thinking on a state-mandated standardized reading test was also found. There were no significant differences between English and Spanish performance of gist-reasoning and fact-learning. Our findings suggest that teaching higher-order cognitive strategies facilitates gist-reasoning ability and student learning.

Keywords: adolescence, reasoning, low socioeconomic status/poverty, gist, cognitive training, education, middle school, higher-order cognition

INTRODUCTION

The ability for the United States to maintain a competitive edge in the global economy is dependent on the reasoning and critical thinking skills of this and future generations of students (Ravitch, 2010). Results from the Program for International Student Assessment (PISA), which provides international testing of reading, math and science literacy in 15 year old students, indicate that students in the United States are not performing as well as their peers in a majority of developed countries (U.S. Department of Education, 2010). Although there are multiple contributing factors, one commonly espoused cause is the over-emphasis on high-stakes standardized testing that relies on "information-in/information-out" processes (i.e., fact-learning or rote memorization) rather than fostering top-down cognitive processes such as reasoning (Ravitch, 2010). Students are primarily tested on how well they learn rote facts rather than evaluating how effectively they assimilate new knowledge with world knowledge to abstract meaning (gist meaning) and apply these meanings and concepts in novel ways to different contexts (Alberts, 2009; Chapman et al., in press). This emphasis on learning rote facts may actually motivate teachers to emphasize strategies to improve the recall of isolated information rather than the application of advanced reasoning principles when reading texts. Students in turn, come to rely on these narrow strategies for comprehension and predictably have difficulties in abstracting and generalizing what has been read. As McNamara et al. (1996) point out, everyday observation confirms the results of laboratory experiments that, in general, students do not like to expend the necessary effort for learning, and are all too easily satisfied with superficial understanding. In short, the current educational system focuses on teaching students "what to learn" rather than "how to learn."

A failure to develop adequate reasoning skills during adolescence may have a profound and lasting effect on the individual in college and throughout adulthood (Willingham, 2009). Research in cognitive neuroscience has identified adolescence as a pivotal developmental stage and critical window for acquiring reasoning and critical thinking skills in terms of both cognitive expansion and brain remodeling (Giedd et al., 2006). In particular, adolescence is the period of life when advanced reasoning skills should be developing and expanding, with continued sophistication and refinement in adulthood (Blakemore and Choudhury, 2006). The underlying neural substrates that support reasoning are undergoing dramatic growth during adolescence. Longitudinal

neuroimaging research reveals extensive brain development and remodeling, particularly in the frontal lobe networks, throughout adolescence and into early adulthood (Gogtay et al., 2004).The complex frontal neural connections which subserve reasoning skills also support higher-order cognitive functions such as problem solving, decision-making, reasoning, judgment, and planning, and are often referred to as "executive control functions" (Sowell et al., 1999; Bunge et al., 2005).

In an effort to advance reasoning and higher-order cognitive skills, research suggests explicit instruction may be beneficial (Pearson and Dole, 1987; Rosenshine and Meister, 1994; Alfasi, 1998; Alvermann, 2002; Phelps, 2005; Fletcher et al., 2006; Deshler et al., 2007; Alberts, 2009). Reduced reasoning competence is elevated in students from low socioeconomic status (SES) families (McNeil, 2005). Low SES has been associated with increased vulnerability of frontal lobe development (Kishiyama et al., 2009), as well as greater risk for academic failure and school dropout, especially for students of Hispanic descent (McNeil, 2005). The alarming dropout rates have motivated educators and cognitive neuroscientists to seek evidence-based studies driven by theoretical models to better evaluate practices that purportedly enhance reasoning and learning potential in the classroom.

In the present pilot study, we focus on gist-reasoning, a form of developmentally advanced reasoning that is pivotal to new learning as defined by Brainerd and Reyna (1990) and Reyna and Brainerd (1995) in their fuzzy trace model. According to fuzzy trace theory, new learning results in two forms of memory: verbatim and gist (Reyna, 2008). Memory at a verbatim level is represented by the explicit facts or concrete details. In contrast, gist-memory involves assimilating and interpreting incoming information at a generalized level of meaning. For example, in explaining what a student learned from a lesson, he or she could respond in one of two ways (Lloyd and Reyna, 2009). At a rote fact-learning level, the student conveys a listing or retelling of literal information, reproducing predominately the surface level meaning. At a gist-level, new information is integrated with previous knowledge to construct and abstract meaning, involving a process called gist-based reasoning (Chapman et al., in press).

Reyna and Brainerd (1995) and Brainerd and Reyna (1990) have synthesized extant empirical evidence supporting a theoretical basis that these two levels of memory, i.e., verbatim and gist, are encoded separately. According to their dual process fuzzy trace model, gist-memory, and precise memory for explicit facts operate independently. Regarding real-life school performance, the verbatim–gist distinction indicates there is not a direct correspondence between the two types of memory, such that an individual who has high memory for factual information may not necessarily have strong gist-reasoning skills. This dissociation between verbatim and gist appears to be counter to previously held notions derived from information processing theory which would predict that increased memory and higher-order cognitive skills, such as gist-reasoning would be linked (LaBerge and Samuels, 1974).

More recently, Reyna (2008) has proposed that when a relationship does exist between these two types of memory, it is more likely that gist-reasoning will shape the content of verbatim memory than vice versa, taking a more top-down processing, constructivism view. The empirical evidence suggests that an individual with higher gist-reasoning skills may demonstrate increased memory for details than an individual with lower gist-reasoning. In this model, verbatim memory is subordinated to gist-reasoning.

Despite educators' recognition of the importance of gist-based reasoning skills, there is little published evidence regarding objective, informative ways to assess these skills within school and classroom contexts (Ablin, 2008). Because of these limitations, our group developed the Test of Strategic Learning (TOSL©, Chapman et al., submitted) to assess gist-reasoning ability in the summarization of texts as well as the ability to remember facts presented in texts through probes. The task of summarization provides an informative way to characterize whether a student spontaneously uses verbatim fact-learning or gist-reasoning to condense information by abstracting meaning (Brown and Day, 1983; Brown et al., 1983; Kintsch, 1998, 2004; Chapman et al., 2006; Gamino and Chapman, 2009; Gamino et al., 2009a). For example, when asked to summarize a text, a student may spontaneously: (1) produce a summary by constructing global gist concepts, that condense and abstract meaning indicative of a top-down process or (2) produce a summary in a condensed verbatim fact-based version indicative of a bottom-up approach reflective of rote surface level learning (Chapman et al., 2006; Gamino et al., 2009a). The condensed, verbatim form of summary may reflect an ability to select the most important facts in a hierarchical manner, but not the ability to go beyond the surface level meaning (Chapman et al., 2006). The distinction between these two summary forms is relevant to previous research focused on training summarization through hierarchical information structure (Taylor and Beach, 1984) or concept mapping (i.e., the latter summary-types described below; Chang et al., 2002) versus the current approach targeting summaries comprised of abstracted meaning.

Whereas the fuzzy trace model states that gist-reasoning may involve various levels of abstraction (Reyna, 1998, 2008), we focus on a specific form of gist, namely gist-reasoning that evokes a deep level of meaning. Thus, we extend the construct of gist-reasoning as described by Brainerd and Reyna (1990, 1995) and Reyna and Brainerd (1995) to focus on a deeper level of meaning derived from complex information. As such, we conceptualize gist-reasoning at an abstracted level of meaning whereby ideas are combined over large sections of text through top-down cognitive processes (Chapman et al., in press). We propose that in order to produce abstracted gist meanings, one must first synthesize pertinent facts within the context of world knowledge and deduce the deeper implication of the information. The heightened capacity to integrate and consolidate information into more generalized/abstracted meanings is a remarkable ability in human cognitive development (Brown and Day, 1983; van Dijk, 1995a,b; Gabrieli, 2004).

In addition to Brainerd and Reyna (1990, 1995), Reyna and Brainerd (1995) and Gabrieli (2004), Chapman et al. (2004, 2006, in press) also suggest that gist meanings are more robustly stored and retrieved as compared to a rapid decline of memory for specific, isolated, concrete details, whether important or unimportant. Corroborating a distinction between fact-learning and gist-reasoning, we found empirical evidence of a disparity between fact-learning and gist-reasoning of text-based information in pediatric populations using the TOSL (Chapman et al., 2004, 2006, in press; Gamino et al., 2008, 2009a,b,c). We briefly summarize some of our findings regarding gist-reasoning and fact-learning that motivate the present study.

Children and adolescents with traumatic brain injury (TBI; Chapman et al., 2006; Gamino et al., 2009a) and those with attention deficit hyperactivity disorder (ADHD; Gamino et al., 2008, 2009a,c) showed comparable ability in basic fact-learning but significantly reduced abilities in gist-reasoning when compared to typically developing youth. In separate empirical studies, we found a dissociation between fact-learning and gist-reasoning skills in both students with TBI and those with ADHD (Chapman et al., 2001, 2005, 2006; Gamino et al., 2008, 2009a,b; Gamino and Chapman, 2009). The TBI populations across studies showed comparable performance on fact-learning tasks as compared to typically developing control groups. In contrast, we found a significantly lower performance on gist-reasoning as compared to typically developing control groups (Chapman et al., 2006; Gamino et al., 2009a,b; Cook and Chapman, in press). The pattern of relatively intact fact-learning indicates that youth with TBI recover the ability to encode details at a level comparable to typically developing adolescents. Moreover, in a longitudinal study of recovery from TBI, we found the ability to abstract gist meanings from text stalls and fails to show improvement when measured at intervals three years and longer after TBI. We described this delay as a neurocognitive stall in developing gist-reasoning (Chapman et al., 2006; Gamino et al., 2009a; Cook and Chapman, in press). Disruptions in frontal neural networks after TBI supporting higher-order reasoning have been implicated as a contributing factor (Levin et al., 1993).

Similarly, we found students with ADHD demonstrated impaired ability to produce gist meanings, whereas memory for facts was comparable to typical students (Gamino et al., 2008, 2009b,c). We postulated that the discrepancy between reduced performance of gist-reasoning and comparable performance of fact-learning is likely a result of the vulnerability of executive control that entails top-down processes found to be compromised in disorders such as ADHD. These findings motivated the question regarding the potential to mitigate or prevent impaired gist-reasoning in different groups through short-term intensive cognitive strategy training. For the purposes of this article we define top-down processing as the ability to spontaneously synthesize numerous details with prior knowledge to facilitate gist-reasoning. We define bottom-up processing as verbatim or paraphrased retell or recall of information without evidence of gist-reasoning.

To attempt to mitigate impaired gist-reasoning in these populations, we developed the Strategic Memory and Reasoning Training© (SMART©) program, at raining program designed to improve top-down reasoning skills (Chapman and Gamino, 2008). SMART is an intensive, 9–10 session program conducted over a 4-week period that specifically trains hierarchical cognitive strategies that support higher-order abstraction of meaning from incoming details and world knowledge. Thus, the training does not teach specific content for a test, but rather trains students to efficiently apply strategies to extract synthesized meanings from a wide variety of texts. The learning strategies are applicable to the content conveyed in a classroom course/textbook, a movie, on the Internet, or song lyrics. As such, SMART goes beyond basic reading and literacy programs in order to teach students how to think about information, such that the student learns to process information at a deeper level rather than surface level, "information in/information out." In short, the SMART program teaches students "how to learn" rather than "what to learn."

In a recent randomized study, we found that the SMART program improved gist-reasoning in youth with ADHD (Gamino et al., 2009b) compared to a control group of students with ADHD who received behavioral, attention training. At baseline testing, both groups performed similarly on gist-reasoning measures. After the training sessions concluded, children who participated in the SMART program significantly improved their gist-reasoning performance, whereas participants from the behavioral attention training did not. We gathered additional evidence for the efficacy of SMART in two summer "camp" sessions of SMART (Gamino et al., 2009c). Students with ADHD were found to improve their gist-reasoning ability after 10 sessions of SMART training in a small group setting.

Previous investigations have explored the effects of teaching higher-order thinking skills through summarization-type activities to improve learning in typically developing students (Brown et al., 1981; Palincsar and Brown, 1984; Taylor and Beach, 1984; Pearson and Dole, 1987; Malone and Mastropieri, 1992; Rosenshine and Meister, 1997; Chang et al., 2002; Kintsch, 2004). The existing evidence supports a view that strategy-based training improves learning, but the best metric remains unclear for measuring change. In fact, in Rosenshine and Meister's (1994) review of 16 studies addressing reciprocal teaching, they reported that significant differences between students receiving reciprocal teaching only and those who received explicit instruction prior to reciprocal teaching varied as a function of the type of assessment used. The results were typically significant when experimenter tests were administered and non-significant when standardized tests were used. While a number of more recent cognitive strategy studies have shown similar results using both types of measures to assess the impact of different reasoning strategies on student's ability to summarize information, predict outcomes; monitor comprehension, and apply gist-reasoning, the measures do not allow for the isolation of reasoning difficulties due to a lack of memory for specific events, difficulties due to an impairment in extracting synthesized meaning from complex text (gist), or both (see Alfasi, 1998; McMaster et al., 2005). This consistent finding may be explained by the fact that experimenter-designed assessments are typically based on tests and/or tasks that are similar to those used in the instruction (Alfasi, 1998).

It is unclear from previous studies if gains are greater for top-down compared to a bottom-up training protocol focused on fact-learning. Taylor and Beach (1984) compared the effect of training summarization skills based upon hierarchical information structure (i.e., identifying superordinate versus subordinate ideas) versus answering questions about main ideas and details on the ability to recall facts from written texts. The effect of the training protocols was measured, through responses to short answer probes, and an overall rating of quality in written expression. Results of their study revealed that both types of training (i.e., hierarchical summarization training and question–answer practice) significantly improved ability to correctly respond to short answer probes as compared to a control group. Also, both training types showed gains in the ability to recall information when writing as much as one could remember from a text about a relatively familiar topic. The hierarchical summary training group showed greater gains when compared to the control group on the recall of facts from an unfamiliar text

and on quality of written expression, but not when compared to the question-answer practice group. The researchers concluded that text structure training can improve both recall of unfamiliar texts and quality of writing; however limited learning benefits were found between training hierarchical summarization and training question answering. The failure to find differences between the two training protocols may be due to the fact that both focused on the explicit important and supporting details, with one elicited through summarization and the other through probe questions.

In a related but different approach from that of Taylor and Beach (1984), Chang et al. (2002) compared the benefits of three modified concept-mapping training protocols (i.e., concept map-correction, scaffold-fading, and concept map-generation; see Chang et al., 2002 for descriptions) on performance measures of fact-learning and summarization in fifth graders. Concept mapping involves constructing a graphic representation of the information according to its importance/hierarchy, which is related to the Taylor and Beach (1984) text structure approach. Fact-learning was measured via multiple-choice questions and summarization efficiency with the latter measured by dividing the number of major idea units by the total word count. The concept map-correction group showed significant improvements in fact-learning when compared to the concept map-generation and control groups. The scaffold-fading group showed higher performance on the summarization efficiency measure than the other training groups. Neither of the concept-mapping protocols appeared to mutually benefit both fact-learning and summarization skills on the employed metrics. Additionally, it is not clear if the metric of summarization efficiency corresponds to abstraction of meaning and higher-order thinking (Ulatowska and Chapman, 1994).

Palincsar and Brown (1984) published one of the first investigations of reciprocal teaching. In an elaborate study, the investigators incorporated summarizing strategies amidst reciprocal teaching for seventh and eighth grade students over the course of 20 training sessions. Reciprocal teaching involves trainers and students taking turns leading a discussion on the text's meaning. The students were asked to summarize what they had learned from a reading, and the teachers used the students' summaries to monitor comprehension levels. As above, the summarization training in this study entailed condensing the information to include predominantly explicitly stated information with a topic sentence that was either overtly stated or, if not present, constructed by the student with the inclusion of supporting facts. Beyond summarization, reciprocal teaching also incorporates questioning, clarifying, and predicting activities. Not only did Palincsar and Brown examine delivery of the training in student dyads, but they also tested the ability to train classroom teachers to deliver the reciprocal teaching intervention in a classroom setting. The researchers found the summarizing task the most helpful activity, demonstrating benefits in comprehension, maintenance of trained skills up to eight weeks post-training, and transfer to classroom learning. The investigators note that it was unclear whether the benefits were due largely to the reciprocal teaching approach, a single summarization strategy, or all were required to attain these benefits. Other researchers have conducted additional investigations of the efficacy of reciprocal teaching finding mostly significant results on experimental measures, with standardized measures showing less sensitivity to improvement (see Rosenstine and Meister, 1994 for review).

Additional evidence that summarization training may enhance learning is reported for students with learning disabilities (Malone and Mastropieri, 1992). In this study, summarization was trained in a method parallel to that described above by Taylor and Beach (1984) wherein the students were trained to write a summary sentence that represented who or what each paragraph was about by including the supporting core facts. An additional training condition consisted of summarization combined with self-monitoring through a check list of questions. Both of these training conditions were compared to a traditional instruction group where participants read the texts and answered fact-based questions. Both summarization training conditions achieved significantly higher levels of recall for specific information when immediately probed as compared to the traditional approach. The summarization training results also generalized to untrained material from a social studies text. However, the impact of the training protocols on higher-order thinking or reasoning was not directly addressed.

The previous theoretical and empirical data (Brown et al., 1981; Taylor and Beach, 1984; Palincsar and Brown, 1984, 1988; Chang et al., 2002) motivated the current study. The aforementioned studies examining or training summarization skills as well as others, indicate promise for enhancing learning ability (Brown et al., 1981; Taylor and Beach, 1984; Pearson and Dole, 1987; Palinscar and Brown, 1984, 1988; Chang et al., 2002; Ladewski et al., 2007). The current study expands previous studies by investigating the efficacy of top-down meaning abstraction training versus bottom-up rote memory training on enhanced performance of gist-reasoning and fact-learning in a group of inner-city eighth grade public school students, most of whom spoke English as their second language. Our study encompassed average students from low socio-economic families of largely Hispanic descent who were randomized into either a training group or a control group. The control group provided evidence for the efficacy of increased, affirmative adult interaction on performance. While summarizing skills were not directly taught to our training groups, we used summarization and directed probe questions to determine the efficacy of our cognitive training. Although previous studies have used summarization as a metric for improved cognition, it is not known if the metrics were based primarily on fact retrieval/recall or gist-reasoning abilities (Palincsar and Brown, 1984, 1988; Taylor and Beach, 1984; Rosenstine and Meister, 1994; Chang et al., 2002).

The current pilot study elaborates previous work by proposing and testing a metric of summarization using the construct of gist-reasoning that measures abstracted ideas that are not explicitly stated. To restate, gist-reasoning is the ability to derive global meaning from explicit details, entailing frontally mediated, top-down cognitive control processes. We propose that gist-reasoning operates independently from and is superior to rote fact-learning. Although gist-reasoning can operate independently from fact-learning one goal in the current study was to explore whether training strategies to abstract meaning benefit both recall of facts and gist-reasoning ability, as set forth in Reyna's fuzzy trace theory of a superiority of gist over fact memory (1998, 2008).

The present study was a randomized, controlled cognitive training trial. The primary goal was to compare the effects of two forms of training in a group of public middle school eighth grade students from low SES families of predominantly Hispanic

descent: (1) Strategic Memory and Reasoning Training and (2) rote memory training. In addition, we employed a control group to mitigate the influence of adult attention and interaction. We evaluated the effect of the two training protocols that used the same content and a control group on three tasks; (a) a measure of gist-reasoning ability, (b) a measure of direct recall of information from a text, and (c) a standardized measure of reading achievement. Another important goal of the study was to test the bidirectional impact of the two forms of training as compared with the control group. Specifically, we examined the impact of SMART and rote memory training on the ability to improve gist-reasoning and recall of facts. A final goal was to compare gist-reasoning versus fact-based recall ability after training between Spanish and English in a subset of students for whom Spanish was the primary language spoken at home.

METHODS AND MEASURES

PARTICIPANTS

Participants in the pilot study included 54 students (30 girls and 24 boys) in three sections of an eighth grade "advancement via individual determination (AVID)" class in an inner-city urban Texas public middle school. The students were recruited for this study by their teacher and through a letter to parents. The parents of the adolescents in the study signed informed consent and the students signed informed assent agreements as required by the University of Texas at Dallas Institutional Review Board for the protection of human participants. Parents of the students provided background information regarding household income, the adolescent's health status, and any diagnosis of learning disabilities. Based on the health status questionnaires, no student was reported to have sustained a brain injury, a diagnosis of ADHD, or other learning deficits. Six students had repeated a grade, and one child was reported as having been in a special education class previously. All but five students received free or reduced lunches, indicating low SES status for over 90% of the class. Additionally, the ethnicity of the class consisted of 93% Hispanic, 6% African American, and 1% Caucasian. The participants ranged in age from 13 to 15 years (see **Table 1**).

The Cognitive Abilities Tests (COGAT ®; Lohman and Hagen, 2001) was administered to determine the verbal and non-verbal reasoning abilities of the students prior to the commencement of the training programs. The COGAT is a norm-referenced standardized measure of cognitive abilities that are purported to be acquired through school and other environments. The cognitive abilities measured by the COGAT are related to successful academic achievement and were most recently normed in 2005. The COGAT has been validated against other standardized achievement tests and is group administered. Two reasoning measures (verbal and non-verbal) were used to determine whether the students who participated in the study fell within the typical range of cognitive development. The standardized scaled scores for the two administered subsections were used as an indicator of general cognitive ability and to control for the confound of atypical development.

The COGAT was administered and scored according to the instructions in the manual provided by the publisher. Standardized age scores were used to determine that the students were all within the normal range of development (see **Table 1**). The median percentile rank for the verbal and non-verbal composite was 40.

Table 1 | Demographic information by group.

Characteristics	Memory	SMART	Teen brain/control
N	18	18	18
Gender	Male: 8	Male: 8	Male: 8
	Female: 10	Female: 10	Female: 10
Age at baseline range	13–14	13–15	13–15
Mean (SD)	13.8 (0.73)	13.6 (0.70)	13.8 (0.51)
Socio-economic status	Free/Red.	Free/Red.	Free/Red.
	Lunch 17	Lunch 17	Lunch 15
Ethnicity	Hispanic 16	Hispanic 18	Hispanic 16
	African-Am. 2	African-Am. 0	African-Am. 1
	Caucasian 0	Caucasian 0	Caucasian 1
Cognitive abilities test			
Standard age score			
Verbal range	78–99	67–98	79–105
Mean (SD)	83.82 (7.39)	87.18 (7.34)	87.39 (6.81)
Cognitive abilities test			
Standard age score			
Non-verbal range	79–114	74–118	89–119
Mean (SD)	95.81 (8.67)	99.29 (13.3)	103.67(9.31)

MEASURES

Baseline measures were assessed 1 week prior to the commencement of the training programs. Outcome measures were assessed from 2 to 3 weeks after the conclusion of training (See **Table 2**).

Test of strategic learning

The Test of Strategic Learning (TOSL©; Chapman et al., submitted) was administered prior to training after randomization of the students into the three groups and 6 weeks later after the commencement of the training. The TOSL assessment tool provides a systematic method to evaluate developmental reasoning skills, in terms of both fact-learning and higher-order gist-reasoning of lengthy text-based information much like that encountered in a classroom setting (Chapman et al., 2001, 2006; Gamino et al., 2009a, b). The validity of the TOSL to measure higher-order thinking skills in general, and gist-reasoning ability in particular, has been established in prior studies (Brookshire et al., 2000; Chapman et al., 2004, in press; Anand et al., 2010; Vas et al., 2010). Gist-reasoning ability as measured by the TOSL has been associated with frontally mediated measures of executive function such as working memory, cognitive switching, and fluid reasoning (Brookshire et al., 2000; Chapman et al., 2006; Anand et al., 2010; Vas et al., 2010). No known standardized measure of abstraction of meaning for complex texts exists.

The TOSL provides two major scores relevant to measuring the ability to construct meaning from complex information. One score examines gist-reasoning ability through spontaneous production of gist concepts/abstracted meanings in a written summary, and the other measuring fact-learning through the ability to retrieve and convey important information from the texts. Gist-reasoning is measured through coding abstracted concepts conveyed through summarization of text-based information. Fact-learning is measured through recall via probe questions that require short answers

Table 2 | Baseline and post-training outcomes by group.

Group	Rote memory	SMART	Teen brain/control
N	18	18	18
Gist-reasoning range pre (age criterion 16)[+]	2–15	6–19	3–16
Mean (SD)	9.06 (3.95)	11.5 (4.15)	9.17 (4.0)
Gist-reasoning range post (age criterion 16)[+]	2–16	9–27	7–19
Mean (SD)	10.89 (3.72)	14.61 (5.33)*	10.89 (3.77)
Fact-learning range pre (out of 48 possible)	12–41	19–42	17–43
Mean (SD)	34.33 (8.39)	33.61 (6.08)	33.22 (6.91)
Fact-learning range post (out of 48 possible)	23–48	35–45	29–44
Mean (SD)	41.61 (4.35)*	40.61 (3.29)*	38.61 (3.6)
TAKS reading 2008 (seventh grade) total standardized range	1877–2438	1994–2532	1994–2400
Mean (SD)	2165 (145)	2230 (141.6)	2214 (101.18)
TAKS reading 2009 (eighth grade) total standardized range	1827–2467	2101–2734	2067–2579
Mean (SD)	2244.89 (185.6)	2347.5 (175)	2201.39 (157.46)
TAKS critical thinking Objective (eighth grade)[++]			
Range (out of 16 possible)	6–16	11–16	10–16
Mean (SD)	13 (2.97)	14 (2)	14 (1.86)

[+]*Age criterion based upon previous control studies.*
[++]*Used for correlation analysis.*
*$p < 0.05$.

regarding detail information from the text. The TOSL consists of three texts of increasing length and complexity (see Summary Examples from the Test of Strategic Learning (TOSL©) in Appendix for examples of students' summaries).

Administration. The students were assessed as a group in their classrooms using the TOSL. The assessment was completed during a 50-min class period. The TOSL consists of three texts to be summarized through written response. Following the summarization task, probe questions regarding information from the original text were administered.

The students were instructed regarding the qualities of a good summary. Specifically, they were told that a summary (a) is a shortened version of the original text, (b) conveys high level ideas while omitting unimportant details (c) is well-organized, and (d) contains enough information so that someone who had not read the information would have a good understanding of the global meanings conveyed in the original text. Subsequently, an example of a well-written summary comprised of gist-based ideas of a common fairy tale, "Little Red Riding Hood," was presented.

Following the instructions and example of a good summary, the first of three texts were presented orally and in written form for the students. Thus, each text was read out loud by the examiner while the text was simultaneously shown on a screen at the front of the classroom through an LCD projector to allow the students to read along as the examiner read. After reading, the displayed text was removed and the students were reminded that they did not have to give all the details but rather they needed to give a generalized summary that included high level ideas to show they were able to interpret the overall meanings conveyed through the text. The students' written summaries for the first text was collected after 10 min; the students were then given a form with eight written probe questions regarding important information from the text. The written answers to the questions were collected after 5 min. The same methodology was followed for three texts and the corresponding questions. The time allotment was based on our prior objective measurement that when writing summaries for the TOSL, more than 95% of students complete a summary within 6–8 min, and finish the written answers to the probe questions within 3 min. The controlled time for each portion of the TOSL allowed comparable time for each student and completion of the assessment during one classroom period. The students were reassessed with the TOSL in the same manner 2 weeks after the conclusion of the 4-week training programs.

Scoring. For the summary gist-reasoning score, a checklist scoring system was established from a normative sample in which one point is awarded for each accurate gist-based concept produced during summarization. Gist-based concepts represent abstracted/higher-order ideas and meanings that were not explicitly stated in the text but were derived through synthesizing the text information with world knowledge. The cumulative total score possible for gist-based reasoning across the three texts was 35. The rubric of 35 abstracted ideas across the three texts provides more accurate reliability between scorers, and was developed from data collected from previous studies. For the fact-learning scores, the written answers to the probe questions regarding the important information from the text were awarded 0, 1, or 2 points depending upon correctness and completeness of the answer. The cumulative score possible for fact-learning questions across the three texts was 48.

Reliability. Two trained raters scored each summary independently and were blinded to the group. Point-by-point reliability between the two raters was 92.7%, with all disagreements resolved through discussion and consensus. The corresponding questions had a

maximum possible score of 16 for each text. Point-by-point reliability between the two raters was 98.7% for the correctness of answers to the probes.

Spanish TOSL

A Spanish version of the TOSL was translated and administered by a native Spanish speaker/interpreter 2 weeks after the post-training English version of the TOSL had been administered. We used an identical method of administration and scoring for a subset of 25 students in the study whose families spoke predominantly Spanish at home. The Spanish-version TOSL assessment was given on a different day than the English-version TOSL post-assessment. The scoring method for the Spanish version of the TOSL was the same as stated previously for the English version. The students who agreed to take the additional TOSL in Spanish had participated in each of the three training groups. Six students from the SMART group, 12 students from the rote memory strategies group, and eight students from the control group participated in this secondary testing. The Spanish TOSL was administered one time after the conclusion of the training programs.

The Texas Assessment of Knowledge and Skills – critical thinking objective

The Texas Assessment of Knowledge and Skills (TAKS; Pearson Educational Measurement, 2003) is a state-mandated standardized test used in Texas primary and secondary schools to assess basic skill attainment in reading, writing, math, science, and social studies. The TAKS reading test is administered in grades three through nine and consists of four objectives: Basic Understanding, Applying Knowledge of Literary Elements, Using Strategies to Analyze, and Applying Critical Thinking Skills.

We used the TAKS reading test for two purposes; first, we used the students' reading TAKS scaled score performance to determine if the training had an effect on score improvement from seventh to eighth grade. Second, we used the students' Applying Critical Thinking Skills objective raw scores to ascertain if there was a relation between the objective and TOSL gist-reasoning scores. The Applying Critical Thinking Skills objective is the subset of 16 questions throughout the reading TAKS that, according to the Texas Education Agency (TEA) and the TAKS publisher, Pearson Educational Measurement, required complex understanding, inferential interpretation, and abstraction of deeper meaning. The Applying Critical Thinking Skills objective questions are interspersed throughout the test and consist of approximately 30% of the reading TAKS.

Administration and scoring. The TAKS reading test was administered by classroom teachers, as required by Texas law, and coincided with the conclusion of the training programs. The TAKS Reading test consists of multiple-choice questions scored by a computer. An overall scaled score of 2100 is considered passing and a scaled score of 2400 earns a "commended" rating.

TRAINING PROGRAMS

Prior to the TOSL administration, the students in three sections of eighth grade classes were randomized into one of three groups (n = 18), to determine the effect of the training conditions on gist-reasoning and fact-learning performance. The groups included (1) the SMART program, (2) a rote memory strategy program, and (3) a control group that learned information about the teen brain. There were 10 girls and 8 boys in each group. Neither the educator of the classes nor the students knew which group was one of the two training groups versus the control group. All three programs were developed to look similar to each other, with student manuals that provided information and pen and paper exercises to practice the training/information provided. The three programs were conducted by three trained researchers in separate classrooms to avoid cross-contamination between the groups of the content of the programs.

All three programs (SMART, Rote Memory Training, and the control group) encompassed nine, 45 min periods across 4 weeks of instruction. Two weeks after the conclusion of the training programs, the students were reassessed with the TOSL, using the same procedure for assessment as mentioned above. The students also completed the state-mandated TAKS reading test three weeks after the training programs.

Strategic Memory and Reasoning Training program

The SMART© (Chapman and Gamino, 2008) program was developed to train individuals to derive a deeper level of understanding by abstracting meaning from texts. The differential aspect of the SMART© program is that it focuses primarily on constructing abstracted meanings through reasoning. The middle school students were trained using this strategy-based program. The strategies include inhibition of extraneous information, inferencing, paraphrasing, and abstracting ideas through reasoning (Brown et al., 1981; Palincsar and Brown, 1984; Mayer, 1989; Chapman et al., 2004, 2006; Kane et al., 2004). Through practice, the students learned to strategically select relevant information in order to abstract and construct meaning through top-down processing extensively during the last four sessions of the training. Thus, the students learned to interpret and abstract meanings in the context of their own world knowledge (see Strategic Memory and Reasoning Training Stages and Sequence in Appendix for description).

The texts used in the program were similar to content that is typically encountered in English, literature, social studies, history, and science texts. The SMART© program is based upon cognitive neuroscience research of higher-order, top-down cognitive skills (Brown and Day, 1983; van Dijk and Kintsch, 1983; Mayer, 1984, 1989; Ulatowska and Chapman, 1994; Luck and Vogel, 1997; Chapman et al., 2004, 2006) and consists of hierarchical strategies that are explained and practiced through group exercises and pen and paper activities in a student instructional manual. The strategies taught over the course of 4 weeks are postulated to bolster cognitive processes that underpin reasoning and higher-order abstraction of meaning (Brown et al., 1981; van Dijk and Kintsch, 1983; Mayer, 1989; Kane et al., 2004; Tenenbaum et al., 2006; Beller and Kuhnmunch, 2007; Garcia-Madruga et al., 2007). The SMART program was validated previously with students with ADHD to teach specific cognitive strategies to enhance comprehension, interpretation, and abstraction of meaning (Gamino and Hull, 2009; Gamino et al., 2009a,b,c).

Rote memory training program

The rote memory training program is based on cognitive neuroscience research related to the basic properties of bottom-up memory processes. The materials used for the rote memory training imitated the SMART program in the use of the same texts and the presentation of activities in a student manual. The program was conducted using the same parameters as the SMART program, utilizing nine classroom sessions over the course of 4 weeks. The rote memory training program institutes direct instruction regarding basic memory strategies as well as the opportunity to practice the processes that extant research has established as important for improvement of memorization techniques. The memory strategies presented and practiced with pen and paper tasks include rehearsal (Cox et al., 1989), retrieval practice (Bjork, 1989), method of loci (Verhaeghen and Marcoen, 1996), and association (Graf and Schacter, 1985). Students practice using memory aids such as mnemonics, visualization (Marschark and Surian, 1989), and flash cards. Through practice, the students were expected to learn to use rote memorization strategies for verbatim recall of facts.

Teen brain information program

The teen brain information program is based on cognitive neuroscience research related to adolescent brain development (Giedd et al., 2006). The informational program is similar in presentation to the treatment programs with the incorporation of pen and paper exercises and activities included in a student manual. Likewise, the teen brain program encompasses nine classroom sessions over a 4-week period. The program includes adolescent-appropriate subjects regarding aspects of healthy brain development such as nutrition, adequate sleep, and physical fitness; as well as dealing with peer pressure; the negative effects of drugs, such as tobacco, alcohol, and illicit pharmaceuticals; and the risk of brain injury. Additionally, the program teaches the importance of managing stress, engaging in mental exercise, and prioritizing important life aspects (i.e., schoolwork and relationships with family and friends). The students learn the names and functions of various lobes of the brain and their functions. In addition, the students discuss various problems encountered in adolescence such as balancing parental and school expectations with peer relationships, as well as other salient subjects such as stress reduction.

ANALYSES AND RESULTS

We used SPSS and SAS (Version 9.2, SAS Institute, Inc., NC, USA) to analyze the data between groups with a single factor analysis of variance (ANOVA) and Chi Square. Post-training we used within group *t*-tests and *post hoc* Bonferroni adjustments to account for multiple tests to determine the significance of change scores within each group. Repeated measures ANOVA was preformed to determine the effect of group, Tukey comparisons were used to ascertain differences post-training, and Pearson correlations to determine the relation between TOSL scores and TAKS Applying Critical Thinking Skills scores. Alpha was set at 0.05. Baseline and post-training assessment outcomes are listed in **Table 2**.

BASELINE ANALYSES

After the students had been randomized into one of three groups (n = 18, 10 girls and 8 boys for each group), the baseline TOSLs were scored by trained raters who were blinded to group randomization. The scores were then analyzed to determine if there were statistically significant group differences prior to training in the ability to produce gist-based concepts or answer probe questions regarding important information from the text. An ANOVA failed to reveal significant differences across means of the three groups on the baseline TOSL measures of gist-reasoning ability ($F(2,51) = 1.72$, $p = 0.20$) and correct answers for probe questions regarding the text ($F(2,51) = 4.26$, $p = 0.54$, see **Table 1**). Chi-Square analysis failed to reveal differences in performance due to gender $\chi^2(2) = 0.45$, $p = 0.80$), and an ANOVA failed to reveal significant differences in age ($F(2,33) = 0.71$, $p = 0.41$) across the three groups. Demographic information for the participants is listed in **Table 1**, above.

An ANOVA failed to reveal significant differences between the groups on the COGAT verbal standardized age scores ($F(2,49) = 1.33$, $p = 0.27$) or the COGAT non-verbal standardized age scores ($F(2,47) = 2.22$, $p = 0.12$; see **Table 1**). Thus, the three groups were found to be equally matched for age, gender, gist-reasoning, fact-learning, and cognitive abilities prior to training. Pearson correlations were performed to determine the relation between baseline gist-reasoning scores from the TOSL and the COGAT composite verbal and non-verbal scores. We found a moderate but significant relation between baseline gist-reasoning score and COGAT verbal and non-verbal composite scores ($r(54) = 0.28$, $p = 0.05$).

POST-TRAINING ANALYSES

Test of strategic learning

To test the hypotheses that gist-reasoning scores would change between baseline and post-intervention assessments, a paired *t*-test for each group was performed, and *post hoc* Bonferroni

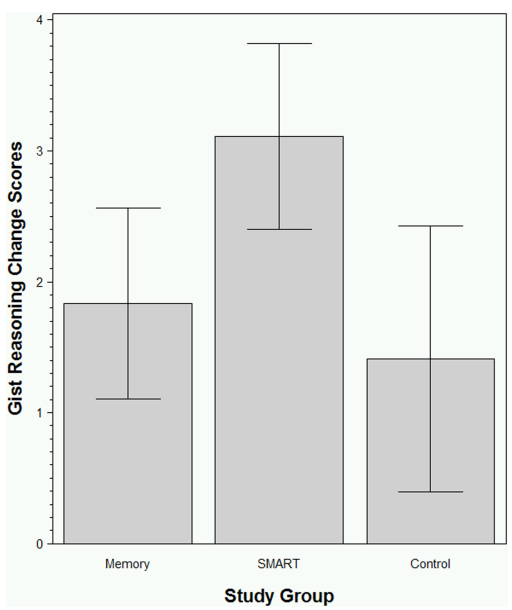

FIGURE 1 | Changes in gist-reasoning scores after training programs for each group. Groups: Memory, Rote Memory Group; SMART, Strategic Memory and Reasoning Training Group; Control, Teen Brain Information Group.

adjustments were made; adjusted p-values are reported. The results of these statistical tests indicated that there was a statistically significant increase in gist-reasoning scores for the SMART group ($N = 18$, $M = 3.11$, SD = 3.00, $t(17) = 4.39$, $p = 0.001$, $d = 0.73$). In contrast, the analyses failed to reveal a significant change in gist-reasoning scores for the fact-based rote memory group and for the control group ($N = 18$, $M = 1.8$, SD = 3.09, $t(17) = 2.52$, $p = 0.09$, $d = 0.33$, and $N = 17$, $M = 1.4$, SD = 4.18, $t(17) = 1.39$, $p = 0.55$, $d = 0.43$, respectively; see **Figure 1**). Only the English TOSL scores were used for the paired t-tests, as a small number of students from each group participated in the Spanish TOSL assessment administered post-training.

To determine the differences between the groups on gist-reasoning ability post-training, a repeated measures ANOVA and Tukey multiple comparisons were performed. The results indicate that there was a significant effect of group ($F(2,51) = 4.24$, $p = 0.02$). The multiple comparisons indicated that gist-reasoning scores for the SMART group were significantly higher than the rote memory group ($p = 0.03$) and the control group ($p = 0.04$) and the control group ($p = 0.04$). There were no significant differences found between the rote memory and the control group on the gist-reasoning measure ($p = 1$). The analysis failed to find a significant interaction between group and time of assessment (i.e., baseline versus post-training $F(2,51) = 1.23$, $p = 0.30$).

To test the hypothesis that fact-learning scores would change from baseline to post-intervention in the SMART group and the rote memory training group, we performed paired t-tests for each group with *post hoc* Bonferroni adjusted p-values reported. A significant difference was found in change scores between baseline and post-training for both the SMART Group ($N = 18$, $M = 7.89$, SD = 4.84, $t(17) = 6.92$, $p = 0.002$ and the memory training group ($N = 18$, $M = 5.2$, SD = 4.05, $t(17) = 5.47$, $p = 0.03$). We failed to find a significant difference between fact-learning ability at baseline and post-intervention for the teen brain information group ($N = 17$, $M = 4.29$, SD = 8.51, $7(17) = 2.08$, $p = 0.99$; see **Figure 2**). As mentioned above, only the English TOSL post-assessment scores were used for the paired t-tests, as a small number of students from each group took the Spanish TOSL post-training.

To determine the effect of group in fact-learning ability post-training, a repeated measures ANOVA and Tukey multiple comparisons were performed. The results failed to indicate a significant effect of group ($F(2,51) = 1.03$, $p = 0.36$). The Tukey multiple comparisons indicated no significant differences between any of the groups.

Texas Assessment of Knowledge and Skills

We used two measures from the TAKS reading test to: (1) ascertain the effect of training groups on total TAKS reading scaled score outcome from seventh grade (2008) to eighth grade (2009), and (2) the raw scores from the "Applying Critical Thinking Skills" objective to help validate the TOSL as a measure of higher-order critical thinking. Analysis of the data sample failed to indicate a significant difference from seventh (pre-training) to eighth grade (post-training) on TAKS reading scaled scores across the three training groups. A trend, however, was found in the expected direction for the SMART group, and a power analysis indicated that given a larger sample size, the results would be statistically significant (See **Figure 3**).

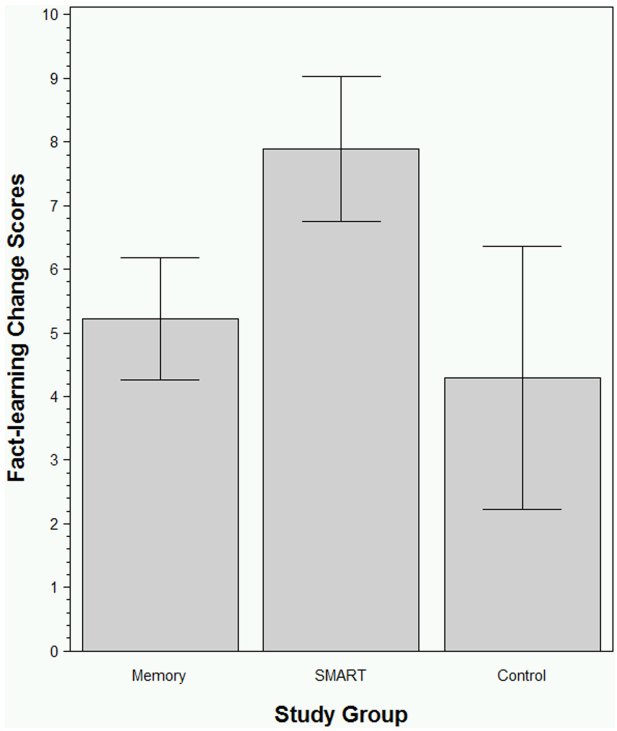

FIGURE 2 | Changes in fact-learning scores after training for each group. Groups: Memory, Rote Memory Training Group; SMART, Strategic Memory and Reasoning Training Group; Control, Teen Brain Information Group.

Pearson correlations were performed to determine the relation between gist-reasoning scores from the TOSL and the TAKS reading objective "Applying Critical Thinking Skills." We found a moderate but significant relation between gist-reasoning score on the post-training TOSL and the post-training TAKS "Applying Critical-Thinking Skills" raw score for all participants ($r(51) = 0.28$, $p = 0.04$; see **Figure 4**).

Spanish versus English test of strategic learning

To evaluate whether reasoning ability in English would be comparable to reasoning ability in Spanish, 25 of the students who primarily spoke predominately Spanish at home were assessed using the Spanish TOSL. The results failed to find a significant difference in performance between Spanish and English versions on gist-reasoning ability ($F(2,22) = 0.39$, $p = 0.28$) or the ability to answer probe questions from the text ($F(2,22) = 0.51$, $p = 0.61$).

DISCUSSION

This randomized pilot study conducted in an inner-city public middle school examined the potential benefits of a training program focused on instruction of higher-order cognitive strategies that support abstraction of meaning versus a rote memory training program. Few studies have specifically investigated gist-reasoning skills and the efficacy of subsequent training of a top-down cognitive strategy program compared against a bottom-up, rote memory training program in a randomized group of minority public school adolescents. In the present experimental study, we examined whether we could improve eighth grade students' ability to engage

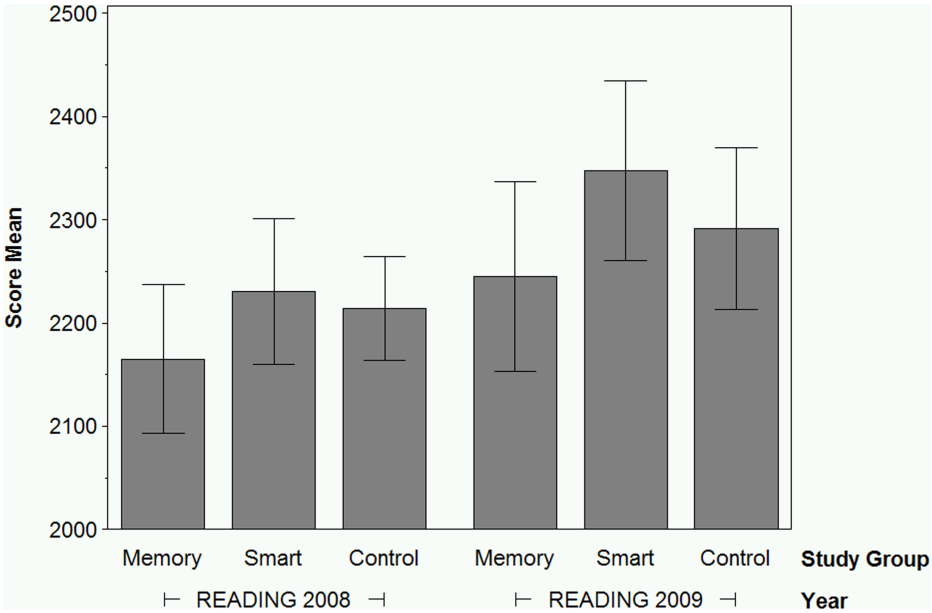

FIGURE 3 | A positive trend for the SMART group of higher scaled scores on TAKS reading test.

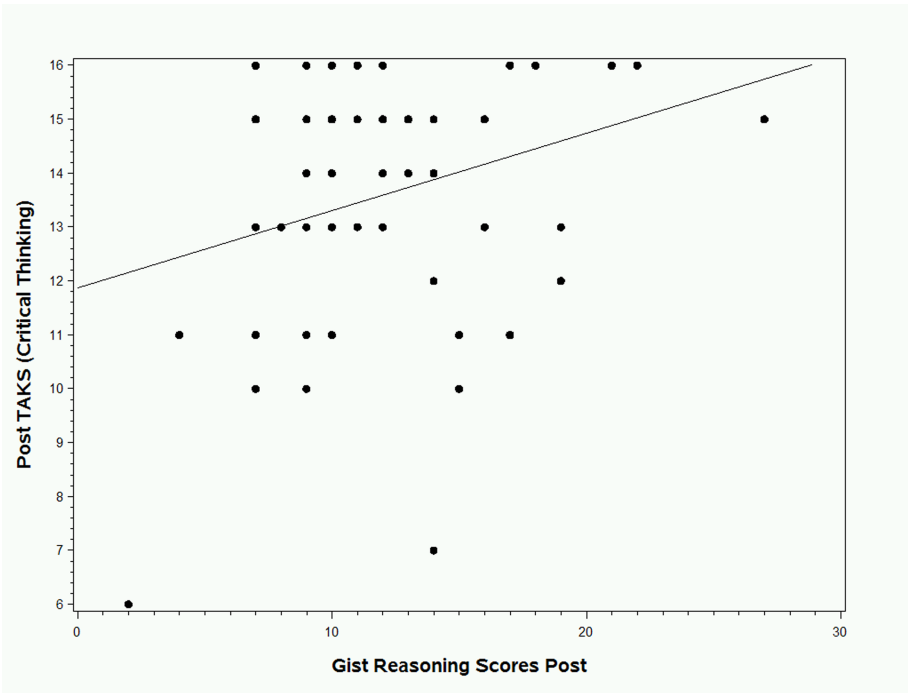

FIGURE 4 | Positive correlation between gist-reasoning scores and TAKS critical thinking objective.

in gist-reasoning after short-term intensive training programs that consisted of less than 9 h delivered over a 1-month period. The effects of the top-down cognitive strategy program, SMART were compared against a bottom-up, rote memory training program and an equally engaging program that provided educational information about adolescent brain health. Training was equated across conditions such that all groups had the same number of sessions, participants, curriculum appearance, and were informed that the activities would help them with their school performance.

Four important contributions of this training study are discussed, followed by the study's limitations which motivate and refine future investigations. The contributions of this research relate

to (1) the potential advantage of teaching eighth grade students higher-order cognitive strategies that are theorized to support top-down processing to abstract meaning (van Dijk and Kintsch, 1983; Reyna and Brainerd, 1995), (2) the transfer effects of reasoning training to untrained areas, including within group fact-learning scores and a school-based measure of reading aptitude, (3) the ability to effect change in one of the most vulnerable demographic groups of middle school students in terms of risk for school failure and drop-out, i.e., a group of students from minority low SES status families (McNeil, 2005), and (4) the preliminary evidence that students who spoke predominately Spanish at home demonstrated similar reasoning ability in both English and Spanish languages after training.

The present findings suggest that cognitive strategies that support abstraction of meaning can be taught in a typical public school eighth grade classroom to improve students' ability to utilize gist-reasoning to convey the meaning of texts. The adolescents who were trained in SMART demonstrated significantly higher post-training scores as compared to baseline performances on the measure of constructing higher-order, gist-based meanings. The benefit was demonstrated after less than 9 h of training in a typical classroom setting. In contrast, neither the rote memory training group nor the control group demonstrated a significant improvement in gist-reasoning.

Our findings suggest that a program that trains higher-level cognitive strategies has the potential to improve gist-reasoning ability and may be a promising way to promote deeper level understanding and transfer of knowledge than one focused on how many facts one learns by rote. Post-training, we found a correspondence between higher gist-reasoning scores and higher performances on two other measures: (1) the ability to recall key facts when answering probe questions regarding textual information, and (2) a skill objective from the Texas Assessment of Knowledge Skills (TAKS) for reading, "Applying Critical Thinking Skills," a state mandated test used as an index of academic achievement. As stated earlier, this latter test was the key objective described by the Texas Education Agency (TEA) as a measure of higher-order verbal reasoning skills in the TAKS reading test.

The present results confirm and extend earlier work by other research teams (Brown et al., 1981; Palincsar and Brown, 1984, 1987, 1988; Taylor and Beach, 1984; Pearson and Dole, 1987; Malone and Mastropieri, 1992; Rosenshine and Meister, 1997; Chang et al., 2002; Kintsch, 1998, 2004; Ladewski et al., 2007). Taylor and Beach (1984), in particular, focused on instructing typically developing seventh graders to organize explicitly stated information according to superordinate and subordinate ideas as compared to learning facts without hierarchical parsing of the information. Similar to our results, these researchers used summarization as a metric to show enhanced learning gains. Our paradigm extended their approach by exploring the ability to train students to derive meaning that went beyond the most important stated facts. In particular, the SMART program trained the students to abstract novel meanings that were not explicitly stated in the text. The capacity to abstract meaning, is illustrated symbolically by a + b = c, where "a" and "b" are explicit important facts and "c" represents novel, unstated, generalized meanings (Chapman et al., in press). The ability to process abstracted meaning has been associated with cognitive measures of executive control and frontally activated neural networks (Chapman et al., 2006; Anand, 2008; Vas et al., 2009, 2010). In contrast to Taylor and Beach's method, we found that training abstraction of meaning was superior to training rote memory as it benefited both gist-reasoning and fact-learning within the SMART group.

Our finding that the meaning abstraction training demonstrated a within group transfer effect to the ability to recall important information is similar to (Brainerd and Reyna's 1995; Reyna, 1998) theory that gist-reasoning shapes memory for details. Specifically, the transfer effect found within the SMART group provides empirical evidence that gist-reasoning ability may influence the ability to learn facts from a text, a crucial aspect of academic success. In contrast, the fact-learning group showed significant improvement within group only for retention of information from a text, as indicated by increased scores for correctly answering probe questions, but showed little improvement of gist-reasoning ability. This finding corroborates evidence of a positive effect of explicit instruction for learning important facts especially when identifying the most important ideas (Brown et al., 1981; Taylor and Beach, 1984). However, in our study the bottom-up approach to learning did not significantly improve spontaneous gist-reasoning production during summarization. Moreover, the control group failed to demonstrate significant changes within the group in either gist-reasoning ability or recall of important information. For this latter group, the focused adult interaction and discussion/learning activities did not have a significant effect on within group change scores for measures of higher-order cognitive processing or basic memory ability.

In recent years, there have been renewed calls to train students to think about information thoroughly in order to produce deeper understanding and abstraction of meaning to support superior critical thinking rather than train students to primarily learn facts by rote (Kaminski et al., 2008; Schwartz et al., 2008; Ramsay et al., 2009).The current findings corroborate this belief. Earlier studies did not examine a superiority of training abstraction of meaning as a window to enhance fact-learning. Nonetheless, they laid the foundation for the current study by revealing improved performances when strategies such as hierarchically parsing information (Taylor and Beach, 1984), concept mapping (Chang et al., 2002), and reciprocal teaching (Palincsar and Brown, 1984; Pearson and Dole, 1987; Rosenshine and Meister, 1997; Ladewski et al., 2007) are compared to more typical classroom learning focused on rote learning. Thus, our current study employed a new metric from those previously used to measure summarization skills, namely gist-reasoning through abstraction of meaning.

The present results of a generalization of gist-reasoning skills suggest an advantage to teaching students strategies that support abstraction of meaning and corroborate a similar pattern found in teaching math to college students (Kaminski et al., 2008). Specifically, Kaminski et al. (2008) showed that students benefited more from learning abstract mathematical concepts as compared to learning multiple concrete math examples in isolation. They also reported greater transfer of knowledge to novel and complex contexts when students were taught to understand math conceptually. Similarly, Schwartz et al. (2008) found that college students who received in-depth conceptual science instruction during high

school retained information longer and generalized concepts better than students who received predominately fact-based science instruction in high school.

The finding of a significant correlation between the TAKS "Applying Critical Thinking Skills" objective scores and post-training gist-reasoning scores is promising and suggests that SMART may improve performance on a high-stakes state mandated test of achievement. We postulate that this finding provides evidence that teaching cognitive strategies that support higher-order processing may benefit academic performance. While the TAKS reading scaled scores increased between seventh and eighth grades for our cohort of students, there are potentially many factors that contributed to the improvement. Nevertheless, the students in the SMART group all passed the reading portion of the TAKS and 7 of those students received commended scores in the eighth grade, compared to 3 students who received commended students in the previous year.

The present findings have implications that go beyond the promising results of achieving significant cognitive effects after less than nine hours of training over a one-month interval. More encouraging is the attainment of these results in one of the most vulnerable demographic adolescent groups, that is, a group of economically disadvantaged students (**Table 1**). Hispanic and African American students living in poverty are at greater risk of school failure, with Hispanic students at greatest risk in Texas, the origin of the current study (Good et al., 2003; McNeil, 2005; Lofstrom, 2007). Eighth grade may be an opportune time to implement specialized training to improve learning in this vulnerable population, as longitudinal evidence indicates that dropout rates for at risk populations escalate in ninth grade (Lofstrom, 2007). Thus, the predominately minority, low-income adolescent students in this study, after participating in the SMART program, showed significant gains in skills necessary for academic success, specifically, gist-reasoning and the ability to correctly answer probes regarding important text-based information (Brown and Day, 1983). It is important to note that the students who participated in the study were all members of AVID classes. AVID students in general are not considered high achievers or gifted, but are average students who show promise; many of whom will become their family's first generation of high school graduates. Perhaps as cognitive training programs are found to improve gist-reasoning and higher-order learning, the potential for these students to succeed will be elevated. This relationship needs to be investigated in a longitudinal study.

In addition to poverty, lack of English proficiency is a key factor associated with high academic failure and dropout rates among Hispanic students (McNeil, 2005; Lofstrom, 2007). However, while the students in the present study were not recent immigrants, English was their second language and many predominately spoke Spanish at home. Interestingly, we failed to find significant differences on gist-reasoning ability or fact-learning from texts when comparing responses in English and Spanish. Thus, preliminary evidence suggests that Hispanic students' ability to utilize reasoning in their first language was no better than their ability in English, their second language, at least by the time they were in eighth grade. These findings indicate that a deficit in higher-order cognitive skills may not be due solely to language differences.

Our findings of improved outcome in the SMART group argue against enhancing reasoning through bottom-up strategy instruction or focused attention from educators, since the later groups did not show a significant improvement in spontaneous gist-reasoning ability. Further, our findings support the efficacy of teaching high-level cognitive strategies to a vulnerable population, Hispanic eighth grade students for whom English is a second language. Subjectively, the AVID instructor noted that the students seemed more focused on their schoolwork after SMART training, with a noticeable organization to their thought processes. Future studies should consider inclusion of teacher and student self-report of perception of training gains.

LIMITATIONS

The current study has a number of promising findings that motivate future studies to address several limitations. One of the primary limitations of this is pilot study is the non-significant interaction between group and time. The small number of students in each group may have contributed to this finding and we will test this hypothesis in a planned study with a larger number of students. Whereas we did not find pre-existing differences between groups in gist-reasoning scores at baseline, the scores obtained by students in the SMART group were relatively higher than those obtained by students in the memory and control groups. Despite these limitations we are encouraged by the significant improvement in gist-reasoning performance among students in the SMART group in contrast to marginal improvements for the memory strategy and control groups and conclude that these findings reflect support for the potential efficacy of the SMART program in the development of reasoning abilities. That said, the findings must be interpreted with caution and warrant further research to address the potential confounds described above.

Additionally, future research will need to determine the feasibility of training a larger number of classroom students at one time. In the present study, each section of the eighth grade was randomized into the three groups, making the training groups small across the three classes. Another factor that needs consideration is the impact of a greater number of training sessions. It will be important in future studies to establish who benefits from short-term training versus who needs more intensive training to receive the same benefits, as well as who fails to benefit at all. Furthermore, all the students were members of an AVID class, a motivated group who are specifically chosen as students with promise. It is unknown from the present study if a larger group of students including those with less motivation to achieve would be as amenable to training. In addition, students need to be followed longitudinally to determine if the SMART program produces lasting and generalized effects that may be measured through improved grades and other measures of academic achievement. We plan to re-evaluate the students to determine the maintenance of reasoning gains. Students should also be queried regarding their ability to use the learning strategies for assignments and/or homework and the impact of using the strategies in various core classes.

Further research should address the efficacy of training programs implemented by educators in the classroom to maximize the potential use and application of the SMART program. Results, such as reciprocal teaching implemented by Palincsar and Brown

(1984) and others (See review in Rosenshine and Meister, 1994), offer the promise that teachers could deliver an effective training program, given proper training. Whereas positive results were found in low SES AVID students, the impact of SMART on students not enroled in AVID classes as well as those from average to high SES levels would be informative to consider. In addition, brain imaging studies should be conducted to determine the impact of reasoning training on brain development and changes in activation levels and/or neural regions.

CONCLUSION

Building a mature reasoning mind is a pivotal goal of education; as such, the evidence for improved gist-reasoning through abstraction of meaning training is highly relevant for educational best practices. That is, theoretical and empirical evidence indicates that educational practices focused predominately on rote fact-learning may fail to reach the goal of promoting gist-reasoning skills. The failure to stimulate development of gist-reasoning during adolescence ignores recent evidence from neuroscience that suggests that the adolescent brain is primed to acquire abstract thinking. Our evidence indicating improved gist-reasoning following training in students with ADHD within a laboratory environment (Gamino et al., 2009a,b) prompted a larger question regarding the efficacy of implementing the SMART program in a typical public school classroom. This paper represents an important first step in elucidating the differential impact of fact-learning versus gist-reasoning to an educational setting of typically developing adolescents.

The evidence provided herein supports the importance of formal cognitive strategy instruction that enhances abstraction of meaning and top-down processing of information within an urban public middle school of minority, low socio-economic status students. This study provides evidence that students who are taught to use higher-order cognitive strategies to enhance abstraction of meaning benefit not only from the ability to spontaneously utilize gist-reasoning when summarizing complex information but also benefit in their ability to recall important information from a text. The evidence from this study also suggests that students who learn to abstract meaning perform better on high-stakes standardized reading comprehension measures, purported to measure critical thinking abilities. Thus, training students to engage higher-order cognitive strategies during learning has the potential to transfer to standardized measurements of critical thinking, purported to be indicative of academic performance.

The current study corroborates and expands the promising outcomes that can be derived when cognitive neuroscience and education partner. Given the importance of reasoning and critical thinking skills across the United States (U.S. Dept of Education, 2004) and the high dropout rate among minority students (Lofstrom, 2007), this work provides hope that viable solutions for these escalating problems may eventually be obtained through evidence-based cognitive training.

ACKNOWLEDGMENTS

This research project was supported by the Meadows Foundation, the Hudson Foundation, and the State of Texas funds through the American Recovery and Reinvestment Act (ARRA). We would also like to express our gratitude to the Dallas Independent School District and AVID instructor Jennifer Tecklenburg. We are equally grateful for the assistance of Dr. Christy Matthews, Sandra Vanegas, and Anne Holland with this project. In addition we appreciate Dr. Michael Motes and Dr. Lori Cook for their assistance with editing this manuscript.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 10 July 2010; accepted: 13 October 2010; published online: 09 December 2010.

Citation: Gamino JF, Chapman SB, Hull EL and Lyon GR (2010) Effects of higher-order cognitive strategy training on gist-reasoning and fact-learning in adolescents. Front. Psychology ***1****:188. doi: 10.3389/fpsyg.2010.00188*

This article was submitted to Frontiers in Educational Psychology, a specialty of Frontiers in Psychology.

APPENDIX A

SUMMARY EXAMPLES FROM THE TEST OF STRATEGIC LEARNING (TOSL©)

The TOSL consists of three texts that the students are requested to summarize. One of the texts is about a crow who finds some peacock feathers and puts them on. The crow goes over to where a flock of peacocks is sitting but when he gets closer they discover the truth and take back the feathers. The crow returns to his fellow crows who have been watching him from a distance. The other crows ignore the crow so he tries to think of an excuse as to why he was wearing peacock feathers. The other crows have been watching him too long to believe him and tell him to get lost. The "fickle crow learns a very important lesson."

The first summary demonstrates a student who is processing the information on a surface level and provided a summary that reflects a verbatim style, with little gist-reasoning. This student earned 2/10 points for gist-reasoning ability.

> *"A crow finds some pretty peacock feathers, puts them on and decides to go over to some peacocks. The peacocks thought he was one of them at first, but then they see that he is a crow and take away the feathers. The crow goes back to the other crows but they ignore him because they saw what he did. He tries to make up excuses but the other crows tell him to get lost. The crow learned a lesson."*

The second summary demonstrates a student who is processing information at a deeper level reflecting gist-reasoning. This student earned 9/10 points for gist-reasoning ability.

> "*A grey crow began noticing how dull he was and spotted some peacock feathers on the ground. He carefully tied them to himself and began walking toward the peacocks. The peacocks thought it was another peacock joining them but as it got closer, they recognized who it was. With anger, the peacocks started plucking off the feathers, and began squawking at him with hatred. Defeated, the dull crow went to his fellow crow friends. They rejected him due to betrayal. The crow learned he should be himself.*"

APPENDIX B

Strategic Memory and Reasoning Training Stages and Sequence

Stages of training	Strategy	Session number(s)
1. Inhibit/select and organize	To delete/inhibit unimportant details and prioritize important information To organize important information into chunks	One
2. Inference	To use inferencing to extract the deeper/abstracted meaning of information	Two
3. Paraphrase	To convey information in own words	Three
4. Combine and connect	To combine details together into gist based concepts, using inferencing and paraphrasing	Four
5. Integrate	To integrate previous knowledge with new information to formulate high-level gist concepts	Five
6. Generalize	To abstract ideas through gist-reasoning from supporting key points, generalizing to other contexts and situations	Six–nine

Efficacy of Cognitive Training When Translated From the Laboratory to the Real World

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ABSTRACT

Introduction:

Research shows that cognitive performance and emotional well-being can be significantly strengthened. A high-performance brain training protocol, Strategic Memory Advanced Reasoning Training (SMART), was developed by cognitive neuroscientists at The University of Texas at Dallas Center for BrainHealth based on 25-plus years of scientific study. Randomized controlled trials with various populations have shown that training and use of nine "SMART" strategies for processing information can improve cognitive performance and psychological health. However, the multi-week intensive training used in the laboratory is not practical for widespread use outside the laboratory. This article examines the efficacy of SMART when translated outside the laboratory to two populations (military/veterans and law enforcement) that received SMART in condensed time frames.

Materials and Methods:

In two translation studies with healthy military personnel and veterans, 425 participants received between 6 and 10 hours of SMART over 2 days. In a third translation study, 74 healthy police officers received 9 hours of SMART over 3 days. Training was conducted by clinicians who taught the nine "SMART" strategies related to three core areas—strategic attention, integrated reasoning, and innovation—to groups of up to 25 participants. In all three translation studies, cognitive performance and psychological health data were collected before and immediately following the training. In one of the military/veteran studies, psychological health data were also collected 1 and 4 months following the training.

Results:

In both translations to military personnel and veterans, there were improvements in the complex cognitive domains of integrated reasoning ($P < .0001$) and innovation ($P < .0001$) immediately after undergoing SMART. In the translation to police officers, there were improvements in the cognitive domains of innovation ($P = .02$) and strategic attention ($P = .005$). Participants in all three translations saw statistically significant improvements in self-reported symptoms of psychological health. The improvements continued among a subset of participants who responded to the later requests for information.

Conclusions:

The results of translating to these two populations provide evidence supporting the efficacy of SMART delivered in an abbreviated time frame. The improvements in two major domains of cognitive function demonstrate that strategies can be taught and immediately applied by those receiving the training. The immediate psychological health improvements may be transient; however, the continued improvements in psychological health observed in a subset of the participants suggest that benefits may be sustainable even at later intervals.

INTRODUCTION

The military today is not only operating in the longest continuous period of armed conflict in our nation's history, but they are doing so with the unprecedented levels of technological challenge and change, with increasing competition for superiority in every domain. For continued success, Warfighters must be more agile, adaptive, and innovative than our adversaries. They must be able to nimbly navigate constantly changing demands and unpredictable factors to make fast, complex, and accurate decisions in life-threatening situations. Police officers, while in a very different context, are nonetheless often having to respond to unpredictable threatening situations in rapid succession, calling upon a skill to quickly decipher the situation and respond with calm. In short, both populations must be equipped with a cognitive advantage to judge a context and respond to meet the quickly evolving demands to save lives.

SMART Description

Over the last decade, research implementing a high-performance brain training has shown improvements in higher-

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Presented as an abstract at the 2019 Military Health System Research Symposium, Orlando, FL; MHSRS-19-01666.

The opinions or assertions contained herein are those of the author/speaker and are not to be construed as official or reflecting the views of the Department of Defense, the Uniformed Services University of the Health Sciences, or any other agency of the U.S. government.

doi:10.1093/milmed/usaa501

order cognitive performance, psychological well-being, and neural health.[1–11] This training, Strategic Memory Advanced Reasoning Training (SMART), is based on 25-plus years of scientific study[12–21] funded by the NIH, DoD, and other sources.

SMART is an evidence-based cognitive training program that is strategy-driven, rather than content-specific. It entails a systematic use of three pivotal executive function cognitive processes of strategic attention, integrated reasoning, and innovation. Facility with these cognitive domains is linked to real-life performance and improved ability to interpret and respond to all types of input, including meetings, briefings, conversations, and contextual ongoings, to mention a few. These cognitive processes are required to execute tasks in everyday life; utilization generalizes to psychological well-being and social adeptness in understanding and responding appropriately to emotions of others. SMART engages the top-down cognitive control of complex data, where concentrated mental effort focuses selectively on important information, while blocking less important input so as to not drain mental resources. Thus, strategic attention strategies help to optimize the brain's focus by narrowing the amount of data allowed in by giving less attention/effort to banalities, reserving mental resources to achieve the critical task at hand. The integrated reasoning strategies encourage inputs to be quickly encoded, synthesized, and reflected upon to improve performance moment to moment. The ability to hone skills to abstract big picture/ideas/interpretations/actions can guide real-life decisions and actions in a timely, yet calm manner based on the incoming data/input. Added to these, SMART trains individuals to make innovative thinking habitual, with strategies that guide individuals to continually generate multiple, diverse perspectives and seek multiple solutions or approaches to any tasks or problems. Innovation helps to prioritize multiple options to solve any situations. Participants are provided exercises to practice real-life tasks that incorporate strategic attention, integrated reasoning, and innovation strategies as often as possible within the context of their own daily responsibilities and relationships. The goal is to make this type of thinking habitual by processing information in a focused, calm, and deeper level way and to make innovative cognition intentional,[1] with a range of situations from daily responsibilities to hefty decision-making. For example, one exercise used in the training is to generate multiple options to improve a difficult team or personal relationship using the higher-order cognitive strategies to override a default reactive mode of response. Assignments are given to identify a situation/person that triggers an automatic negative emotional response. The trainees practice the strategies by consciously zooming out to take a broader perspective without the burden of emotional details and then utilizing innovation strategies to identify what is good and bad/threatening about the situation and listing numerous possible responses to improve the situation/interaction. What this exercise does is activate the integrated reasoning of the frontal networks to downregulate the automatic, flight-or-fight response of the amygdala.[1,10]

Prior Research

The efficacy of SMART for improving higher-order cognitive functions has been demonstrated in nine randomized controlled trials,[3,10,15–18,20–22] the two most comprehensive of which were the Healthy Adults study and the Traumatic Brain Injury (TBI) study. The Healthy Adults study was conducted following review and approval by the Institutional Review Boards at The University of Texas at Dallas, the University of Texas Southwestern Medical Center, and Cooper Institute (registered at ClinicalTrials.gov, NCT# 00977418).[1–5] Cognitively normal adults over 56 years of age were randomized into a cognitive training cohort ($n = 19$), a physical exercise group ($n = 19$), or a non-intervention, wait-list control group ($n = 20$). The cognitive training group participated in 12 hours of SMART, plus 24 hours of at-home exercises (total = 36 hours) over a 12-week period; the physical exercise group participated in 36 hours of physical training over a 12-week period. The cognitive training cohort showed statistically significant improvements in integrated reasoning ($P = .01$), working memory ($P = 0006$), and innovation ($P = .014$) across three time points from baseline to mid-training to 12 weeks from start. Further, there were improvements in functional connectivity of the Central Executive and Default Mode Networks, which corresponded with gains in integrated reasoning and innovation.[1,2] Psychological health was not assessed in this study.

The TBI study was conducted following review and approval by the Institutional Review Boards at The University of Texas at Dallas and the University of Texas Southwestern Medical Center (registered at ClinicalTrials.gov, NCT# 01552473).[6–11] After providing written informed consent, adults with mild symptoms of chronic-phase traumatic brain injury were randomized into a cognitive training cohort ($n = 31$) and an active control ($n = 29$). The cognitive training group participated in 18 hours of SMART over a 12-week period, while the active control group participated in 18 hours of the BrainHealth Workshop, an education-based workshop providing information about the brain and approaches to keeping it healthy. The cognitive training cohort showed statistically significant gains in cognitive performance over the active control group on integrated reasoning ($P = .02$), working memory ($P = .002$), and task switching ($P < .001$). With regard to psychological health, the SMART group showed significant reductions in depressive ($P = .003$, $d = 0.97$) and stress-related ($P = .004$, $d = 0.94$) symptoms.[6] The SMART-trained group showed gains in self-reported real-life function as well.

Although the results of the clinical trials were encouraging, to be able to scale SMART to the military and police officers, efficacy in a phase I trial must be demonstrated outside the laboratory environment. These groups, in particular,

have unpredictable and uncontrollable demands on their time, which restrict availability for both training and data collection.

Hypothesis

This article reports on the translation of the SMART brain training protocol out of the laboratory and applied to two populations: military veterans and police officers. In both translations, the number of hours of cognitive training and the period of time over which the training occurred were dramatically reduced, as compared to the prior randomized controlled trials. We hypothesized that (1) post-training outcome measures would show statistically significant improvements in cognitive functions of strategic attention, integrated reasoning, and innovation and (2) post-training outcome measures would demonstrate improvements in self-reported symptoms of psychological health.

METHODS

There were two translational studies for military populations, both of which included veterans, reservists, National Guard, and active duty soldiers. Both studies were approved by the Institutional Review Board at The University of Texas at Dallas. Participants in both studies were recruited through the Center for BrainHealth website, Veteran Service Organizations, and fliers distributed at public events held at the Center for BrainHealth.

In the first study, 246 military personnel and veterans participated in SMART, and in the second study, 179 additional military personnel and veterans participated in SMART. The training schedule varied from 6 to 10 hours to accommodate external schedule constraints, with all participants consistently receiving the first 6 hours of training within 1 week, and some returning for an additional 3- to 4-hour session 4 weeks thereafter. During the first 6 hours of training, the core SMART strategies for strategic attention, integrated reasoning, and innovation, each strategy composed of three components, were taught and practiced. About 60% returned for a 3- to 4-hour session 4 weeks later, where they were given a refresher briefing of the core strategies, additional practice exercises, and opportunities to ask questions based upon their experiences in applying the strategies during the previous 4 weeks. The attrition rate of approximately 40% at this 1-month session was due to conflicts with participants' unpredictable schedules. All training sessions were conducted in an interactive workshop with up to 25 participants and two trainers, at least one of which was a speech-language pathologist (Appendix). The second trainer was either another speech-language pathologist, or "subject-matter expert," i.e., an individual with history serving in the military.

The police officer translation was conducted following review and approval by the Institutional Review Board at The University of Texas at Dallas. The leadership command from a police department requested SMART as a professional development activity; the research team had no involvement in recruitment.

In this translation, 74 police officers, aged 28-60 years, ranging in rank from Senior Corporals to Chief of Police underwent 9 hours of SMART, with the first 6 hours of training in 3-hour blocks over 2 consecutive days, and the last 3-hour block delivered 4 weeks later. As with the military translations, all core SMART strategies were taught and practiced in the first 6 hours of training; the subsequent 3 hours were used to refresh the learning on the SMART strategies, provide additional practice exercises, and answer questions. All training sessions were conducted with two trainers. The primary trainer was a speech-language pathologist. The secondary trainer was, again, an individual with history serving in the military, since an experienced SMART trainer with subject-matter expertise in law enforcement was not available.

For all three translations, participants were required to be healthy adults over the age of 18 years and native speakers of English, as the language for which assessments were developed and normed. No exclusions were made based on race or gender. Table I lists basic demographics data from all three translation studies.

For all three translation studies, pretraining and post-training data were collected. For the first military training, psychological health data were solicited from all participants at the 1- and 4-month time points following training. Table II lists the assessment tools used in all three translation studies. All of the test instruments were standard except for the Test of Strategic Learning (TOSL), which was developed at The University of Texas at Dallas' Center for BrainHealth.[22] The TOSL was developed to assess real-world complex cognitive functions in healthy individuals who require synchronization of multiple cognitive processes simultaneously. The multidimensional aspect of TOSL helps to address the hurdle of current neurocognitive measures that were developed primarily to detect impairments of specific cognitive domains, not to assess the upward potential of human performance optimization on tasks requiring cognitive systems working together. The cognitive domains assessed by TOSL include strategic attention to quickly sort relevant information, integrated reasoning to adeptly boil complex ideas into the essence, and adaptive generative capacity of innovative possibilities. The TOSL does not suffer from ceiling effects observed in traditional neuropsychological tests, and it has been found, in combination with a brief test of proverb interpretation, to have both superior specificity and sensitivity to the Wechsler's similarities test of executive functioning.[22,23]

Statistical Analysis

Each of the outcome measures (dependent variables) listed in Table II was modeled using standard linear mixed effects models to assess the efficacy of cognitive training over time. The models included pretraining, immediate post-training and, in the case of the first translational veteran sample, 1-month and 4-month post-training sessions. Two variance components, one due to variability within subjects and one

TABLE I. Demographics of Translational Studies

Demographics			
	First military/veteran translation	Second military/veteran translation	Police officer Translation
Number of participants	246	179	74
Age	18-85 ($M = 39.5$, SD = 13.5)	20-85 ($M = 44.8$; SD = 14.7)	28-60 ($M = 45.2$; SD = 8.3)
Gender	154 male	118 male	32 male
	55 female	42 female	42 female
	38 NA	19 NA	
Service status	16 active duty	25 active duty	Senior Corporals to Chief
	69 reservists	15 reservists	
	114 veteran	104 veterans	
	1 ROTC	30 retired	
	36 retired	5 NA	
	1 active duty/retired		
	1 active duty/reserve		
	2 reserve/veteran		
	7 NA		
Years of service	1-45 ($M = 10$; SD = 8.5)	1-30 ($M = 10.1$, SD = 8.1)	NA
Years of post-high school education	None—14	None—6	1 to 4-51
	1 to 4-112	1 to 4-72	5 to 7-21
	5 to 7-45	5 to 7-42	>8-1
	>8-30	>8-25	NA—1
	NA—46	NA—34	

Abbreviation: ROTC, Reserve Officers' Training Corps.

TABLE II. Outcome Measures of Translation Studies

	First military/veteran	Second military/veteran	Police officers
Outcome measures			
Integrated reasoning	Proverb interpretation[26,27]	Proverb interpretation	Proverb interpretation
Selective attention	Visual selective learning (VSL)[28]	VSL	VSL
Innovation	Test of Strategic Learning (TOSL),[22] Part II	TOSL, Part II	TOSL, Part II
Depression	Depression, Anxiety, Stress Scale-21 (DASS21-D)[29,30]	Beck Depression Index[31]	DASS21-D
Anxiety	DASS21-A	Beck Anxiety Index[32]	DASS21-A
Stress			DASS21-S
Overall well-being	Satisfaction with Life survey[33]	Quality of Life survey[34]	
Resilience	Connor-Davidson Resilience Scale[35]		

due to variability across subjects, were included and estimated by restricted maximum likelihood. Primary interest was in measuring mean change from the pretraining session (baseline), and we hypothesized that cognitive training would improve mean assessment measures in post-training sessions relative to baseline. Inference was based on t-statistics for all change-from-baseline contrasts. The models were implemented in the R statistical computing language (http://r-project.org), and significance levels were set at .05.

RESULTS

Military and Veteran Translation Studies

Both groups in the military translation studies showed improvement in higher-order cognitive functions and psychological health. In the first translation to the military, 200 of the 246 participants participated in both pre- and post-training assessments. Post-training testing indicated significant improvements in integrated reasoning ($P < .0001$, $d = 0.43$) and innovation ($P < .0001$, $d = 0.48$), with no significant improvements in strategic attention ($P = .15$, $d = 0.1$). There was also a significant decrease in self-reported symptoms of stress ($P < 0.0001$, $d = 0.62$), depression ($P < .0001$, $d = 0.5$), and anxiety ($P < .0001$, $d = 0.36$). Self-reported satisfaction with life was improved post-training ($P < .0001$, $d = 0.41$), as was resiliency ($P < .0001$, $d = 0.29$). None of the participants reported symptoms in the range to be diagnosed with significant mental health issues, but nonetheless, improvement in a positive direction to reduce symptom complaints was noted. Results are summarized in Table III.

As shown in Fig. 1, the psychological assessments were repeated 1 month post-training (69 participants responded) and four4 months post-training (77 participants responded). Across all measures, scores continued to improve, with the

TABLE III. Summary of Results

Outcome measure	Pretraining Mean	Pretraining SE	Post-training Mean	Post-training SE	*P*-values
First military/veteran translation study					
Integrated reasoning	2.86	0.09	3.64	0.11	<.0001
Selective attention	52.91	1.26	55.32	1.49	.15
Innovation	5.29	0.16	6.94	0.22	<.0001
Depression[a a]	4.46	0.26	3.05	0.20	<.0001
Anxiety[a]	4.08	0.25	3.06	0.21	<.0001
Stress[a]	7.22	0.27	5.22	0.24	<.0001
Overall well-being[a]	22.31	0.46	24.35	0.43	<.0001
Resilience[a]	74.07	0.93	76.86	0.96	<.0001
Second military/veteran translation study					
Integrated reasoning	2.90	0.09	3.55	0.12	<.0001
Selective attention	51.55	1.38	50.77	1.62	.63
Innovation	5.27	0.19	6.56	0.21	<.0001
Depression	14.39	0.98	11.83	0.88	<.0001
Anxiety	11.17	0.84	8.73	0.86	<.0001
Stress			Not assessed		
Overall well-being	78.51	1.34	83.48	1.44	<.0001
Resilience			Not assessed		
Police officer translation study					
Integrated reasoning	4.43	0.25	4.34	0.28	.67
Selective attention	46.83	3.14	56.04	3.20	.005
Innovation	6.09	0.36	7.21	0.40	.02
Depression	2.34	0.24	1.61	0.25	.004
Anxiety	1.87	0.24	1.51	0.26	.12
Stress	5.60	0.38	4.56	0.37	.007
Overall well-being			Not assessed		
Resilience			Not assessed		

[a]See Fig. 1 for 1- and 4-month follow-up data.
DASS21, Depression, Anxiety, Stress Scale-21; SMART, Strategic Memory Advanced Reasoning Training.

statistically significant improvements still occurring between 1 and 4 months following training in all psychological measures except for anxiety.

The results of the second translation to 179 military personnel and veterans were in the same domains as the first, with post-training measures indicating statistically significant improvements in integrated reasoning ($P < .0001$, $d = 0.44$) and innovative cognition ($P < .0001$, $d = 0.45$), and no significant improvement in strategic attention ($P = .63$, $d = 0.03$). Stress was not evaluated in this second translation, but participants reported a decrease in symptoms of depression ($P < .0001$, $d = 0.40$) and anxiety ($P < .0001$, $d = 0.34$). They also reported an improved assessment of quality of life ($P < .0001$, $d = 0.36$). Results are summarized in Table III.

Police Officer Translation Study

Similar to the military translation studies, the police officers also showed improvements in higher-order cognitive functions and psychological well-being. The 74 police officers showed improvements in innovative cognition ($P = .013$, $d = 0.47$) and strategic attention ($P = .005$, $d = 0.54$). This translation did not, however, yield an improvement in integrated reasoning ($P = .79$, $d = 0.05$). In the law enforcement population, symptoms of anxiety did not improve significantly following the training ($P = .12$, $d = 0.29$), but they did report reduced symptoms of depression ($P = .004$, $d = 0.55$) and stress ($P = .007$, $d = 0.52$). Results are summarized in Table III.

DISCUSSION

Translating SMART outside the laboratory required moving from SMART delivered over extended hours and time course (i.e., 18-36 hours over a 12-week period), to an abbreviated time frame of 6 to 10 hours over a 4-week period. We sought to determine whether participants could learn the core cognitive strategies in a reduced time that would improve their complex cognition and generalize to psychological well-being, despite limited opportunities for practicing the strategies during training. Both military translation studies support the hypothesis that participants of these SMART workshops would show gains to cognition function, as their performance on measures of integrated reasoning and innovation showed significant improvement. Concerning the police officers, they demonstrated gains in innovation, the same domain as the military groups, but unlike the military group showed significant gains in strategic attention. The police officers failed to show improvements in the domain of integrated reasoning, a domain in which gains were manifested by both military groups.

Improvements in cognitive performance immediately following training indicate that participants understood and immediately applied the SMART strategies to improve cognitive function (i.e., integrated reasoning and innovation and, to a lesser degree, strategic attention). Without follow-up data, we do not know whether the SMART strategies endured beyond the training effects. We recognize that what is important in training is to habituate utilization of the strategies to achieve sustained improvements in cognitive performance and yield concomitant neural changes as observed in our clinical trials.[1–3,5–9,11]

All three translation studies supported the hypothesis that post-training self-report measures would indicate improvements in psychological well-being. Although all the participants of three translation studies indicated, on average, good psychological health, these improvements were, in fact, similar to other studies involving group-based cognitive behavioral therapy directly targeting depressive symptoms.[24,25] These results suggest a potential for some trainings, such as SMART, to intercept early psychological symptoms with strategies to mitigate the complaints from increasing in symptom severity. Such a possibility would need to be validated in longitudinal studies but certainly offer hope that preclinical depression and stress should be assessed and not delayed until full diagnosis is made. The improvements observed immediately following the training may reflect solely the benefits of social interactions during the training and have nothing to

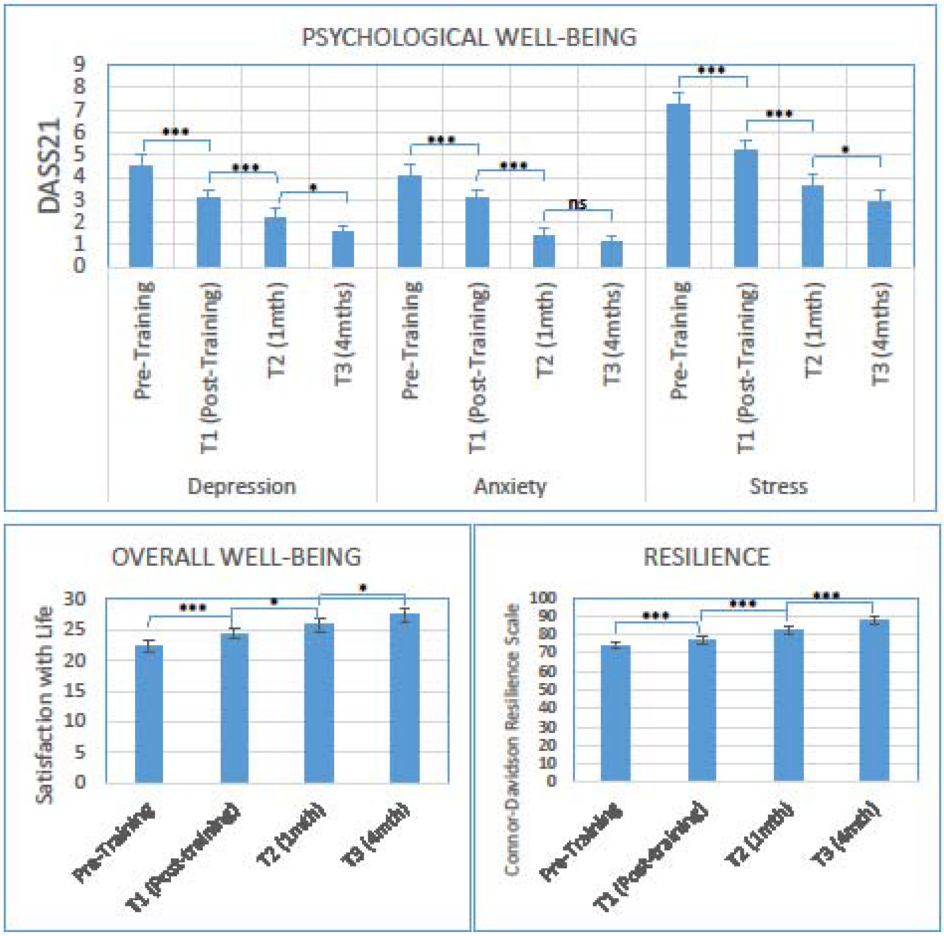

FIGURE 1. Psychological health and well-being results in the first translation to military personnel and veterans show statistically significant improvements that are sustained or continuing to improve up to 4 months following learning the Strategic Memory Advanced Reasoning Training strategies (*t*-test: ***$P < .0001$; *$P < .05$; ns indicates that results were not significant).

do with utilizing cognitive strategies to overcome hurdles.[25] One point suggesting it may be adoption of strategies and not just the time with social interaction is implicated by the evidence that the first translation military/veteran participants' responses to the neuropsychological well-being assessments at 1- and 4-months following training showed that improvements continued long after the social activity of the training. We cautiously interpret our results regarding continued improvement in psychological well-being given only a small percentage of the original cohort (31%) responded to the 4-month post-training questionnaires. It may be that those who did respond were those who enjoyed and/or benefited from the training. Nonetheless, this preliminary data suggest that long-term improvements in psychological well-being may be due to strategy application and not merely socialization, as supported by our TBI randomized controlled trial.[6] In this randomized controlled trial, the SMART cohort and the active control group had equivalent levels of socialization, but improvements in psychological health were specific to the SMART cohort.[10]

Limitations

The present work represents a necessary first step of phase I pilot studies to explore whether a condensed shorter-term (reduced hours and days) training delivered to the military and police officers in their own training context would show benefits. We acknowledge that translational research inevitably has significant limitations, making it difficult to address the possible factors that may have contributed to the gains reported. The motivation for these pilot trials was strong evidence from prior laboratory randomized trials that showed significant gains in cognition, neural health, psychological well-being, and real-life function.

One limitation is sorting out whether the gains were due to SMART participants paying more attention to how they process information or to actual application of the SMART strategies. We are cautiously optimistic that the results may be valid, since similar findings emerged across the three pilot translations, and previous randomized trials showed similar gains among participants in SMART, but not in active con-

trol groups. Nonetheless, a good next step from the present pilot studies would be a randomized field trial against another training approach, such as mindfulness training or a brain health workshop that delivers information about general ways to keep your brain healthy.

A second limitation in these studies was attrition. In the military translation studies, we had two time periods to consider attrition. The first was immediate and had an attrition rate of roughly 20% between the pre- and post-training data collections. This rate is fairly modest and, in fact, common in longitudinal studies. Further attrition occurred in our samples which obtained data 1 and 4 months following the training, with attrition rates of 40% and 69%, respectively. Some contributing factors could be that participants were not incentivized (e.g., payments), and e-mailed requests for information are easily disregarded or, perhaps, concerning to individuals from a privacy standpoint.

A third limitation is the lack of detailed histories from study participants. In both the military and police officers populations, there is a reluctance to provide demographic information or medical histories, so a robust comparison of the participants to those in randomized controlled trials was not possible. This type of comparison would be particularly interesting in both of the translation populations, where traumatic events are common and can result in post-traumatic stress and both transient and chronic physical and psychological health issues. The reluctance to reveal personal information in real-life contexts is understandable, given the persistence of stigma that is pervasive about cognitive performance being assessed. Until we update the outdated notion of a fixed mindset and labels that identify problems rather than the upward potential of the human brain to improve, this will be a constant concern.

Future Directions

The translations of SMART from the laboratory to the "real world" in the form of 6- to 10-hour in-person "workshops" offer a promising first step toward scalability. However, even the workshops are labor-intensive and can only be attended by participants who have the ability to set aside time to participate. Moreover, neuroplastic changes require habituation of the SMART strategies, something that is difficult to accomplish with just a one-time workshop. To address these limitations, BrainHealth researchers have developed an online version of SMART, which replaces the in-person delivery with a series of short (1-2 minutes) videos and quick questions/exercises. Individuals receiving the training online will also receive access to additional content, both related to the strategies and related to lifestyle factors influencing brain health. The additional content will be "packaged" with questions and exercises that transform the content from being something that is passively viewed to something in which the participant actively engages as a brain training exercise. The "micro-learning" format for SMART improves the accessibility to SMART and supports habituation of SMART strategies, but it does so at the cost of the social activity of in-person training. A pilot of online SMART is ongoing, which will provide data to quantify its efficacy.

CONCLUSION

Military and law enforcement personnel work under increasing pressure to make faster and more accurate complex decisions in unpredictably risky environments. Hence, equipping them as effectively as possible, not only with the appropriate gear and technology but maybe even more importantly with the tactical cognitive tools, is a vital line of research. This article offers preliminary evidence that a research-based, high-performance brain training that had previously been restricted to the laboratory (with other populations) could yield consistent results of improved cognition and self-reported symptoms of psychological health when delivered in an abbreviated format with military veterans and active duty law enforcement personnel. As these individuals significantly improved from baseline, the present results also provide valuable exploratory evidence that cognitive training is not limited to remediating deficits but can be an effective performance-enhancing tool. More work is needed to understand the generalizability of gains from a short-term workshop to the varied demands out in the field.

ACKNOWLEDGMENTS

The University of Texas at Dallas' Center for BrainHealth would like to recognize the law enforcement and military personnel who participated in this research and give so much to keep our nation safe.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Military Medicine* online.

FUNDING

Five studies are included in this article. Funding sources were as follows: (1) Healthy Aging Study—Funded by the National Institute of Health, grant RC1-AG-035954; (2) Traumatic Brain Injury Study—Funded by the US Army Medical Research Acquisition Activity (grant no. W81XWH-11-2-0194); (3) The first translation study to military personnel and veterans was funded by the State of Texas Health and Human Services Commission's Texas Veterans and Family Alliance Grant Program (grant no. 529-16-0088-00003); (4) The second translation study to military personnel and veterans was funded by the State of Texas Health and Human Services Commission's Texas Veterans and Family Alliance Grant Program (grant no. 519-17-0058-00008); (5) The translation to law enforcement personnel was funded through philanthropic donations from the community of Dallas, Texas.

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frontiers in Psychology

SYSTEMATIC REVIEW
published: 28 December 2021
doi: 10.3389/fpsyg.2021.797913

Emotional Peer Support Interventions for Students With SEND: A Systematic Review

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Emotional peer support systems have benefits for student-student relationships and allow for children and adolescents' participation in schools. For students with specific educational needs and disabilities (SEND), positive relationships seem to be more difficult to attain and these students are more vulnerable to suffer negative peer experiences such as bullying and social exclusion. Systems in which peers can show helpful behavior are beneficial for schools in order to create a positive, supportive climate. Emotional peer support entails social interaction through emotional or practical help based on what these peers have in common and many times with benefits for both. This systematic review identified interventions of emotional peer support in schools for students with SEND. Twenty-three studies were identified that involved four types of befriending: circle of friends, peer buddying, peer networks, and social lunch clubs. Studies reported mainly positive outcomes for both focus students and peer supporters in terms of increased social interaction and social acceptance, as well as enhanced self-esteem and empathy on the individual level. Further bonding of the students by friendship was also perceived, but more precise data is required to draw further conclusions. Support by the school as an institution, the specific role of the teacher, and family participation are important factors related to the impact of peer support systems. Information on these aspects was scarce, and it is recommended to include variables of this nature in future research. Intervention descriptions revealed students' active participation through suggestions for activities, however their involvement in organizing the systems was limited. More research is needed to learn about the opportunities of emotional peer support to improve student-student relationships including the active involvement of the peers themselves in this support.

Keywords: peer support, SEND, school ethos, student participation, peer interaction, emotional support

OPEN ACCESS

Edited by:
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University of the Bío-Bío, Chile

Reviewed by:
Helen Cowie,
University of Surrey, United Kingdom
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Specialty section:
This article was submitted to Educational Psychology, a section of the journal Frontiers in Psychology

Received: *19 October 2021*
Accepted: *14 December 2021*
Published: *28 December 2021*

Citation:
van der Meulen K, Granizo L and del Barrio C (2021) Emotional Peer Support Interventions for Students With SEND: A Systematic Review. Front. Psychol. 12:797913. doi: 10.3389/fpsyg.2021.797913

INTRODUCTION

Peer interaction and the building of positive peer relationships are essential for young people's development (Piaget, 1932; Hartup, 1979, 1996; Johnson, 1980). However, for students with specific educational needs and disabilities (SEND), positive relationships seem to be more difficult to attain. They are more vulnerable to being bullied or suffer from social exclusion in school (Thompson et al., 1994; Carter and Spencer, 2006) including after transitioning from primary to secondary school (Hughes et al., 2013). Students with autism spectrum conditions (ASC)

seem to be more at risk for being bullied than students with other types of SEND (Humphrey and Hebron, 2015). Moreover, Lasgaard et al. (2010) found that adolescents with ASC reported often or always having feelings of loneliness. Feeling lonely was associated with a lack of social support from classmates. Therefore, the need to improve peer experiences in schools for students with SEND has been underlined by many researchers and practitioners.

Over the last decades, scholars have highlighted the importance of the involvement of the peer group in promoting positive student-student relationships (e.g., Johnson et al., 2010), and reducing bullying and social exclusion in schools (Salmivalli, 1999). Peers show qualities that make them more effective agents than adults in schools: they share the same status, and are therefore more easily accessible and more influential, among other reasons.

In literature on school ethos there are references to students taking an active role in decision-making or norms settlement in their schools, as well as to the benefits of these practices. Some of these experiences are based on the Just Community Schools approach (Power et al., 1989). Another example is The Three R action (*rights, respect, responsibility*). On the basis of The Three R action, Covell et al. (2008) conclude that the combination of actions promoting participation together with students' knowledge about their rights help them act as mature citizens. Students' participation in areas affecting them directly is one of the rights of children (United Nations, 1989), has positive consequences for them along with the school community (Edwards and Mullis, 2003; Saiz-Linares et al., 2019), and prepares them for social commitment (Flanagan et al., 1998; Haste, 2005), especially when pupils' actions respond to social environmental needs, as in service-learning experiences (Hart et al., 2006; Traver-Martí et al., 2019). However, adults in schools seem to not be prone to sharing power with pupils. Students themselves report on their low participation level in school (Coiduras et al., 2016) and point to a more reactive nature by merely deciding on ideas and proposals that come from teachers and which are rather non-essential matters. Many times decisions are taken hierarchically, and sometimes students feel pressure to accept these in a non-voluntary way (Granizo et al., 2019).

The creation of systems in which peers can show helpful behavior is beneficial for schools in order to build a positive, supportive climate. Peer support is about social interactions that involve giving information, emotional or practical help based on what peers have in common and many times with benefits for both (Cowie and Wallace, 2000). Various types of peer support systems exist, which can be broadly divided into two categories (Cowie and Wallace, 2000). The first involves methods related to education and information-giving, such as peer tutoring and mentoring. The contents of the support are mainly academic such as reading activities or mathematical problems. There is a considerable amount of literature available on this type of peer support, including analyses on the effectiveness of their application with SEND students, for example peer tutoring (Talbott et al., 2017; Alzahrani and Leko, 2018).

The second category involves emotional support given by peers to others who are in need, and refers to befriending, mediation/conflict resolution, and counseling-based approaches (Cowie and Wallace, 2000). Befriending implies support in various formats, such as offering companionship to students perceived as solitary or helping peers who are bullied or find it hard to make friends. Conflict resolution entails mediating between peers, or a peer and an adult, who are in disagreement. Counseling-based interventions require more extended training in counseling skills. Students ask for help to one of the counselors directly or the student contacts the service and is referred to a counselor. All these types of emotional peer support systems share several aspects (Sharp and Cowie, 1998). For a start, they require a recruitment or selection process. Students receive training focused on listening and communication skills, empathy for peers with social or emotional difficulties and problem-solving strategies (Cowie and Sharp, 1996; Cowie and Wallace, 2000). Adults are in charge of this training and maintain a supervisory but non-directive role during the intervention. The peers themselves fulfill the most important role and have the capacity to manage the helping practices. And finally, as it typically takes place outside the classroom, whether the support system succeeds or fails depends on the commitment of the students who volunteer for it.

The effectiveness of emotional peer support has been demonstrated in several general population studies in secondary schools, with respect to counseling-based systems (Naylor and Cowie, 1999; Cowie et al., 2002; Houlston and Smith, 2009; Del Barrio et al., 2011). Results showed these were efficient in terms of the helping process; students who were supported by peers reported feeling emotional relief and an increased ability to cope with problems. Benefits for peer supporters included increased self-esteem and communication skills.

Peer support in schools is more effective when it is integrated into a whole school supportive ethos or policy (Cowie and Jennifer, 2007; Cowie and Smith, 2010). This means that it is an integrated element among practices and attitudes related to the improvement of relationships and the well-being of the entire educational community. Moreover, the degree to which students and teachers know about the peer support available in their school is important. In addition, the active backing of the head teacher or those involved in the school's management contributes to the program's success (Cowie and Smith, 2010). School staff as well as families are able to be positive influences by spreading the word and motivating participation. Finally, the extent to which students are able to have control over the intervention, properly contributing to it by themselves, needs to be taken into account.

Peers are included in psychosocial treatment approaches for students with SEND, more specifically for children and adolescents with ASC or Attention-Deficit Hyperactivity Disorder (ADHD), who show difficulties with social interactions (De Boo and Prins, 2007; Schall and McDonough, 2010). These interventions allow for opportunities in which they can learn new social skills and/or how to appropriately apply them. Three types of approaches in which peers are involved have been distinguished (Cordier et al., 2018): peer involvement, peer proximity and peer mediation. Peer involvement entails participants facilitating each other's learning when receiving instruction on social skills and frequently implies peers with

similar difficulties should work together in a group therapy context. Peer proximity means that a carefully selected peer with adequate skills is placed in proximity to the focus student, for example sitting near them in the classroom. Peer-mediated intervention (PMI) is a treatment approach in which peers are trained or directed by an adult to instruct and/or facilitate social interactions (Chan et al., 2009). Students support their peers with disabilities typically by modeling and reinforcing appropriate behavior (DiSalvo and Oswald, 2002). Consequently, of these three groups of approaches, only PMI can be considered an emotional peer supporting practice—more particularly befriending—as detailed in the description presented above, if specific conditions are met. Peers should be able to facilitate social interactions with students with SEND and not have a mere instructional task. Additionally, the intervention should not be directed, at least not completely, by adults. Finally, the goal of the support lies in its befriending character. It aims to improve peer relationships in the school and not at the treatment of an individual's disorder.

Reviews of studies on PMI have demonstrated positive results for students with ASC in terms of treatment (Chan et al., 2009), substantial improvement in social interactions (DiSalvo and Oswald, 2002) and advancement of social skills (Miller et al., 2014). However, DiSalvo and Oswald noted that the nature of social interaction improvements varied across participants and studies. A review on augmentative and alternative communication intervention research showed that interventions for students with SEND that incorporated peers (including PMI) had a positive effect on communication (Fisher and Shogren, 2012). Travers and Carter (2021) reviewed the effects of PMI on students without disabilities (i.e., peer supporters) and found benefits in various areas, including social impact (interaction, friendships with others), increased knowledge about disabilities and changes in self-perception. Cordier et al. (2018) searched for research on peer proximity/involvement/mediation for children with ADHD but did not find studies on peer-mediated intervention. No conclusions about the efficacy of these types of interventions to improve these children's social functioning could be drawn.

In summation, the reviews on PMI interventions are important contributions, but as they only partially fit into the group of emotional peer support, further synthesis is necessary. Moreover, to our knowledge no review is available on this specific area. Therefore, our purpose is to perform a systematic review that focuses on emotional peer support interventions in school contexts (kindergarten, primary, and secondary school) for students with SEND and facilitate knowledge about this type of evidence-based practice. This paper's research questions can be grouped together in three areas:

(1) Which types of peer support have been employed and what is their degree of success in terms of interpersonal outcomes between students, as well as results on the individual level for the SEND students and their peer supporters?
(2) How is the selection and training of the peer supporters completed? What is the level of participation of the students themselves in the intervention? Are they able to contribute to the intervention (e.g., by proposing activities, etc.), or has it been fully structured by adults? And finally, are there possibilities for further relationship building outside the usual settings or is peer interaction limited to a fixed structure (in terms of time, space and activities)?
(3) How is the adult support performed? Furthermore, do the school and families support the intervention and in which way?

METHODS

Search Procedure

The present literature review was conducted according to the PRISMA guidelines for systematic reviews (Liberati et al., 2009). First, in November 2020, we searched the peer-reviewed scientific literature for which the following EBSCO databases were used: APA PsycInfo, ERIC, Academic Search Premier, Education Source, MEDLINE, Psychology and Behavioral Sciences Collection, APA PsychArticles, PSICODOC, APA PsycBooks, Teacher Reference Center, Humanities International Complete, and Open dissertations. Additionally, the databases PsyArXiv and Search Open Grey were employed in order to include gray literature. Key search terms were selected on the basis of Cowie and Wallace (2000) differentiation of models of peer support (i.e., counseling but not tutoring) in order to include only specific types of emotional support, with the addition of the more general term *peer support*. Two Boolean searches were conducted, the first using combinations of the following keywords: 1. *peer support* OR *peer counseling* OR *peer mediation*, 2. *disability* OR *disabilities* OR *disabled* OR *impairment* OR *impaired* OR *special needs*, 3. *school* OR *education* OR *k-12* OR *elementary* OR *kindergarten*. In the second search, keywords of the first series were substituted for 1. *befriending* OR *conflict resolution* OR *circle of friends* OR *telephone help*; the remaining keywords were the same. A filter was used for age in order to include only abstracts of studies with participants in childhood and adolescence.

The PRISMA diagram **Figure 1** shows the selection of included studies. Searches yielded 787 records in the EBSCO databases and 59 trials in the unpublished report databases, of which 133 were duplicates. After removing these duplicates, each of the 713 records was first screened by title and abstract by one of the authors. An intercoder was performed on 20 articles to ensure that all articles were identified correctly on the basis of the abstract, and consensus was reached on 95% of the sample. The initial disagreement on one paper was jointly reviewed until an agreement was obtained. A total of 665 papers, which included the total number of unpublished works, were excluded from further analysis. Of the remaining 48 records, the full text was obtained and assessed for eligibility applying the pre-established criteria with 11 papers meeting the criteria. Finally, the reference lists of the identified articles and relevant literature reviews were examined, and 12 additional studies were located, summing up to the total of 23 papers.

Inclusion and Exclusion Criteria

Studies were included in this review if they met the following criteria: a. it involved an empirical examination of peer

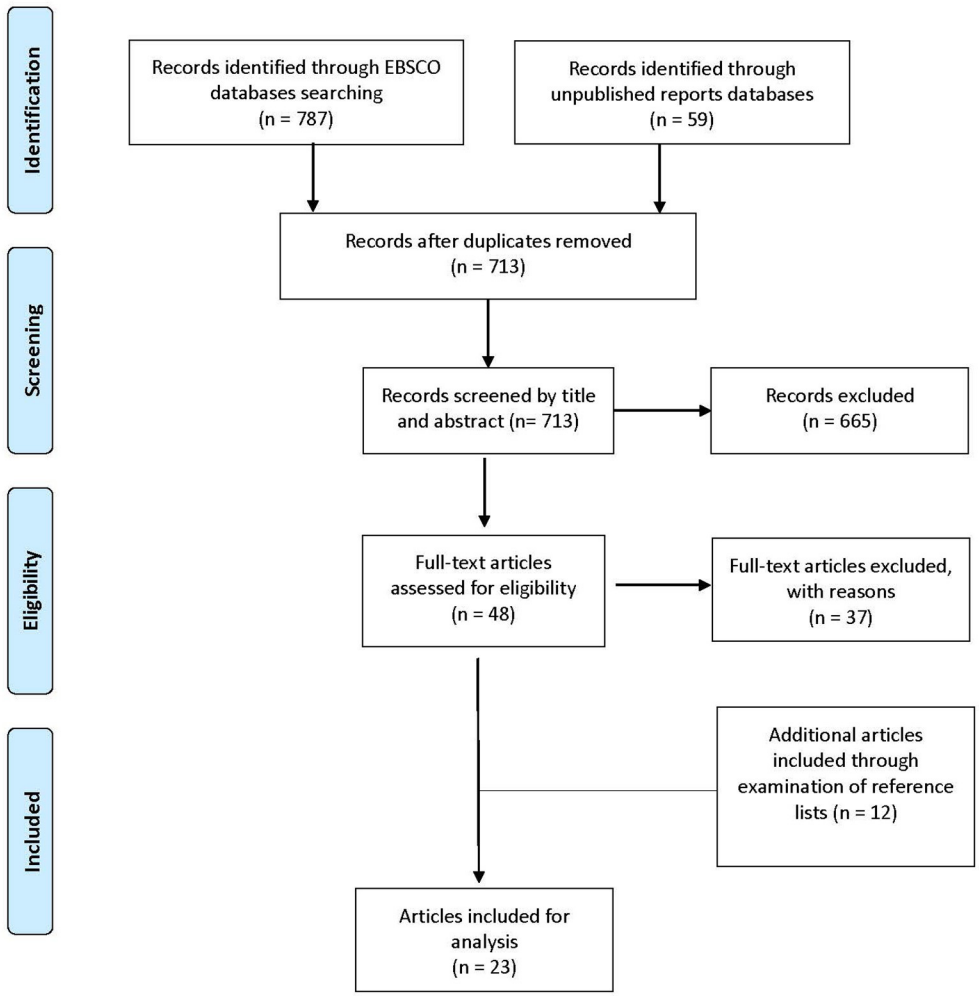

FIGURE 1 | PRISMA flow diagram of study selection.

supporting actions, b. it took place in the school context: in kindergarten, primary or secondary school, c. participants were between 2 and 18 years of age, d. it was published in English or Spanish. There was no restriction related to the year of publication. Unpublished dissertations were excluded from the review, as they were not available online. The present review is not expected to be influenced by this since Vickers and Smith (2000) showed that the inclusion of unpublished dissertations rarely affects the conclusions of a review.

A paper was included only if the intervention involved one of the three types of emotional peer support of befriending, mediation or counseling. Practices that included didactic instruction, for example academic peer support as peer tutoring, or only physical assistance from peers to students with physical disabilities were excluded. Finally, interventions in which adults, e.g., teachers or therapists, were constantly involved in the process in a directive role by giving instructions when peers interacted were also excluded. Adults should mainly have an organizing and supervising role in the described practices.

RESULTS

The 23 papers that were included in the present review focused on four different types of emotional peer support. Nine articles involved a circle of friends (CoF) intervention, eight papers reported a type of peer buddying, four studies focused on peer networks and two articles portrayed social club interventions. Therefore, all papers document befriending interventions, and no articles were found on peer mediation or counseling-based support. The intervention procedures that were reported in these papers are briefly described below. In **Table 1**, data on participants, research methods and outcomes of each study are shown.

Description of Emotional Peer Support Interventions

Circle of Friends

With respect to the procedure of CoF, seven papers (Whitaker et al., 1998; Frederickson and Turner, 2003; Frederickson et al.,

TABLE 1 | Features of studies on emotional peer support interventions for students with SEND.

References, Country	Educational level Participants: focus students, peer supporters, adult facilitators	Research design, methods, and measures	Peer and self-esteem related outcomes
Circle of friends			
Bowen (2010), UK	Secondary education Focus student: Boy (12 yrs.) with visual impairment Peers in CoF: 7 children (not further specified) Adult facilitator: classroom teacher	Design: Pre-post and follow-up evaluation Method: questionnaire Measures: self-esteem, locus of control (focus student)	- Increased self-esteem, improved locus of control
Frederickson and Turner (2003), UK	Primary school Focus students: 20 students in different classrooms (19 boys, 1 girl, age 6–12 yrs.; Grades 1–5) with special educational needs (emotional and behavioral difficulties; learning difficulties). Peers in CoF: 4 to 8 classroom peers in each CoF (number of boys in each CoF, M = 3.47, girls M = 2.94); 19 CoF. Adult facilitators: educational psychologist (from outside school), graduate students in educational psychology, classroom teachers, specialist teacher/support assistant.	Design: Two-phase small scale evaluation. Phase 1: between-groups pre-post design; Phase 2: within-subjects design. Phase 1 (CoF set up for 10 focus students; 10 focus students served as control group). CoF led by graduate students. Phase 2: (CoF created for 9 focus students of control group in Phase 1). CoF led by school staff. Method: questionnaires Measures: Social acceptance/inclusion, social rejection of focus child. focus child's scholastic, athletic competences, physical appearance, behavioral conduct, social acceptance (self-perception by focus student, teacher's ratings). Global self-worth (focus student). Perceptions of classroom learning environment (all students in classroom).	- Improvement of social acceptance of the focus students by the peers in their classrooms; although more reduced to peers in CoF in Phase 1 - Increase of focus children's perceptions of self-worth participating in Phase 2 - No changes in perceptions of social acceptance (evaluated by focus students), behavioral conduct (rated by focus students, teachers) - No changes in perceptions of classroom's ethos (by whole class)
Frederickson et al. (2005), UK	Primary school Focus students: 14 students in different classrooms (11 boys, 3 girls; age between 6 and 11 yrs., Year 2–6) with learning difficulties (7), emotional and behavioral difficulties (6) and ASC (1) Peers in CoF: 6 to 8 classroom peers in each CoF; 14 CoF. Adult facilitators: assistant educational psychologists, classroom teacher (or other school staff) as participant observer	Design: Baseline (Time 1, before whole-class meeting) -intervention (Time 2, 3–5 days after whole-class meeting) -follow-up (Time 3, 1 week after circle meetings; Time 4, 1 term afterwards, only 7 CoF). Method: questionnaires Measures: Sociometric measure: acceptance, rejection of focus students Peer nominations for positive behavior (cooperating, leading) and negative behavior (disrupting, fights, bullying, victim of bullying)	- Increase of acceptance and reduction of rejection by full group of students in the class after the whole-class meeting - Weekly circle meetings did not produce further improvements in terms of acceptance and decrease of rejection, not for the whole class, and neither for students in CoF - No changes found in peer ratings of focus student's pos itive nor negative behavior - Exception of one CoF involving student with ASC, with continued improvement of acceptance and rejection scores, as well as a decrease in ratings of disruptive behavior.
Gus (2000), UK	Secondary school Focus student: boy w/ ASC (Year 10) Peers: whole classroom Adult facilitators: classroom teacher, external educational psychologist	Design: Case study. Qualitative evaluation 23 weeks after information session. Method and measures: Questionnaire (classroom peers)	- Classroom peers changed their attitude (more sympathetic, patient, understanding his feelings), as well as their behavior toward focus child (allowing him to join in, trying more to talk to him, telling others not to treat him badly).
Kalyva and Avramidis (2005), UK	Preschool Focus students: 3 boys w/ ASC (age 3/4 yrs.) Peers in CoF: 15 girls, 10 boys from same classes, typical development, similar age as focus students; 3 CoF. Adult facilitators: classroom teachers, therapist	Design: Baseline-intervention-follow-up evaluation. Comparison with control group (2 boys w/ASC, age 3–4 yrs.) Method: Observation Measures: 1. Responses to initiatives by peers to make contact, 2. Contact initiation attempts (by the focus child)	Focus children in comparison to control group showed: - Significant increase of successful responses and initiations of contact, - Significant decrease of unsuccessful responses and initiations of contact. Differences maintained during follow-up (2 months after intervention).

(Continued)

TABLE 1 | Continued

References, Country	Educational level Participants: focus students, peer supporters, adult facilitators	Research design, methods, and measures	Peer and self-esteem related outcomes
O'Connor (2016), Ireland	Primary school Focus student: boy w/ ASC (Asperger Syndrome, age 10 yrs.) Peers in CoF: children of same class (unspecified) Adult facilitator: classroom teacher	Design: Pre-post evaluation Methods and measures: 1. Observation. Behavior of focus child. 2. Questionnaires. Sense of belonging in school (focus child). Sociometric status (Peers in CoF)	- More contact between focus child and class group, higher quality of contact. - Increase of successful social initiations by focus child - Increase of focus child's feelings of social acceptance - Increased willingness of 70% by peers to work with focus child Peer group 80% more likely to accept behaviors shown by focus child - Outside school activities: invitation to 2 birthday parties, going to cinema - Peers in CoF also showed acceptance of other students (no ASC) who had been socially excluded
Owen-DeSchryver et al. (2008), USA	Primary school Focus students: 3 students with ASC (age 7, 7 and 10 years; grades 2 and 4). Peers in CoF: 7 girls, 3 boys from same classes, typical development; 3 CoF. One CoF of 2 boys substituted by CoF of 3 girls. Adult facilitators: Researchers	Design: Baseline-intervention-post-intervention evaluation (6 months). Method: Observation. Multiple sessions during lunchtime and recess Measures: For trained peers and untrained peers: 1. Social initiations toward focus student, 2. Responses to initiations made by focus student. For focus students: 1. Social initiations toward peers, responses to social initiations by peers. Both initiations as responses defined as positive social behavior.	- Increase of social initiations by both trained and untrained peers toward focus student, and of responses to initiations by focus student - Increase of social initiations and responses by focus children toward peers - One group of 2 male trained peers did not show an increase of social interactions, substituting group of 3 girls did show increase.
Schlieder et al. (2014), USA	Secondary school Focus students: w/ ASC, further unspecified Peers in CoF: unspecified, number of CoF unspecified but > 5 Adult facilitators: school personnel working with special needs students	Design: Multi-site collective case study. Qualitative evaluation. Method and measures: (Phone) interviews w/ (a) group facilitators, (b) parents of focus students, (c) community partnering agency program directors. Comparison of perspectives in data analysis. Use of measures to increase trustworthiness such as triangulation, member checking.	- Peer acceptance and less fear of classmates toward focus students, increased interaction, friendships - Peers in CoF showed increase of empathy, understanding of classmates w/ ASC and other disabilities, as well as to students outside CoF - In settings outside school (without adult facilitators), peer acceptance generalized as seen in outside activities (e.g., birthday parties, movies, gaming clubs)
Whitaker et al. (1998), UK	Primary and secondary school Focus students: 7 students w/ ASC (Years 3 to 10). Peers in CoF: 52 classroom peers; 7 CoF. Adult facilitators: classroom teachers, member Autism Outreach Team	Design: Qualitative evaluation. Repeated measures during intervention. Methods and measures: Interviews (focus children, school staff responsible for CoF, parents, other school staff). Questionnaires followed by discussion (CoF peers). Self-esteem measure (CoF peers).	- Improved quality and quantity of contacts between focus child and peer group - Reduced anxiety in focus children - Perception of focus children mainly as recipients of help, more than participating in a relationship in which both parts are equally supportive. - Only 3 CoF peers perceived focus child as a friend. Few outside school activities (one focus child received invitation to visit home of CoF peer, one focus child visited at home). - Increased levels of empathy and improved understanding in CoF peers, improved group participation, more CoF peers showed enhanced self-esteem in comparison to non-involved classmates over same period.

(Continued)

TABLE 1 | Continued

References, Country	Educational level Participants: focus students, peer supporters, adult facilitators	Research design, methods, and measures	Peer and self-esteem related outcomes
Peer buddying			
Artiles et al. (2016), Spain	Secondary school Focus students: School 1 (no peer support), Classroom 1: 7 students (age between 14 and 17 yrs.). School 2 (with peer support program). Classroom 2: 6 students (age between 17 and 20 yrs.). Classroom 3: 6 students (age between 15 and 20 yrs.). Various disabilities, including Down Syndrome, labeled as intellectual disability and ASC (except for classroom 3). Peer buddies: unspecified Adult facilitators: Special education teachers Classroom 2: teachers	Design: Multiple case study Method and measures: 1.Observation during break time Type of communication (oral, -type of-gestures, no interaction), transmitters and receivers (classmates, peers in school, teachers) 2.Semi-structured interviews with focus students Interactions during break time	For students from School 1 (without peer support) moments of no interaction (68%) during break time were more frequent than those of interaction. They mostly interacted with their classmates (77%) and very little with teachers (4%). The opposite happened for students from School 2: Classroom 2 interacted during 63% of the time observed, with other peers (44%), teachers (32%), classmates (24%); Classroom 3 interacted during 83% of the time, with other peers (21%), teachers (24%), classmates (55%). In School 2, teachers supervised interactions during break time, in School 1 they did not. Overall, interactions were close and without tension, frictions and anger were very infrequent.
Carter et al. (2001), USA	Secondary school Focus students: 109 students with severe disabilities, including ASC (73 boys, 36 girls), age between 13 and 20 yrs., 10th-12th grade. Peer buddies: 30 students (26 girls, 4 boys), age between 14 and 18 yrs., 10th-12th grade. Adult facilitators: Special and general education teachers, with assistance from researchers.	Design: Pre-test-post-test Method: Structured questionnaire for peer buddies and non-volunteers ($n = 30$; 26 girls, 4 boys; age between 14 and 18 yrs., 10th-12th grade). Measures: SDQ (Haring et al., 1983). - Social willingness to interact with students w/ disabilities - Knowledge of people w/ disabilities - Affect - Prior contact	Pre-test: peer buddies reported more social willingness and more prior contact with persons with disabilities than the non-volunteers. No differences were found in knowledge and feelings toward individuals with disabilities. Post-test: After participating one semester in the Program, peer buddies scored higher on social willingness, knowledge and prior contact. Additionally, a positive correlation was found between prior contact and social willingness. No changes between pre- and post-test-scores of the non-volunteers were observed.
Copeland et al. (2004), USA	Secondary school Focus students: 152 students with moderate/severe disability including ASC, limited communication skills (36% girls; age between 14 and 20 yrs.) Peer buddies: In study, 32 out of 53 participating students in the Program at least one semester (78% girls, 78% seniors), age between 16 and 18 yrs. Adult facilitators: Same as Carter, Hughes, Copeland & Breen (2001)	Design: qualitative research Method: 6 focus groups (2 to 11 participants) Measures: Perceptions of - Learning about Program - Peer buddy role - Benefits for themselves and others in school - Improvement of Program	- Actions of peer buddies to increase participation of students with disabilities in general education: enabling opportunities for interaction, advocating for students, modeling acceptance for other peers, increasing their own knowledge and skills, adjustment to friendship instead of teaching role - Perceptions of benefits for themselves (knowledge, attitudes, friendships, feelings of accomplishment), focus students (functional academic skills, social interaction), other students (opportunities for interaction, increased awareness of disabilities), teachers (assistance)
Copeland et al. (2002), USA	Secondary school Adult facilitators: special education teachers	Design: qualitative research Method: open-ended questionnaire for general ($n = 13$) and special education teachers ($n = 13$). Minimum experience in Program $\geq$ 1 yr.; most teachers $\geq$ 4 yrs. Measures: perceptions on: - Benefits for students w/ disabilities - Benefits for general education students - Challenges in implementation - Recommendations	- Benefits for students with disabilities. Special education teachers emphasized social-related benefits (increased interaction opportunities with peers and age-appropriate social skills acquisition. general education teachers primarily mentioned academic or functional skills related benefits. All teachers reported benefits in terms of establishing positive relationships (including friendships), enhanced personal growth

(Continued)

TABLE 1 | Continued

References, Country	Educational level Participants: focus students, peer supporters, adult facilitators	Research design, methods, and measures	Peer and self-esteem related outcomes
			(self-confidence). Additionally, peer buddy assistance is less disruptive in the classroom, therefore does not draw attention to focus student (marking them as "different"). Benefits for general education students. Socializing opportunities, students with disabilities are also positive role models, increased diversity.
Hughes et al. (2001), USA	Secondary school Focus students: 200 students (34% female) w/ severe disabilities (e.g., mental retardation, multiple disabilities, physical disabilities) participating in program Peer buddies: 115 students (82% female, 74% in grade 12) of 169 (83% female) students participating in program (10th-12th grade). Participation in Program: 50% participated ≥4 months; 50% ≥8 months (max. 2 yrs.) Adult facilitators: Same as Carter et al. (2001)	Design: qualitative research Method: open-ended questionnaire for peer buddies Measures: Attitudes toward focus students Benefits from interaction Type of activities Contributions made to focus students Suggestions for maintenance and improvement of program	Perceptions of peer buddies: - Positive attitudes toward peers w/ disabilities - Perceiving more similarities than differences (especially related to needs, desires and feelings) - Benefits for themselves (personal growth, friendships, knowledge about, strategies for interaction with people w/ disabilities) - Benefits for focus students: 1. Helping focus students learn skills (e.g., functional life skills, employment training skills) 2. Befriending, promoting social interaction, and acceptance
Hughes et al. (2002), USA	Secondary school Focus students: 1 male student, 4 female students w/ mental retardation, autism, language impairment (severe disabilities; age 15–22 yrs.). Peer buddies: 12 students (7 girls, 5 boys; 10th-12th grade) Adult facilitators: Classroom teachers. Intervention sessions: research team (graduate students)	Design: multiple baseline design across participants Method: Observation Measures: - Social interaction - Quality of interaction - Reciprocity of initiation of social interaction - Exhibition of communication behaviors - Type of conversational topics (e.g., peers, school events, jokes, movies)	- Increase of engagement of social interaction, as well as quality and reciprocity of students' interactions - Increase in range of communicative behaviors (focus students) - Increase in variety of topics discussed in conversations by focus students and peer buddies
Staub et al. (1996), USA	Secondary school Focus students: 3 female, one male students with moderate and severe disabilities (age 13–14 yrs., 7th and 8th grade). Student aides: 31 students (25 girls, six boys) in grades 7, 8 or 9). 7 student aides had mild special education needs. Adult facilitators: General and special education teachers, school administrators (principal).	Design: Case study Qualitative research. Methods and measures: 1. Observation of focus students, in classroom and during lunch time. Observations of behaviors, interactions and interpretations, judgments of these. 2. Semi-structured interviews with student aides, teachers, special education assistant, focus students and their parents. Including questions on inclusion of students w/ disabilities, on student aide program and its outcomes.	Focus students: increased independence and academic skills, behavioral changes, and expanded socialization with typically developing peers (including developing friendships). Student aides: increased socialization, acknowledgment by school community leading to improved self-esteem, increased understanding and appreciation for persons with disabilities, enhanced patience (for some students only), being more responsible.
Whitaker (2004), UK	Primary school Focus students: 9 male students, one female student (age between 6 and 7 yrs.), with moderate/severe ASC and limited expressive language. Peer supporterss: 10 students from Year 6. Adult facilitators: Experienced learning support assistant, nursery nurse.	Design: Qualitative study Methods and measures: 1. Observation. Joint attention behaviors, communication by focus student, shared play. 2. Semi-structured interviews with peer tutors. Perceptions of experience 3. Semi-structured interview with mother of peer tutor. Benefits and disadvantages of child's involvement.	- Increase of shared play Very little increase of communication of requests, communication for other purposes rare - No change in level of joint attention behaviors. - Although focus students showed to be enjoying activities, awareness of a shared experience was more difficult to detect. However, when these moments of connection happened, rated by peer supporters as best part of their work.

(Continued)

TABLE 1 | Continued

References, Country	Educational level Participants: focus students, peer supporters, adult facilitators	Research design, methods, and measures	Peer and self-esteem related outcomes
			Most difficult were moments of not feeling acknowledged or rejected. - Classmates were perceived as overall supportive.
Peer network			
Gardner et al. (2014), USA	Secondary school Focus students: 2 male students w/ ASC (age 18 yrs., 12th grade; 14 yrs., 9th grade) Peer supporters in 2 networks: 3 students (1 girl, 2 boys, 11th−12th grade) 3 students (3 girls, 10th−12th grade) Adult facilitators: special education paraprofessional and special education teacher (received training), research team	Design: Multiple baseline design across participants. Method: Observation Measures: Social interaction (communicative behaviors), social engagement, specific chosen communication skill for each focus student, support behaviors by peer supporters and adult facilitator, interaction quality, proximity.	- Increases in social engagement and peer interactions. - Medium quality of 18 yr. old focus student's interactions, lower quality of 14 yr. old's interactions. - Decrease of social interactions when peer network was withdrawn temporarily. - Network members considered each other friends. However, when no meeting was held, peers spend time with other people, on other activities.
Haring and Breen (1992), USA	Secondary school Focus students: 2 male students (age 13 yrs., 8th grade) w/ moderate-severe disabilities (ASC diagnosis for 1 student). Peer supporters in two networks: 4 non-disabled students (2 girls, 2 boys, age 12 and 13 yrs.) 5 non-disabled students (5 boys, age 13 yrs.) Adult facilitators: Unspecified.	Design: Multiple baseline design across participants. Methods and measures: 1. Observation. Social interactions (i.e., initiations and response), appropriate social responding, interactions outside of school (including weekends). 2. Qualitative self-reports. Peers' ratings of relationship w/ focus student, satisfaction w/ program. Degree of satisfaction of focus student with peer network.	- Increase of social interactions between network members. - Increase of appropriate responding by focus students - More positive perceptions of focus students Increase of descriptions of network members as friends - Interactions outside school (e.g., trips to the mall, beach), 12 times for one focus student, 5 times for the other (Baseline: no interactions outside school.)
Harrell et al. (1997), USA	Primary school Focus students: 3 students (2 boys, 1 girl) w/ ASC, communication difficulties (age 6–7 yrs., 1st grade) Peer supporters in 3 networks: 5 students w/ typical development (1st grade) in each network Adult facilitator: Researcher	Design: Multiple baseline design across settings nested within multiple baseline across participants. Methods: Observation, expressive behavior recording, computerized data collection, friendship and peer nomination scales. Measures: Social interaction duration Peer acceptance of focus student Inappropriate behaviors (focus student) Use of augmentative communication system (focus student, trained, and untrained peers) Frequency of expressive verbalizations (focus student)	- Increase of social interaction time across the various settings - Increased acceptance by peers ("like to play with") Minimal exhibition of disruptive behaviors - Increase of augmentative communication systems by focus students and network peers in several settings - Increased expressive language for 2 students
Hochman et al. (2015), USA	Secondary school Focus students: 4 male students w/ ASC (age between 15 and 17 yrs., 9th−11th grade). Peer supporters in 4 networks: 9 female students and 2 boys (age between 16 and 18 yrs.) were trained; finally 7 girls and 2 boys participated in networks. Adult facilitators: one special educator and two paraprofessionals (received training), research team.	Design: Multiple baseline design across participants. Method and measures: 1. Observation. Social interactions (communicative behaviors), social engagement, specific chosen social/communication skill for each focus student, support behavior by adult facilitator, proximity.	- Increase of social interactions and social engagement during network meetings, but only remained high for one focus student on non-network days. - Modest gains of specific social/communication skill for 3 students, high improvement for 1 student - Increase of proximity to peers supporters in network, as well as other peers (without disabilities).

(Continued)

TABLE 1 | Continued

References, Country	Educational level Participants: focus students, peer supporters, adult facilitators	Research design, methods, and measures	Peer and self-esteem related outcomes
		2. Questionnaires with Likert-type and open-ended questions. Focus students, their parents, peer supporters and facilitators. Questions on friendships and well-being (focus student), network experience and perceived outcomes.	- Positive perceptions of intervention by all agents. More interactions and friendships among peers w/ and without disabilities observed by adult facilitators. Peer partners noticed that focus students were interacting more with other peers outside network meetings. All focus students named peer supporters as friends; also peer partners considered student w/ ASC to be a friend.
Social lunch clubs			
Koegel L. K. et al. (2012), USA	Primary school; summer day camp Focus students: 3 students w/ ASC (boy 9 yrs., 3rd grade; boy 10 yrs., 5th grade; girl 12 yrs., 6th grade). Peer supporters in 3 clubs: 6–10 typically developing students in same grades Adult facilitators: university students	Design: Repeated measures baseline experimental design. Method: observation Measures: 1. Time engaged with peers (i.e., remaining in club area and interacting with peers) 2. Verbal initiations toward peers (questions, comments, activity directions)	- Increase of engagement with peers during club meetings. Increase of verbal initiations during club meetings. Average number of initiations was lower for focus students than for peers. However, on some sessions, all three children reached their peers' level.
Koegel R. L. et al. (2012), USA	Primary school, middle school Focus students: 3 male students w/ ASC (student 1: 13 yrs., 8th grade; student 2: 11 yrs., first school 6th grade, second and third school 7th grade; student 3: 14 yrs., 8th grade. Peer supporters in 3 clubs: unspecified Adult facilitators: unspecified	Design: repeated measures baseline experimental design. Method: observation Measures: 1. Time engaged with peers (i.e., remaining in club area and interacting with peers) 2. Verbal initiations toward peers (questions, comments, activity directions)	- Increase of engagement with peers during club meetings. Before intervention, focus students did not at all or nearly not engage with peers, although many clubs were available to them. - Increase of verbal initiations during club meetings. - Student 1 received multiple invitations to hang out/birthday parties from peers in same club. - Student 2 showed some generalization of engagement /and initiations to his second and third school.

2005; Kalyva and Avramidis, 2005; Bowen, 2010; Schlieder et al., 2014; O'Connor, 2016) refer to the procedure as described by Taylor (1996; 1997; or to Whitaker et al., 1998 who in turn cites Taylor). According to Taylor, establishing a CoF involves several key components or steps. First, the commitment of the school is necessary for resources, and permissions from parents or guardians also need to be obtained. Second, a discussion is held with the entire class, but without the focus student, which is usually led by an external agent (e.g., educational psychologist or school staff member with no direct relationship to the class) and with the teacher being present. The key element of this session is a participative group discussion of the focus child's strengths and difficulties, in addition to a talk about friendship, the lack of it and the effects of that absence on feelings and behavior. At the end of the meeting, volunteers for a support group are sought for. Next, a group of six to eight students are selected for the CoF and in the first meeting with the focus child and the adult facilitator, goals and strategies are identified for the following week. Hereafer, the CoF meets weekly, again with help from the adult facilitator, to evaluate the progress and to make practical plans for the following week. These weekly meetings continue for about 6–10 weeks.

Of the seven reports, five had introduced small changes in the procedure of the intervention. Frederickson et al. (2005) changed the class meeting of one of the CoF into a session in which social interaction and communication difficulties of ASC children were explained, and how these difficulties affect their behavior. The goal was to make children aware of the low probability that the behavior of the focus student would change. Schlieder et al. (2014) followed the description by Taylor, although they also report having included specific CoF lessons about autism and motivation for positive interaction (without further detail). Kalyva and Avramidis's (2005) CoF implementation took place in preschool, therefore, it was adapted to that educational level. First, the peers for the CoF were selected by the teacher. She explained (in absence of the focus child) that the circle's goal was to help their classmate to learn how to ask other children to play. In the circle sessions, the teacher gave directions to the children for an imitation activity with toys. Bowen (2010) reported a CoF intervention for a boy with visual impairment, but in her rather short description a class discussion was not mentioned.

Exceptionally, an exact reference to Taylor's model (or Whitaker) was not provided. Finally, O'Connor (2016) does not mention a whole-class discussion either in her report.

The last two papers involve a somewhat different procedure of the CoF. While Gus (2000) reports a regular application of only the first two steps, she also included a talk about autism in the class session as a replacement for the talk about friendships. A third step involved a feedback session 1 week later with the whole class, in which students answered questions about what they learnt and what they could do to support the focus student. No circle of peers was established hereafter; every decision was left in the hands of the class. In Owen-DeSchryver et al's. (2008) intervention, firstly peers were selected for a "training." The first phase of this training consisted of either a book reading and a discussion about a child with autism (second graders) or a friendship awareness activity (fourth graders). In a second phase, a discussion about the strengths and weaknesses of the child with ASC took place, while during a third phase the CoF participated in a guided discussion in which concrete information and strategies for interaction were presented. The focus children were unaware of the peer training.

Peer Buddies

Eight papers involved a type of peer buddying, all in secondary education except for one intervention in primary school. Staub et al. (1996) described a "student aide program" in a junior high school in the USA. In every class period, a different student aide helped one of the focus students. Their tasks were varied: monitoring the focus student's behavior, helping with academic work and daily activities, and offering companionship (befriending). Student aides received training (unspecified in the paper) and obtained course credit as well as a course grade.

Artiles et al. (2016) carried out a study on the "Friend Project" implemented in a secondary school. Focus students were in special education classrooms in mainstream schools. Peer supporters accompanied focus students during recess to increase their participation and to help them acquire the skills they were working on in class. They also went with the focus students to complementary activities during break time, such as choir, dance and workshops. Peer supporters volunteered to participate and they received training (unspecified in the paper). Artiles et al. compared this school, in which teachers supervised interactions between students during recess, with a second school without a project nor teacher supervision.

Whitaker (2004) portrayed an intervention in a primary school, in which so-called "peer tutors" met focus students individually in their own special education unit in the school for play sessions on a weekly basis during lesson time (20–30 min). Supervising adults adopted a low-key role, giving only general advice when appropriate. The playing involved games and activities that were popular with the focus students. During the first 3–4 weeks, no instructions were given. Hereafter, peer supporters received one training session on how to support interaction (e.g., getting close, slow, and simple talking).

Implementation of the Peer Buddy-Program (Hughes et al., 1999) in several high schools in the Metropolitan-Nashville school district in the USA was evaluated and documented in five papers included in this review (Carter et al., 2001; Hughes et al., 2001; Copeland et al., 2002, 2004). The program consisted in providing support to peers with disabilities for at least one class period each day (50–90 min), in both in-school (e.g., classrooms, libraries, school cafeterias) and out-of-school settings (e.g., stores, shopping malls, employment sites). Activities were instructional (e.g., academic support, job training skills) and non-instructional (e.g., "hanging out," participation in sports). Teachers chose both the activities and the settings for the students. Peer buddies were paired one-on-one with focus students or with several partners. For participation in the program, students earned course credit and they were able to participate for one or more semesters. Before starting, they received an orientation session in which several issues were discussed, including course expectations, disability awareness, communication strategies, dealing with inappropriate behavior and activity suggestions. They also obtained a "Peer Buddy Manual" with information about disability issues and interaction strategies.

The peer buddy intervention described by Hughes et al. (2002) seems to be related to the Peer Buddy-Program, however it is described in an independent way. Each day, classroom teachers assigned responsibilities to the peer buddies but they did not instruct them to socially interact with the focus students. Peer buddies aided focus students with assignments in their classes, or during extracurricular activities. In specific intervention sessions (led by the research team), peer buddies were asked to "hang out like a friend with the focus student," engaging in a leisure activity with the focus students in three settings: classroom, cafeteria during lunch and gymnasium during physical education. Peer buddies were told it was not necessary to teach the focus student anything and no further instructions were given. Activities (e.g., playing games, walking laps) were drawn from a pool developed for each focus student and varied daily. Activity pools were created based on the observation of the students' leisure activities (by the research team) and classroom teachers' suggestions. Peer buddies were rotated across participants, with a total of 5–8 buddies helping one focus student. Participating students received a training course which was not further described and obtained course credits.

Peer Networks

A total of four articles described a peer network or "social network" intervention. Haring and Breen documented probably the first implementation in a junior high school in 1992. During transition periods one peer supporter met with the focus student, for example to hang out in the hall or walk to the next class. The group of peers in a network would also meet for lunch with the focus student on some days. A schedule of assigned transition periods was made by adult facilitators and provided to the peer supporters, who were also allowed to hang out freely with the focus student. Network meetings took place once a week, with the presence of an adult facilitator. These meetings included a discussion of skill areas that required support, the development of appropriate interaction strategies as well as the adjustment of schedules and problem solving. The role of the peers was maximized in these activities. During a following

"maintenance" phase, that occurred only for one focus student, network meetings (2x per month) involved only discussing extended friendship interactions (e.g., meeting on weekends) and problem solving. To set up the networks, special education teachers selected students who had some previous contact with the focus student. The selected students (1 or 2) recruited 2 to 4 close friends for participation. Throughout the network meetings peer supporters were taught about specific aspects of the intervention, for example how to model appropriate social responses to the focus student.

In Harrell et al.'s (1997) intervention in three elementary schools, peer networks were implemented over three settings: (1) academic games and cooperative learning activities during reading activities (one focus student) or language-art sessions (two focus students). (2) interaction and conversation during lunchtime in the lunchroom. (3) language and arts/computer games/recess activities on the playground or in the classroom. Network meetings took place one to three times per day for 20 min, on 3–4 days per week. The activities were selected by the first researcher and by teachers. Conversation topics during lunch were chosen beforehand by the students themselves. Peers were instructed to interact with the focus student via an augmentative communication system and participate in activities. All students were trained in the use of the augmentative communication system, consisting in one-to-one teaching sessions (18–21 sessions for each focus student). Also the peer supporters received training on several issues, including instruction about the use of the augmentative communication system, the use of social skills for interaction with the focus student, discussions of autism, qualities of a friendship and how the network could help the focus student make friends. Training for each network comprised of eight sessions for two weeks before the start of the peer network meetings. The focus students attended the last two sessions as well.

Hochman et al. (2015) worked with four peer networks in two high schools. Weekly meetings were held during lunch periods in the cafeteria and included eating, activities (e.g., board games), conversations on events in and outside of school, planning new activities and reporting interactions which took place outside the weekly meetings. Other peers (with or without disabilities) sometimes joined the group. Adult facilitators were present for at least 10% of the meetings and intervened sometimes, for example by facilitating interaction or mentioning new school events. Generalization probes took place once a week and on that day no meeting was held. Students could then sit with whom and wherever they wanted. At the beginning, an orientation meeting was held with the focus student and the peer supporters, in which network goals were discussed and ways to work toward social interactions were considered by the group. A peer buddy program was also present in one of the schools.

Network meetings in Gardner et al.'s (2014) intervention were held once or twice a week with the presence of an adult facilitator, who was aided by a research team member. During the meetings, peers participated in at least one shared activity, e.g., a conversation about school events, playing or teaching others to play a game. Specific social-related goals for each focus student were selected by the educators and addressed during 50–75% of the meetings. An orientation meeting of the same characteristics as reported by Hochman et al. (2015) was arranged at the beginning of the intervention.

Social Lunch Clubs

Finally, two interventions involved so-called "social lunch clubs." Koegel L. K. et al. (2012) described their intervention as following. First, the focus student's favorite activities were determined in an interview with the child; parents were also consulted. Second, a club was created with the favorite activity as the club's theme. Club meetings happened twice per week during the lunchtime period for 15–30 min. At the start of each meeting, peers were invited to join the club (verbally or with a poster advertising the club). One or two adult facilitators conducted the activities: games and arts and crafts activities. In the club of the participating 12-year-old girl, the group was also led by peers and included planning and celebrating a party at her house.

Koegel R. L. et al. (2012) reported on a social club intervention in one primary and four middle schools, in which diverse ongoing clubs (academic activities, sports, arts, and crafts) were already available to students during lunchtime. A social club was created for each focus student around their perseverative interest and presented through announcements, flyers and notes to parents (just as for other clubs). The focus student's diagnosis was not disclosed to their social club partners. Peers were not informed that the club was created around the focus student's interests either. In both reported interventions, peers participated on a voluntary basis in the clubs, and did not receive previous training.

Educational Level, Age, and School Type

In sum, more than half of the CoF interventions ($n = 5$) were carried out in primary education (one in preschool, three in secondary school), while all peer buddy interventions were implemented in secondary education except for one project taking place in a primary school. Five of the papers reporting on these last interventions involved a Peer Buddy Project with overlap in the participating schools of one school district. Furthermore, peer networks were also mostly implemented in high school (three against one in primary education), while social clubs were created in one middle and two primary schools.

In relation to age, it can be observed that in three CoF studies, the age range of the focus students was large (6–11, 6–12, 7–15 years). The remaining CoF interventions were set up for students of a particular age, which on the whole showed a varied set of ages up to 15 years (3/4, 7, 10, 12, 14/15 years). The ages of the CoF members were never specified, but they were mostly labeled as classroom peers, or of a similar age. Wide age ranges were also described in the peer buddy interventions, both for focus students and peer buddies, although they all included the period of adolescence (e.g., 14–17, 13–20 years). Ages of the participants in the remaining studies were again diverse, between 6 and 18 years, with peer supporters in the same grade or having a similar age, except for Whitaker's (2004) study in which peer supporters were 3–5 years older.

CoF were all applied in mainstream schools, one special school was also involved. Focus students had learning or emotional/

behavior difficulties ($n = 2$), visual impairment ($n = 1$), but in most cases ($n = 7$) the CoF were set up for students with ASC. Permanent support by an assistant in the classroom was reported in three papers. Focus students were described as victims of bullying in three occasions, however in four papers, descriptions or indirect references to poor peer relationships or isolation problems were found. In contrast with CoF interventions, focus students in the peer buddy, peer network and social club studies were mainly in self-contained classrooms (as reported in 12 out of 14 papers), in addition to receiving part of their classes in general education (all Peer Buddy Project papers (n = 5); social clubs, $n = 1$; peer networks, $n = 3$). Exceptions were two interventions taking place in mainstream education, and three reports in which some children and adolescents received education in special education (some receiving classes in general education) and others in mainstream schools. The focus students in all these described practices were students with ASC (12 papers), severe disabilities ($n = 9$) or moderate disabilities ($n = 5$). Explicit references were not given to these students being victims of bullying in any of the articles.

Study Methods

The research included in this review comprised various types of designs such as a single case study or group experimental design. Investigators used diverse measurement tools, including, for example, interviews with various stakeholders, observation of children's behavior during recess, as well as peer nominations and self-esteem measures. To summarize common measurement aspects, 15 studies collected experimental data to measure impact, either by means of questionnaires ($n = 5$), observation ($n = 8$) or both ($n = 2$). In addition, 10 studies involved qualitative methodologies, performing interviews (n= 2), observations and interviews ($n = 3$), focus groups ($n = 1$), or collecting questionnaires (n= 6), on one occasion the collection of the questionnaire was followed by a discussion with the participating students.

Outcomes for Focus Students and Peer Supporters

Interpersonal outcomes between students as well as results on the individual level for SEND students and peer supporters were analyzed. Overall, interpersonal results of the interventions were mainly positive for the focus students. In 19 of the total 23 papers an increase of social interaction with peers was found, also labeled as enhanced engagement, socialization, or shared play. Looking in more detail, in four studies focus students were found augmenting their proximity to peers, or their levels of successful initiations and responses of contact. On four occasions, enhanced quality of interaction was reported. An increase of communicative behaviors was found in six papers (including verbal initiations, expressive language, more variety of topics in conversations). Additionally, peers showed increased social acceptance of the focus students, as reported in six articles. On the individual level, focus students improved their self-esteem ($n = 2$), social skills ($n = 3$; students with ASC/severe disabilities), changed their locus of control ($n = 1$), increased their feelings of social acceptance ($n = 1$); reduced their anxiety ($n = 1$), challenging behavior ($n = 2$) and their needs for adult support ($n = 1$). Poor social outcomes for the focus students were reported more infrequently: no increase of interactions, e.g., during a particular period of the intervention ($n = 3$), decrease of interaction when peer network was withdrawn ($n = 2$), lower quality of interactions ($n = 1$) and unchanged perceptions of social acceptance ($n = 1$).

For the peer supporters, the interventions also mainly produced benefits. Apart from the increased interaction with the focus students, the reviewed studies showed: enhanced empathy and improved understanding, changing to positive attitudes toward classmates with disabilities, perceptions of similarities more than differences, thinking of focus students as positive role models, feelings of connection (with severe ASC students), increase of interaction strategies, communicative behavior ($n = 2$), and enhanced self-esteem and self-expression. Only few difficulties were found, which were in relation to engaging with the behavior of ASC students and the feeling of not being acknowledged by the peer with severe ASC (each of the cited effects was reported in one paper except where noted).

To analyze true "befriending effects" of the interventions, the papers were checked for information on peers sharing other spaces and activities than merely the planned group meetings (e.g., network, CoF), in addition to findings related directly to friendships. Most papers included limited information on these issues or offered data of an anecdotal nature. In 11 papers a reference to friendship as an outcome was made in terms of an increase of peers describing themselves as friends, or the enhanced creation of positive relationships that included friendships. However, these were general descriptions that gave no information allowing for a more detailed analysis on the extent of the friendships between peers. Nevertheless, six papers included data on the peers' involvement in other activities, mostly outside school: meetings on the weekend, the focus student receiving invitations to hang out, to birthday and holiday parties, shopping trips, gaming clubs and movies. Adults observed typical friend behavior; students exchanged phone numbers. An exception to the overall positive perception of friendship gains is the more precise report by Whitaker et al. (1998) on the effects of the implementation of seven CoF. Of the 40 involved peers, only three students considered the focus child to be their friend and invitations or visits home by the peers were scarce (two for two focus children).

Description of Peer Supporters. Selection and Training

Peer supporters were children and adolescents with typical development, excluding the interventions reported by Staub et al. (1996) and Whitaker et al. (1998) in which they were peers with mild special educational needs or students in special education. Overall, multiple peers aided one focus student, except for the peers in the Buddy Project, who were involved in a one-to-one support format. Information about the gender of the peer supporters was only available in 11 papers. In three CoF studies with reported data, participation was equal between girls ($n = 78$) and boys ($n = 79$). Data from the three peer network interventions also showed similar numbers for both genders: girls ($n = 13$) and boys ($n = 11$). From the four papers with data on the "Peer Buddy Project," the article by Hughes et al.

(2001) was selected to analyze participant data, as it reported the highest number of participants and it was suspected there would be an overlap with figures from the other papers. A significant higher amount of volunteering girls ($n = 144$) than boys ($n = 25$) participated in the project. However, in the study by Staub et al. (1996) more boys ($n = 25$) than girls ($n = 6$) were selected. No data was found in relation to the social lunch club interventions.

The criteria that were used to select the peers for the CoF ($n = 9$) were emotional skills ($n = 1$), diversity in gender ($n = 1$), varied abilities ($n = 3$), adequate attendance, ability to make up schoolwork, compliance with teachers and willingness to participate ($n = 1$) or unspecified ($n = 3$). In the remaining study, no selection was performed, as the whole class participated in the circle of friends. For the peer buddy interventions ($n = 4$), selection was based on skills ($n = 2$), availability ($n = 1$), adequate grade point average ($n = 1$), attendance ($n = 1$), age ($n = 2$), presenting an application reference ($n = 2$), likely commitment ($n = 1$) or merely volunteering (n = 2). In addition, students received credits for participation ($n = 2$). The papers on the "Peer buddy project" were counted as a single study in this analysis. With respect to the peer networks ($n = 4$), selection criteria were skills ($n = 3$), previous contact with focus students ($n = 1$), dependable ($n = 1$), with a network of friends ($n = 1$), social status ($n = 1$), consistent school attendance ($n = 1$), compliance with teachers' requests ($n = 1$), merely volunteering (some students in one study). In one peer network study, peers recruited close friends for the intervention. Finally, participation in the social lunch clubs ($n = 2$) was only based on the students' interests. In sum, in most interventions peers were selected for the intervention, except for the social clubs and two other practices, in which the whole class participated, or in which involvement was purely voluntary. In part of the CoF interventions, children with varied abilities were selected, while for peer networks, the student's skills as well as having a social network were important. Partaking in the "Peer Buddy Project" was based on students showing interest and availability, although in two other peer buddy practices students' competences and likely commitment were taken into account.

Training of peer supporters was described in all interventions except for the social clubs. As explained earlier, in four of the reported CoF interventions, a whole- class session was held in which students learned about autism ($n = 4$) and positive interaction or interaction strategies ($n = 3$). In both the peer network and peer buddy interventions ($n = 8$; "Peer buddy project" papers considered as one), training involved building awareness of disabilities-autism ($n = 2$), social and communication skills ($n = 5$), use of an augmentative communication system ($n = 1$) or was not further specified ($n = 2$). Students in the "Peer buddy project" received a Peer buddy manual.

Peers' Opportunities for Participation in the Interventions

Circle of Friends

How peers can contribute to the implementation of the CoF is included in Taylor (1996; 1996) description of the process, mostly in a more general way. Students were asked to participate in the definition of goals, evaluation of progress, identification of difficulties and the planning of ways to solve them, accompanied by an adult whose tasks have a primarily facilitating role. Nevertheless, the extent to which children participated in these tasks does not become clear, as it was not precisely documented in the papers.

Exceptions to this form of participation were found in the two reports. The practice of Gus (2000) consisted of two sessions in which the adult fulfilled a complete leading role; hereafter the task of supporting the focus student is left in the hands of their peers. More limited opportunities to participate seemed also evident in Owen-DeSchryver et al. (2008) intervention because of the accentuated guiding role of the adults, even though the children were asked to make their contributions in discussion-sessions.

Peer Buddies

In the primary school interventions (Whitaker, 2004; Artiles et al., 2016), children were just told to play as they were supervised by adults, they were not involved in organizing the intervention. Students' participation in planning tasks in Staub et al. (1996) intervention (secondary school) was not specified. In the Peer Buddy Program implementation in high school, students participated in a structured plan of leisure activities, however they also had opportunities to freely interact with the students.

Peer Networks

In meetings of peer networks (Haring and Breen, 1992; Gardner et al., 2014; Hochman et al., 2015), secondary school students were motivated to actively participate by the suggestion of activities or conversation topics. Adult facilitators were present for at least 10% of the meeting (Gardner et al., 2014; Hochman et al., 2015). However, Gardner et al. informed that early activities were mainly designed by the adult facilitators, and support behavior (encouraging focus student to interact with peers or vice versa, etc.) oscillated between 29 and 37%. Hochman et al. also reported that support behavior varied between groups (7–30%) and remained high in two networks. Peers were able to freely spend time with each other outside weekly meetings and outside the school setting. In Harrell et al. (1997) intervention in primary school, student participation seemed to be more reduced: activity selection was performed by adults. Nevertheless, conversation topics were selected by the children.

Social Clubs

Although club activities were conducted by adults, the researchers pointed at the high implication of the children themselves during the sessions, directing the group's activities and organizing meetings outside the club, at home.

Adult Facilitators and Support by School and Families

Adult facilitators in the reviewed interventions were general education classroom teachers (cited 9 times), special education teachers, therapists, nursery nurses ($n = 9$), special education support assistants ($n = 2$), (assistant) educational psychologists ($n = 3$), school staff ($n = 1$), school administrators ($n =$

1), unspecified (n = 2: peer network (n = 1), social lunch club (n = 1).

In the nine reports on CoF, classroom teachers were involved in six studies, either alone (n = 2) or with other staff or external agents. With respect to Taylor (1997) recommendation to involve an external facilitator for the whole-class discussion while the class teacher is present, four interventions followed this suggestion by introducing an educational psychologist. General education classroom teachers were never involved in peer network interventions; networks were facilitated by either special educators or researchers. In three studies, only researchers acted as implementers (CoF = 1, peer network = 1, social lunch club = 1). The various adult facilitators cited in the reports on the "peer buddy project" (reported in five papers), were included only once in the analysis. From the full set of peer buddy interventions, special education workers were the only implementers on two occasions, classroom teachers were facilitators in three interventions (twice with other professionals).

In addition, papers were screened for information on the support that was received from the school as an institution as well as particular school staff, in addition to families. Only the articles that reported on this matter are cited below. Copeland et al.'s (2004) reported in their study that the high school students in the Peer Buddy Program perceived the general education context as unsupportive for the inclusion of SEND students caused by aspects such as lack of accommodations or differential expectations of educators. This fostered negative attitudes toward students with SEND by some teachers and students, affecting the program negatively. The authors also observed that in each school, typically, the promotion of the support system depended on only one adult; students might therefore not be aware of the possibilities for participation.

Hochman et al. (2015) emphasized the role of a teacher by reporting that getting the students involved, training them and keeping them in the program with ongoing support was much easier at the school where this was a very popular teacher, meaning that he connected very well with the students. These authors also comment that a peer buddy program was present in one of the collaborating schools, therefore showing that the peer network intervention was not a casual, isolated practice.

Staub et al. (1996) describes the participating school in their study as one in which best practices in education, striving for equality and cooperation, were common. For the CoF intervention, authors referred to the first step of setting up a circle (Taylor, 1997), in which it is necessary to check if the school is a place where the CoF can come to life and be given continued support. Although most evidently referring to a commitment from the school staff to provide the necessary resources (staff time, organization) and cited as such by Frederickson and Turner (2003), Frederickson et al. (2005), Schlieder et al. (2014). Whitaker et al. (1998) described the participating schools as having "an ethos compatible with the values underlying the 'circles approach'" (p. 61).

Family participation was mentioned in the reports on the social club interventions. Koegel R. L. et al. (2012) also sent information to the families in order to encourage student participation in the clubs. In their second study (Koegel L. K. et al., 2012), a club session also took place at the focus child's house. In addition, Whitaker (2004) highlighted the important role of the parents and the support of their children in participating in the peer buddies project was extremely high.

DISCUSSION

The aim of this systematic review was to examine emotional peer support interventions for students with SEND. A limited number of studies were found evaluating this type of educational practice, all involving befriending interventions. The most documented practice was Circle of Friends, which already has a history of several decades, starting off as an intervention for the inclusion of adults with disabilities in their communities and for SEND students in mainstream schools (Sullivan, 2010). This was followed by the more recent peer buddying interventions such as the "Peer Buddy Project," on which multiple papers were found including articles on peer networks and social club interventions. Empirical reports on peer conflict resolution or counseling-based support were not found. This finding might not be surprising as these system formats are usually not aimed at specific groups but rather at the general student population. Still, researchers could have collected data on the use that students with SEND make of these types of peer support, but this was not the case. In the future, it would be useful to know more about the peers who offer and receive counseling or conflict resolution support, and whether there are students with SEND among them.

The focus students in the reported interventions were mostly children and adolescents with ASC or, to a lesser extent, labeled as having severe or mild disabilities. Only in CoF interventions a reduced number of students with other (visual, emotional-behavioral) difficulties were included. Despite the existing literature on available psychosocial interventions for students with ADHD that include peers (see Cordier et al., 2018), in the present study no paper with explicit reference to participants with ADHD was found. CoF were mainly applied in general education schools and the participating peers in the interventions were classmates. On the contrary, most of the remaining interventions were performed in a fairly non-inclusive context, aiming at promoting interaction between students who received education in separate places (classrooms, buildings), and who only coincided in time and space on some occasions (one or two class periods, cafeteria, at recess). This proves to be a difficult task to be accomplished. As Copeland et al. (2004) point out, just being in proximity to peers who are in special education does not easily result in interaction. The lack of contact seems evident in those study settings, but also in the CoF studies, in which several focus students were described as having "isolation problems" or as suffering from negative interactions from their peers as victims of bullying. Nevertheless, outcomes for the targeted students of the interventions were overall positive with respect to several areas. In the majority of studies an increase of social interactions was found, in addition to other findings, though less reported, such as an increase of contact initiations and responses, proximity, communicative behaviors, quality of interaction, social acceptance by peers and improved self-esteem.

Moreover, CoF seems to have been successful in addressing social difficulties or bullying experienced by students with SEND, especially ASC. However, the extent to which the reported increase of peer interactions happened for all students, and in each setting (classroom, school, outside immediate intervention context) remains uncertain. In Copeland et al. (2004) study for example, students declared that interaction with peers in special education was unlikely to occur unless a peer buddy (or a teacher) prepared the way for it.

Social skills improvement of students with ASC or severe disabilities was reported in a few studies. According to Hughes et al. (2002) this merely stems from interacting more with peers in mainstream education. They argue that for particular social skills, students with intellectual disabilities may need instruction, but when opportunities for interaction are provided, they are able to improve communicational behavior and gain conversational topics. Nevertheless, to obtain social acceptance from peers, an increase of social skills might not even be necessary. Based on the impact of their interventions, Frederickson et al. (Frederickson and Turner, 2003; Frederickson et al., 2005) stated that the CoF had resulted in a greater understanding of the classmate's difficulties by their peers rather than changing their behavior. They also observed that the weekly meetings of the CoF process did not produce any effects, while the whole-class meetings resulted to be essential for the intervention's outcome. The reason for this was the participation of all the students in the session. The CoF members already showed positive attitudes toward the focus child before the intervention, but other students in the classroom made a change after the meeting. In line with this stands the intervention by Gus (2000) who modified the CoF procedure by using only the whole-class meeting, in order to have all students participate in helping the child with ASC who had been socially excluded.

Outcomes for peer supporters were also mainly positive, showing benefits such as increased self-esteem and empathy, which are in accordance with earlier findings (Naylor and Cowie, 1999; Del Barrio et al., 2011). They also increased their interaction with the class or schoolmates with SEND. These interactions seem to have led to further bonding, reported by the authors through anecdotic evidence and general observations, resulting in an overall perception of friendship expansion. However, Whitaker et al. (1998) found less promising results and more precise research is needed.

Peer supporters were mainly typically developed children and adolescents, who received training when required for the intervention. Overall, boys and girls were found equally involved in these practices when a selection was performed by adults. This stands in contrast with the data from the Peer Buddy Program, whose requisites for participation were, above all, interest and availability and for which girls showed to be significantly more willing to volunteer than boys. This is in line with Cowie and Smith (2010), who claim that a frequently reported finding is that it is easier to recruit girls than boys for peer support. Boys might be afraid that the caring qualities they exhibit as peer supporters will not be considered manly (Naylor and Cowie, 1999). This points at the need for a gender approach in school ethos perception, in which boys and girls are equally responsible for mutual care.

Student possibility for real participation in the intervention has been underlined as an important success factor. In relation to the CoF, Taylor (1997) points out that when students are asked for their opinions and feelings, power is being redistributed from the adult to the children. Taylor argues that the way in which the teachers handle this, in combination with the school ethos, is crucial for the effectiveness of the intervention. However, in the reviewed papers on CoF interventions it is not clear to which extent the children were able to participate in the various tasks (e.g., in the weekly meetings). In other support practices, students contributed by suggesting activities or conversation topics, which in several cases, especially the social clubs, this was highly successful. Although some of the reports pointed at adults still playing an important role in designing tasks or supervising interactions, other studies succeeded in making students more in charge of the activities. Haring and Breen (1992) conclude that allowing for enhanced peer control instead of adult mediation may contribute to improved, more solid and long-lasting peer relationships.

On the other hand, student involvement in the proper organization of the systems (e.g., recruitment and selection processes) was hardly mentioned. Only in one peer network study did students recruit close friends to join the intervention. As a final point, students usually do not merely interact in the structured context of school, especially not adolescents. Therefore, the possibilities to socialize outside the established frame are important for genuine peer inclusion, and in several practices of peer buddying and peer networks opportunities to do so were given.

Information on support from school as an institution was scarce in the reviewed studies. However, it is a relevant factor to take into account when analyzing the effectiveness of peer support systems (Cowie and Smith, 2010). In the reviewed papers only some CoF implementers referred to commitment of the school's administrators, and even fewer remarks were found on the school ethos. An exception to this was Copeland et al.'s (2004) analysis of student perception on how negative attitudes toward students with SEND challenged the peer buddy's program, next to their observation on the significance of depending on a single adult for the promotion of the support system. The authors explain that the school's management and teaching staff might not be aware of the benefits of a support scheme for and by peers, and recommend promoting information about such programs.

Furthermore, the involvement of the class teacher is highly relevant, as they are role models for their students. In peer support systems for the whole school, such as the buddying programs or peer networks, this is manifested by the positive attitudes and participation of the general education classroom teachers. The anecdotal evidence by Hochman et al. (2015) is seemingly an example of this. In relation to CoF, Taylor's observation cited above emphasizes the teacher's style as one of the keys to success. Although an external agent is strongly recommended to allow children to speak honestly, the teacher is also requested to participate throughout the intervention process. However, Taylor's suggestions are only followed up in part of the reviewed CoF applications. In addition, references should be made to the involvement of external experts such as the researchers themselves. These professionals bring

knowledge to the school by promoting the intervention in and of itself as well as training the facilitators (e.g., reported by Gardner et al., 2014). To be successful, intervention actions must derive from previous knowledge of two kinds. First, the corpus of scientific knowledge from research in the field. Second, knowledge already existing in the school, of problems, identified needs, strategies proved to be successful, and those unsuccessful, etc. This empiric knowledge comes from school staff, families and students, and should be the starting point for intervention in order to be effective in improving the school ethos. Hence, the setting up of a peer support program implies the necessary involvement of the school staff itself. When only the researchers implement the intervention, this seems to be less efficient.

Finally, families' support toward the peer support programs was hardly documented, although their commitment is markedly an important factor for successful education (Eccles and Harold, 1996; Bouffard and Stephen, 2007). Taken together, it is strongly recommended that research on the impact of peer support systems includes variables that represent these contributing factors of school and family support.

The reduced number of studies that were traced in the present review do not allow for firm conclusions, pointing at the need for more investigation on emotional peer support practices for SEND students. Still, the included documents covered a varied set of elaborated studies that allowed for several observations which might be useful for practitioners and researchers planning new initiatives for school ethos improvement through the valuable participation of peers. Improving relationships between students does not function without the involvement of the peers themselves.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

KM, LG, and CB contributed to conception, design of the study, reviewed studies in relation to study's aims, and wrote sections of the manuscript. KM completed the systematic search for studies and wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

GOMOHEALTH

A Bridge to a New Life
BRIDGEWAY
Rehabilitation Services

Transforming the Perception of Mental Health Community Services:

A Behavioral Science of Human Activation and Resiliency

2019

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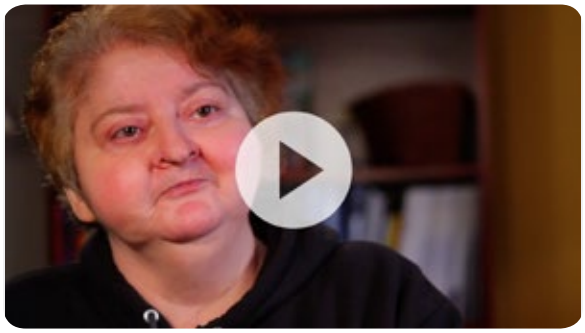
Table of Contents

Prelude

As members successfully navigated their behavioral health journey, they agreed to share their success to influence and motivate others.

Before reading this paper, please watch one of these two short videos featuring members of the Every Day Matters program to help with an initial, actualized understanding of the application and impact of BehavioralRx®.

To watch the videos, click on one of the thumbnails below or visit
gomohealth.com/bridgeway



A Story of Courage (4 minutes)

Finding Peace (5 minutes)

Introduction:
A New Approach to Delivering and Extending Precision Healthcare

In cognitive neuroscience, an AHA Moment is a sudden comprehension — or a coming together of neurons — that allows someone to solve a problem, reinterpret a situation or resolve an ambiguous percept. Stimulating an AHA Moment makes a person 3-5 times more likely to take an immediate action.

How do we establish a relationship with an individual via their healthcare delivery so that they are inspired to take action and become active in their own care? To switch their mindset? To feel capable of setting and meeting goals? To want to change habits?

This white paper provides an overview of a method and protocol of treatment, BehavioralRx®, that has produced dramatic outcomes by combining and integrating evidence-based scientific principles in behavioral psychology and cognitive neuroscience with a new form of technology delivery that includes, amongst many factors, the stimulation of AHA Moments to get people to take action or alter a mindset.

Bridgeway Rehabilitation Services, in partnership with GoMo Health, revised their system of care model to increase retention, participation and improve the experience of persons served in a mental health rehabilitation day program. **Over that period, retention in the program increased 40.9% (a clear indication of resiliency) with a yearly revenue increase (per 100 members) of $162,528. Moreover, participants reported increased feelings of positivity and empowerment in times of struggle, including moments of suicidal ideation.**

You will learn how we:

- *Converted the program from a day program to a lifestyle program*
- *Redefined persons served as "members" and created a membership model program that has never been done in this setting*
- *Enabled the "members" to directly and continuously influence their care plan*
- *Integrated science and technology using a new form of two-way "action/response" care messages that provide immediate reciprocity, fostering changed outlooks and increased resiliency*
- *Increased Joy in Practice for the care team*

Day Program Becomes Activated Lifestyle Program

Identification of the Problem

Day Program In Session

6hrs

- Behavioral Learings
- Positive Reinforcement
- Motivation
- Inclusion/Peer Support
- Resources

Day Program In Recess

16hrs

- Isolation/Boredom
- Negative Thoughts
- Substance Abuse
- Discouragement
- Hopelessness

GOMOHEALTH

Solution: The *Every Day Matters* Program

BEHAVIORAL Rx

Bridgeway Rehabilitation Services

PRA's 12 Core Principles & Values

- Cultural Relevance
- Exercise Rights Of Citizenship Within The Community
- Peer/Self Support Initiatives
- Health & Wellness
- Personal Recovery
- Self-Determination & Empowerment
- Hope, Respect, Capacity For Learning & Growth
- Build On Strengths & Capabilities
- Shared Decision Making
- Social, Occupational, Educational, Residential, Intellectual, & Financial Skills
- Easily Accessible Support & Resources
- Person-Centered Practices

BehavioralRx®

6 I's of Community & Belonging

- Identity
- Influence
- Interaction
- Involvement
- Investment
- Introduction

Behavioral Technologies

- **Conditioning Technology:** Reinforcing Target Behaviors
- **Influence Technology:** Persuasion Through Shared Decision Making
- **Nurturing Technology:** Guided Persuasion
- **Suggestion Technology:** Intervening At The Right Time
- **Tailoring Technology:** Persuasion Through Customization

Engagement Approach

Membership Model

- Launch Event
- Iconic Speakers
- Membership Kit
- Welcome Message
- Member Enrollment Form
- Response Analysis

Engagement Stratification

Risk Assessment

- **Low** Probability of Not Attending
- **High** Probability of Not Attending

Engagement Frequency

- **7AM** Mornings Scheduled to Attend
- **5PM** Every Day; 7 Days a Week

Engagement Tone

- **Light Tone** *Encouraging, Upbeat, Less Serious*
- **Real Tone** *Motivating, Disciplinary, Realistic*

Multi-Media Messaging

Care Messaging

7am & 5pm Messaging

- Motivational Content
- Inspirational Quotes
- Lifestyle/ Activities
- Life/Skills Reflection

Program Notifications

- Closing/ Delays
- Events/ Activities

Bidirectional Messaging

Member Initiated Keywords

- **SMILE:** Joke, Game, Reward
- **MOOD:** "Feel Good" Content
- **PEER:** Excerpt of Peer Story
- **FENCE:** Motivation to Attend

Overview

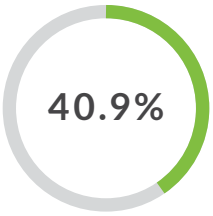
Each year, approximately one-fifth[1] of adults enrolled in mental health treatment programs drop out before completing their recommended course.

This is an issue faced by all mental health care programs. How can a program keep persons served motivated, accountable and supported 24-hours-a-day for as long as they need in order to improve their lives? At their core, successful programs are those that provide the support necessary for someone to become an active participant in their own health and well-being.

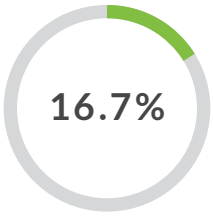
Because politics, economics and federal regulations all keep the relationship between health care providers and patients in a constant state of flux, increasing staff is often not viable. Programs cannot rely on government funding and shifts in reimbursement models require that we address patient populations with complex or chronic conditions in a new way.

BehavioralRx® is a science that considers the behavioral/cognitive triggers that motivate individuals to take action through remote, round-the-clock support that is personalized and responsive. A year after its introduction, this new "lifestyle" system of care resulted in higher patient retention, improved patient experience and increased revenue.

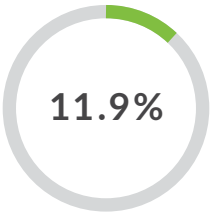
12-MONTH PILOT RESULTS



Increase in Patient Retention



Increase in Weekly Attendance



Increase in Yearly Attendance

BehavioralRx care plans combine the science of human behavior with cognitive learning, memory retention and a delivery via interactive mobile "smart" technology — a combination that has the potential to revolutionize the way we provide health care.

[1] Olfson, M., Mojtabai, R., Sampson, N. A., Hwang, I., & Kessler, R. C. (2009, July). Dropout from Outpatient Mental Health Care in the United States. Retrieved June 29, 2018, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2774713/

Case Study

Bridgeway's Partial Care Program is a day program that provides psychiatric rehabilitation services in a free-standing, community-based setting. Partial Care offers clinical and support services that allow participants to work on personal, social, vocational, educational and wellness goals. The aim is to help participants to feel valued and valuable, live independently in their community and prevent the need for more acute psychiatric services.

Although Bridgeway's partial care program was considered successful by industry standards, it shared the same challenge as any other treatment option: participants needed to remain motivated to attend, and they needed to incorporate learnings into their everyday lives.

Studies confirm that therapeutic interventions are most effective when the participant has community support. However, even with highly innovative face-to-face protocols and methodologies, there are times when patients are without access to their treatment and support.

Being alone at times is a normal part of life, but for someone in treatment, it is often accompanied by feelings of isolation. They may wake up in the middle of the night and start ruminating, trying to justify why it's a good idea to skip their next meeting, or they may pine for old, familiar, unhealthy behaviors that only made their lives unmanageable in the first place. If they do show up to their program again, they have often regressed.

Recovery or rehabilitation programs that can serve participants day and night, whenever the *patient* needs support, in whatever *way* the patient needs it, are likely to be the most effective.

Introducing **EDM**

The *Every Day Matters (EDM)* program was created as an added support solution for Bridgeway's Partial Care participants using an interactive combination of on- and off-site methodology that optimizes human activation and resiliency by focusing on three key components.

> **Individual, in the Moment Support:** *A tailored program that address each person's individual needs as they arise.*
>
> **Relational Support:** *A feeling of membership and reciprocity; the person is not a passive recipient of information but rather part of a community that has the ability to shape and affect the precise type of support that's offered.*
>
> **Continuous and Ongoing Support:** *Available whenever it is needed, for as long as it is needed.*

EDM was designed to better activate a spirit and feeling of community by redefining a participant's role from "patient" to "member," and allowing members to play an active role in the components of the lifestyle care plan while enabling them to provide peer-to-peer motivational messaging and support. Implementing the evidence-based engagement capabilities of BehavioralRx provided a fully-personalized, interactive experience that could be initiated by both the participant and the day program any time of the day or night. In other words, members were now able ask for specific types of support 24 hours a day, and Bridgeway could provide additional support remotely, during off-site times, when they were likely to feel vulnerable.

This Personal Concierge™ system of patient-empowered care serves as a model for increasing the efficacy and improving the qualitative experience of patients in any healthcare environment.

The EDM program uses the GoMo cloud-based platform to receive and deliver ongoing support developed from the mental health care community's best practices in behavioral and cognitive science. In essence, it is a fully responsive, reciprocal intelligence model that can easily and effectively accommodate every participant.

First Year **Results**

Every Day Matters was launched in October 2017 to help increase attendance to Bridgeway's Partial Care day program (which met either 3 or 4 days per week), improve the participants' ability to reach their goals and increase the program's positive positioning to garner state and/or federal funding.

12-Month Increases:

Comparisons between those enrolled in the *EDM* program and the non-*EDM* group over the course of a 12-month period:

- Weekly attendance increased by ***16.7% — from 60.5% to 71%***
- Retention increased ***40.9% — from 61.5% to 86.7%***
- The yearly revenue increase, per 100 members, based on increased retention and attendance was ***$162,528 — an 11.9% higher revenue rate per member compared to non-EDM.***

Most notably, the qualitative feedback from participants has been overwhelmingly positive. Members have shown more vested activation in the program and have reported making better choices about their own self-management, attributing those choices directly to *EDM* methodology. In addition to increased feelings of empowerment and motivation, since its instatement, the *EDM* program has reportedly diverted two people from consideration of suicide.

The 5 Guiding Principles of BehavioralRx:

- *Ensure persons served are perceived as active partners in the care process*
- *Allow people to guide their care process*
- *Help people stay engaged even when they are alone*
- *Give people a way to be active in their care process, not passive recipients*
- *Help people increase self-management with skills, confidence and practice*

The positive impact from *EDM* became evident almost immediately and has affected everyone involved in the care process: those providing care, those receiving care and those providing care coverage.

Redefining Participants As "Members"

Beginning in October 2017, participants in Bridgeway's Partial Care day program were invited to become members of the *Every Day Matters* program.

The *EDM* program was introduced on-site and was based on a best-practice format that fostered participants' feelings of membership, such as feelings of belonging, of being wanted and needed, and of being expected to attend.

Its technology component was built upon a patient-engagement model that incorporated principles of several well-respected, community-oriented behavioral paradigms:

1. The Clubhouse Model of Rehabilitation — An integrative program focusing on members' strengths rather than their illness.

2. The 6 I's of Community Development — The academic model used for understanding community-building. These six concepts, as seen below, are widely recognized as the essential factors needed for a person to become and remain committed to their community:

Introduction	*Members of the community must receive a welcome and orientation. They must learn the norms, values and rules of the community.*
Interaction	*The community must provide opportunities for its members to form a bond.*
Involvement	*The members must be encouraged to participate. The community should provide expectations of involvement and communicate rewards for participation.*
Influence	*The members must have the opportunity to influence the community, making them feel important and showing them that their perspectives and opinions are valued.*
Investment	*Investment is the reflection of psychological ownership that flows from involvement and influence. The members must feel invested in their community.*
Identity	*The members must share a common purpose and identity. Collectively referring to the group as "we" and "us" establishes rituals and standards with which all members can identify.*

3. The Psychiatric Rehabilitation Association's 12 Core Principles and Values (PRA-12) — The premiere industry guidelines for all rehabilitation facilities serving persons suffering from mental illness.

At the launch event, Bridgeway CEO Cory Storch, GoMo Health Chief Behavioral Technologist and Founder Bob Gold, and Partial Care Team Leader Ron Allen all spoke to the community about how *Every Day Matters* would work to support them in their recovery. In addition to welcome kits, members were provided information about their privileges, influence and how they would be able to become more active in the formulation of their own care plan as well as the program itself.

The Six I's of Community and Belonging	The Psychiatric Rehabilitation Association's 12 Core Principles and Values
	Principle 1: *Psychiatric rehabilitation practitioners convey hope and respect and believe that all individuals have the capacity for learning and growth.*
	Principle 2: *Psychiatric rehabilitation practitioners recognize that culture is central to recovery and strive to ensure that all services are culturally relevant to individuals receiving services.*
Influence, Investment	***Principle 3:*** *Psychiatric rehabilitation practitioners engage in the processes of informed and shared decision-making and facilitate partnerships with other persons identified by the individual receiving services.*
Involvement	***Principle 4:*** *Psychiatric rehabilitation practices build on the strengths and capabilities of individuals.*
Introduction	***Principle 5:*** *Psychiatric rehabilitation practices are person-centered; they are designed to address the unique needs of individuals, consistent with their values, hopes, and aspirations.*
Introduction, Interaction, Involvement	***Principle 6:*** *Psychiatric rehabilitation practices support full integration of people in recovery into their communities where they can exercise their rights of citizenship, as well as to accept the responsibilities and explore the opportunities that come with being a member of a community and a larger society.*
Influence, Investment	***Principle 7:*** *Psychiatric rehabilitation practices promote self-determination and empowerment. All individuals have the right to make their own decisions, including decisions about the types of services and supports they receive.*
Interaction, Involvement	***Principle 8:*** *Psychiatric rehabilitation practices facilitate the development of personal support networks by utilizing natural supports within communities, peer support initiatives, and self- and mutual-help groups.*
	Principle 9: *Psychiatric rehabilitation practices strive to help individuals improve the quality of all aspects of their lives, including social, occupational, educational, residential, intellectual, spiritual, and financial.*
	Principle 10: *Psychiatric rehabilitation practices promote health and wellness, encouraging individuals to develop and use individualized wellness plans.*
Introduction	***Principle 11:*** *Psychiatric rehabilitation services emphasize evidence-based, promising, and emerging best practices that produce outcomes congruent with personal recovery. Programs include structured program evaluation and quality improvement mechanisms that actively involve persons receiving services.*
Identity	***Principle 12:*** *Psychiatric rehabilitation services must be readily accessible to all individuals whenever they need them. These services also should be well coordinated and integrated with other psychiatric, medical and holistic treatments and practices.*

Converting from a Day Program to a **Lifestyle Program**

The first step in stimulating AHA moments was to create a support system that allowed the member to feel continuously "known and supported."

After completing a personal risk assessment survey during *EDM* enrollment, each member was given access to care messaging through the Personal Concierge system — a cloud-based, patient-activated solution through which supportive and motivational messages could be sent to a member at any time of day, either based on the member's perceived needs, or based on actual requests from the member. In other words, a "smart" interactive system that could be initiated by either the member or the program provider.

The following 6 BehavioralRx engagement methods are used in *EDM*:

Anchoring Technology	*The over-arching technology that allows participants to cognitively connect a desired action with an existing everyday action.*
Conditioning Technology	*To reinforce target behaviors.*
Influence Technology	*To persuade through shared decision making.*
Nurturing Technology	*To provide guided persuasion.*
Suggestion Technology	*To provide intervention at the "right" time.*
Tailoring Technology	*To persuade through customization.*

These technologies were used to develop a system of interactive Care Messages™ to address a participant's needs.

Integrating Scientific Technology and Community

Care Messages were developed based on three ideals:

- *Short and always accessible*
- *Able to engender a feeling of reciprocity (knowing someone is responding)*
- *Able to be used to interrupt a mindset that is not supporting the member's well-being*

The following chart maps some of the ways BehavioralRx was applied to the *EDM* Program:

BehavioralRx Technique	*Every Day Matters* Application
Influence Technology: *To persuade through shared decision making.*	When a person joins *EDM*, they become a member of the *EDM* community. They can then collaborate with other community members to provide input and dictate the structure and concepts incorporated into the program.
Suggestion Technology: *To provide intervention at the "right" time.*	Themed regimens are planned and timed according to each member's daily/weekly schedule, and to provide intervention when weaknesses/high risk behaviors are likely to occur.
Tailoring Technology: *To persuade through customization.*	Care Messages are designed to promote the motivational concepts that are most relevant to their specific conditions, lifestyle, beliefs, values and physical/emotional surroundings.
Nurturing Technology: *To provide guided persuasion.*	The *EDM* program uses keywords that members can text in to receive motivational messaging at any time in an effort to provide them with the support they need in the moment, making best teaching and practices available at all times. Members are motivated to attend program through Care Messages that relate to their need and desire to learn, grow and improve.
Conditioning Technology: *To reinforce target behaviors.*	Members are motivated to continue learned practices even when they are not at program through Care Messages. Care Messages sent during the evening promote social interaction and activity engagement. They incorporate best practices learned at program and include small writing exercises that allow members to reflect on their learnings and set individual goals and milestones towards improvement.

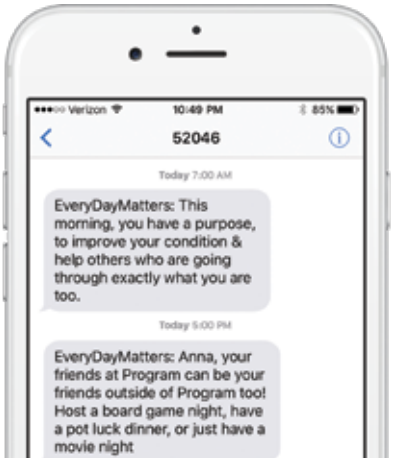
Bi-directional
"Action/Response" Care Messages

Personal Concierge technology allowed for messaging to be initiated in both directions: Provider to Member and Member to Provider

Provider-Initiated Care Messaging

Provider-initiated messaging included reinforcing concepts that were introduced in the day program setting or promoting social interaction during non-program hours.

Based on their survey, members were assigned a different Care Message regimen, each with a specific tone, content, frequency and overall positioning determined to best support their personal journey to recovery. For example, motivational messages were sent to all members at 7:00 AM and 5:00 PM, before and after attending the program. However, additional messages were planned and tailored to each member's individual challenges, values and personal schedule, providing intervention during the times that members perceived themselves as most isolated and, therefore, more likely to engage in high-risk behaviors.



Member-Initiated Care Messaging

BehavioralRx technologies also included a system of Care Messages that were sent to the participant on an as-needed basis. For example, if a member was experiencing a challenging situation at any time, they could text in a specific word to receive support content tailored to their particular need. This Care Messaging provided in-the-moment support when a participant needed it most, but members also reported relying on them at later times as well, re-reading specific messages in the middle of the night rather than perseverating about negative experiences.

Enabling
Members To Influence Their Care Plans

Bi-directional Care Messages allowed members to identify what they needed, and the system would provide it. These member-initiated support messages were sorted into categories, so a member was able to call for anything from a motivational push that would get them to a meeting to a joke to lift their spirits. This was a critical aspect of the program, as it allowed members the experience of altering their mind-set and changing their habits in real time.

Messages could be generated through a simple keyword that allowed members to quickly identify the type of support or challenge they were facing. The initial categories were:

FENCE	Provided motivational messages if someone was "on the fence" about attending a meeting.
MOOD	Provided “feel good” motivational messaging.
PEER	Provided a peer story about someone successfully managing a similar challenge or experience.
SMILE	Provided members with a joke, quick game or small surprise reward.

Bi-directional messaging allowed members to feel a sense of ownership over their own mental health treatment, one of the foundations for a successful recovery journey. This was proven in two separate instances, where members came to the day program and asked for additional support categories and even supplied content suggestions. These member contributions to the program are examples of the BehavioralRx principle of Influence Technology, which is shared decision making that makes the person served an active participant in their care plan. As a result, four more were added:

HALT	Coping strategies to manage feelings of being hungry, angry, lonely and tired.
SPIRIT	Faith-based advice, quotes and words of wisdom.
RELAX	Reassuring and comforting words as they relate to dealing with mental health stigma.
SONG	Links to uplifting songs.

The reciprocity of the Personal Concierge program and Care Messaging reportedly enhanced a sense of belonging, fostered change in outlooks and increased resiliency.

Increasing
Joy in Practice

Joy in Practice is often difficult to measure. There are systemic indicators that can lead to conclusions, such as increased or decreased turnover, however, the measure that appears to be most important in healthcare is the observations reported by team leaders, supervisors and the caregivers themselves.

Among the most prevalent barriers to Joy in Practice are compassion, fatigue and burnout. Clinicians and support staff can easily feel emotionally drained from the complex issues and challenges faced by persons served, with which practitioners can over-empathize and at times, over-personalize.

Supervisory tasks include monitoring and addressing these barriers that detract from feeling productive and helpful. Additionally, clinicians must work within an often compassion-challenged care system, impacting the ability to feel effective. Learned helplessness is a real risk for both persons served and practitioners. These factors can affect the perception of quality of care, sense of efficacy and feelings of competence. Joy in Practice becomes a casualty.

The *EDM* program offers a way for Bridgeway Partial Care staff to feel effective beyond face-to-face interaction; bolstering care delivery to participants even when not physically present. In this way, everyone involved in the program feels a strong collaboration, working together towards the shared, attainable goal of success in the community – post live interaction and regardless of the location of person served. This keeps the principle motivation - the vision of recovery - in sight, even as smaller individualized goals are highlighted. Although application of skills and utilization of resources in the environment of need have always been the theoretical mindset, in practice, persons served struggle to apply learned skills outside of direct interaction with and direction from providers. It is easy for persons served to lose sight of "why" and "when" to use skills and resources. As a result, application and utilization in the needed environment – home, with family or friends and in the community, fall off. In turn, providers often feel as if work with persons served loses effectiveness and at times, stops after the interventions are provided. The *EDM* program helps to actively engage persons served in the overall rehabilitation process and often unexpectedly, empowers them to use skills independently.

EDM's application of the Clubhouse "membership" model, designed as a continual communication loop, allows for more regular and frequent support to participants *as well as* a more regular and frequent stream of feedback to care providers regarding what participants need and find useful. Membership fosters feeling of community, connection and having a voice – both for persons served and for staff.

The membership model works in tandem with the principles of being wanted, needed and expected; as well as promotes a feeling of belonging, reinforcing a change in the mindset of (Bridgeway) program participants who face stigma, isolation and ostracizing as a result of their illness. It offers providers another channel through which to reinforce and maintain the all-important rehabilitation relationship, essential in motivating a desire to change. Participants feeling supported, valued and empowered is essential to Bridgeway's success as a psychiatric rehabilitation provider.

> According to Diane Piagesi-Zett, Director of the Sussex Community Support Teams at Bridgeway, seeing the increased engagement and response to messaging made her staff feel that their work was more meaningful, and that their impact didn't end at the completion of the program day. Says Piagesi-Zett, "Staff are not with members all day, every day, to support, reinforce or remind them of the tools available, of their resilience, of natural supports and resources, or of their strengths. *EDM* has offered a way to actualize the rehabilitation process when we are not with persons served. There is so much riding on our effectiveness as rehabilitation practitioners. Extending our impact increases our staff's feeling of being helpful and making a real difference. This renews the sense of joy in the work that we do."
>
> "We know of two occasions in which the messaging interfered with suicidal ideation," Piagesi-Zett continues. "Persons served not only felt lifted by the regularly scheduled message, they were able to scroll through previous messaging for reminders, and actively access messaging related to mood. Members reported that they successfully changed their thinking in the moment, sustained it overnight and shared it in program the next day. Obviously, this is a win for those struggling to utilize skills independently to manage symptoms, but I have to say, it affected the staff at least as much. When counselors see persons served successfully intervening in their own lives, having their own 'AHA Moments' and feeling empowered to take responsibility for their recovery – well, there is no better feeling. It's exactly why we got into a helping field."

Every Day Matters messaging extends the impact of direct engagement during the on-site Bridgeway Partial Care program day. Staff share, teach, instruct and give feedback in tandem with persons served. The basic messaging in *EDM* was developed from the curricula, methods, information and resources used during live interventions. The members review, approve, edit and add content based on what they have found helpful and motivating in their own recovery journeys. The collaboration on messaging reinforces the information and interventions, making them accessible and useful in a text format. In addition, it connects staff and persons served in a shared belief and confidence in the value and effectiveness of what is being provided in the live program. Creating messaging is empowering for staff as well as persons served, reinforcing that what is being taught, shared and offered makes a difference to persons served.

In addition to applying the behavioral principle of *influence* via having an active role in developing the messaging, members are able to initiate specific support by texting a keyword in their moment of need. The opportunity to take action offered members more self-activation in their own care, applying skills independently and not as a passive "recipients" of rehabilitation. Members reported they felt more empowered and able to better self-manage, enabling them to return to program with a more positive attitude, stronger belief in their ability to change and the power to exercise that positivity to *influence* other members.

Analysis and **ROI Data**

Member testimonials have confirmed that the *EDM* program helped create a sense of belonging as well as helped influence members to show up and remain in the program.

Statistical data over a 12-month period supported member reports, with the *EDM* group boasting a retention rate of 86.7%, a 40.9% improvement over the non-*EDM* group.

	Retention Rate	12 Month Attendance Rate	12 Month Revenue Per Member
EDM	86.7%	71.0%	$10,855
Non-*EDM*	61.5%	60.5%	$9,682

Over twelve months, the EDM group generated an 11.9% higher rate of revenue per member than the non-EDM group.

Over the same 12-month period, the non-EDM group experienced a revenue leakage of $45,741 compared to the EDM group.

Coordinating Science and Care

Based on a 100-member program, with the average member scheduled for 15 days per month, the increased revenue generated by implementing the *EDM* program is projected to save nearly $11K monthly, or $162,500 annually. This type of savings can not only help keep a program alive, it can also allow for budget models designed to continually help advance and improve the program.

Future Applications

GoMo Health Concierge Care is currently in use in a variety of health care sectors, including applications tailored to patient care, provider administration and insurers. This technology-based support has been used to reduce readmissions, collect valuable ePROs (electronic patient-reported outcomes), and take advantage of opportunities for CMS MACRA value-based and bundled payment reimbursements.

BehavioralRx technologies allow a proven, evidence-based interactive platform to be mapped to other mental health care providers as well as to any other provider whose patients could benefit from additional, personalized support. These systems are particularly well-suited for patients requiring long-term care, as in the case of pre- and post-natal care, as well as for complex chronic conditions such as diabetes, cardiological care, oncological care, and difficult-to-manage comorbidities.

BehavioralRx and Concierge Care can reduce cost of care, provide extended and inexpensive support, increase revenue and improve patient experience and outcomes. Additionally, doctors and nurses currently using GoMo Health technology report being able to spend more time on clinical care delivery, which has led to increased job satisfaction, retention and Joy in Practice.

The Every Day Matters pilot allows us to see some of the many ways that the health care sector can harness technological solutions to provide meaningful, personalized care that greatly benefits both patient and provider.

GoMo Health

GoMo Health® is a leader in population health management and patient engagement solutions that support the continuum of care, improved patient satisfaction and MACRA value-based reimbursements. GoMo Health Concierge Care® personalizes patient interactions using our proprietary science, BehavioralRx®, The Science of Precision Health, building trust and credibility to motivate higher levels of activation and resiliency. In partnership with health care organizations worldwide, GoMo Health delivers a highly scalable and cost-effective solution for the management of high-risk, chronic, and complex conditions, enabling better self-management, healthy decision making and improved outcomes.

Bob Gold, Chief Behavioral Technologist and Founder, GoMo Health

Bob Gold is one of the world's leading behavioral technologists with more than 20 years applied research and development in the behavioral and cognitive science of human motivation, activation, and resiliency; with a specialty in the human factors of precision health and care coordination leading to increased activation of patients and clinicians.

Bob focuses his energy on recrafting clinical care plans into behaviorally-based remote care coordination, transitions of care, and telehealth patient engagement protocols to achieve a sustainable Population Health business model for health systems, health plans, pharmaceutical companies, and governments; reducing readmissions, collecting valuable ePROs (electronic patient-reported outcomes) and taking advantage of opportunities for CMS MACRA value-based reimbursements associated with the implementation of these programs.

Bob's proven evidence-based methods provide a more personalized, disciplined, and nurturing experience within the framework of a person's lifestyle and typical day while improving satisfaction and adherence; especially for complex and chronic conditions that include co-morbidities and difficult to navigate patient health journeys.

Bob's BehavioralRx® and Concierge Care® system has also shown to bring back Joy in Practice for doctors and nurses enabling them to spend more time on high impact clinical work.

Bridgeway Rehabilitation Services

Bridgeway Rehabilitation Services has been assisting individuals to recover from mental health conditions since 1968. Now serving over 4,000 people annually, Bridgeway combines a multi-disciplinary, wrap-around approach with supportive housing and social network enhancement to serve those who are frequent service users and who are at the most risk of hospitalization and homelessness. We inspire and support individuals to become productive citizens who are fully engaged in their communities by creating opportunities for wellness, independent living, learning, working, and social inclusion.

Diane Piagesi-Zett, Director of the Sussex Community Support Teams, Bridgeway Rehabilitation Services

Diane Piagesi-Zett, MA, LRC, CRC, has dedicated her life to the field of psychiatric rehabilitation for over 40 years.

She has worked at Earth House and Sussex House at Newton Memorial Hospital where she served as a clinician for mental health. She has been at Bridgeway Rehabilitation Services since 2010; her current position is Director of the Sussex Community Support Teams where she oversees Partial Care, Integrated Case Management, Program to Assist with Transition from Homelessness, Community Support Services, and Supported Employment.

Piagesi-Zett has published works with Bill Anthony in the Psychiatric Rehabilitation Journal, contributed a chapter in the first edition of Psychiatric Rehabilitation Programs, and has presented at national, state, and local conferences and trainings. She has also served intermittently on the board of the New Jersey Psychiatric Rehabilitation Association (NJPRA) since 1982, including twice as Secretary and most recently as Vice President. Additionally, she is the 2010 recipient of NJPRA's prestigious Mort Gati Award.

frontiers in
HUMAN NEUROSCIENCE

ORIGINAL RESEARCH ARTICLE
published: 09 December 2014
doi: 10.3389/fnhum.2014.00924

Enhancing inferential abilities in adolescence: new hope for students in poverty

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The ability to extrapolate essential gist through the analysis and synthesis of information, prediction of potential outcomes, abstraction of ideas, and integration of relationships with world knowledge is critical for higher-order learning. The present study investigated the efficacy of cognitive training to elicit improvements in gist reasoning and fact recall ability in 556 public middle school students (grades seven and eight), vs. a sample of 357 middle school students who served as a comparison group, to determine if changes in gist reasoning and fact recall were demonstrated without cognitive training. The results showed that, in general, cognitive training increased gist reasoning and fact recall abilities in students from families in poverty as well as students from families living above poverty. However, the magnitude of gains in gist reasoning varied as a function of gender and grade level. Our primary findings were that seventh and eighth grade girls and eighth grade boys showed significant increases in gist reasoning after training regardless of socioeconomic status (SES). There were no significant increases in gist reasoning or fact recall ability for the 357 middle school students who served as a comparison group. We postulate that cognitive training in middle school is efficacious for improving gist reasoning ability and fact recall in students from all socioeconomic levels.

Keywords: inferential abilities, cognitive training, poverty, adolescence, gist reasoning, higher-order cognition, middle school

As students reach adolescence, they strive to cope with the increased demands of advanced and more complex curricula. Their ability to make sense of and abstract meanings from information encountered through inferential processing is foundational to academic achievement (Brown and Day, 1983; Bunge et al., 2005; Chapman et al., 2006; Bunge and Wright, 2007). Unfortunately, recent studies (Stern and Ahlgren, 2002; Gamino et al., 2010) indicate that many students in middle school focus primarily on learning circumscribed details presented in textbooks without showing an ability to understand issues at a conceptual, in-depth level. Whether the problem rests in the superficial coverage of vast amounts of information in class or how the students are learning, evidence is mounting that critical gist reasoning (i.e., the ability to derive synthesized meanings by combining facts and applying inferential reasoning) is failing to develop in early adolescence—an age where the brain is at a critical stage to acquire advanced reasoning skills (Alberts, 2012). An over-reliance on straightforward fact recall in recent academic performance is readily apparent when one examines the downward trajectory of standardized state tests and National Assessment of Education Progress (NAEP) reading scores from fourth to eighth grade levels (Aud et al., 2011). The NAEP, administered at the eighth grade level, assesses the ability to glean deep meaning from texts through analysis and synthesis of information, inference of abstract concepts, prediction of outcomes, and relating what is presented in text to one's own background knowledge.

Gist reasoning allows one to "connect the dots" between separate pieces of information, facilitating construction of generalized meanings rather than processing facts in isolation (van Dijk, 1995; Reyna, 1996, 2012; Chapman et al., 2006; Ryena and Mills, 2014; Wolfe et al., 2014). The ability to use inference to abstract meaning from incoming information (gist reasoning) is a skill that applies to formal as well as informal learning activities, such as reading a school assignment, listening and taking notes from a lecture, writing a class report on a specific topic, watching a movie or television program, or listening to a friend's joke. Abstracting generalized meanings from class readings, for example, may be a more important indicator of meaningful, in-depth and efficient learning than recalling the specific facts (Brown et al., 1983; Ryena and Mills, 2014; Wolfe et al., 2014). Indeed, remembering exact wording has been found to be independent of remembering the inferential meanings conveyed in texts (Reyna and Kiernan, 1994; Wolfe et al., 2014). Research suggests that learning through gist-based concepts rather than trying to absorb and recite verbatim details supports long-term retention and decision-making (Ryena and Mills, 2014; Wolfe et al., 2014), affirming Reyna's (2012) seminal theory that asserts the importance of gist to efficient memory and learning processes.

Brainerd and Reyna (1996, 2004) proposed a distinction within developmental trajectories between gist-based and verbatim memory processing (Reyna, 2012). Gist-based processing provides representations of semantic and relational information, or information abstracted from details. Conversely, verbatim processing provides representations of the explicit facts or concrete details. Whereas both gist and verbatim memory capacities generally have been found to increase with development, gist-based processing follows a more protracted trajectory (e.g., Brainerd et al., 1998). Reyna (1996) reported that meaning is rarely stored in its concrete/explicit form, but rather is quickly synthesized to a more generalized gist-based meaning.

We posit that gist reasoning involves goal-directed, frontally-mediated cognitive comparison processes that serve to enhance learning (Chapman and Mudar, 2014). Research in cognitive neuroscience has identified adolescence as a pivotal developmental epoch and critical window for acquiring reasoning and critical thinking skills in terms of both cognitive expansion and brain remodeling (Giedd et al., 2006; Yurgelun-Todd, 2007). In particular, adolescence is a critical life stage when executive functions such as advanced reasoning skills should be developing and expanding, with continued sophistication and refinement in adulthood (Blakemore and Choudhury, 2006; Bunge and Wright, 2007; Yurgelun-Todd, 2007). In particular, refinement of the connectivity within the frontal lobes is postulated to be a primary component of increases in working memory and the ability to hold and manipulate information (Bunge and Wright, 2007). The underlying neural substrates that support reasoning are undergoing dramatic change during adolescence (Yurgelun-Todd, 2007). Longitudinal neuroimaging research reveals extensive brain development and remodeling, particularly in frontal lobe networks, throughout adolescence and into early adulthood (Gogtay et al., 2004; Yurgelun-Todd, 2007), by way of pruning and strengthening neural connections. The complex frontal neural connections support higher-order cognitive functions such as problem-solving, decision-making, reasoning, judgment, and planning, and are often referred to as "executive control functions" (Sowell et al., 1999; Bunge et al., 2005; Bunge and Wright, 2007; Yurgelun-Todd, 2007).

Although extant studies have determined that cognitive training of executive functions such as reasoning skills promotes brain plasticity in children and young adults (Mackey et al., 2011, 2012), to date, few studies have examined gist reasoning growth trajectories among adolescents in the middle-school grades and even fewer have examined gist reasoning growth as a function of well-defined training protocols (Gamino et al., 2010). Previous research has implicated that both fact recall and gist reasoning competencies can be improved with a systematic strategy-based cognitive training approach (Gamino et al., 2010). However, the extent to which improvements are mediated by economic factors is not clearly understood, particularly with respect to whether living within a particular income level facilitates or hinders the magnitude of improvement. Poverty exerts a detrimental influence indirectly on both behavioral/cognitive and neurobiological outcomes via a collection of interacting mechanisms to include among others, maternal sensitivity, home environment, parental education, parent-child conflict, nutrition, and parental stress (Bradley and Corwyn, 2002; Mayer, 2002; Gershoff et al., 2003; Farah, 2010; Raver et al., 2012; Luby et al., 2013). Unfortunately, low-income environments tend to be associated with poorer nutritional, physical, and psychological conditions (Brooks-Gunn and Duncan, 1997; Mani et al., 2013). More importantly, children from low-income families often have reduced exposure to stimulating adult interactions and opportunities that positively influence vocabulary development and academic readiness skills (Gou and Harris, 2000; Fletcher et al., 2007). Thus, socioeconomic status (SES) may affect developmental trajectories in maturation of brain regions thought to mediate reasoning abilities and attenuate the gains of cognitive training beyond what is explained by the effect of age and gender alone.

In addition to SES, gender differences in higher-order cognitive functions are of interest given that the development of the neural systems, previously shown to be influenced by gist reasoning in adults (Chapman et al., 2013), differs for males and females. Specifically, male and female differences in developmental rates of brain size suggest that students in middle school, roughly 11–15 years of age, are in a transitional period when the brain's complex frontal networks involved in higher-order thinking begin to undergo maturational changes (Stuss and Knight, 2013). Females reach maximum frontal volume approximately 1 year before males (11 vs. 12.1 years of age) and maximum parietal volume approximately 1.6 years before males (10.2 vs. 11.8 years of age) (Giedd et al., 1999; Klingberg et al., 2002; Gogtay et al., 2004). These data suggest that females tend to reach a state of anatomical maturation within brain regions thought to mediate reasoning abilities (Bunge et al., 2005; Jung and Haier, 2007) before males. This notion is further supported by findings that girls outperform boys on fluid reasoning tasks (Wright et al., 2008), suggesting that girls might be more responsive to cognitive training at an earlier age than boys. Understanding how gender affects gist reasoning ability and cognitive training outcomes will advance our knowledge of cognitive development and inform educational practices directed at promoting reasoning performance.

The present study explored the effects of strategy-based cognitive training on gist reasoning ability and fact learning among seventh and eighth grade public middle school students who varied in poverty status and gender. We examined whether cognitive training would increase gist reasoning abilities in seventh and eighth grade students, above and beyond that of typical development, which was validated in a separate comparison group. Furthermore, we explored the effects of gender and SES on response to cognitive training. Based upon previous research (Gamino et al., 2010), we hypothesized that students who received strategy-based cognitive training would show a significant increase on measures of gist reasoning and fact recall; whereas those without training would not show gains over a longer passage of time. Additionally, we hypothesized that adolescents from non-poverty level backgrounds would show greater training gains; however, even those from impoverished homes would show significant gains pre- and post-testing. With regard to gender, we posited that

girls would show higher baseline performance on gist reasoning; however, both boys and girls would show significant gains in response to cognitive training. The goal was to ascertain the potential of cognitive training to improve the ability to infer meaning and recall facts for students living in poverty. This research is important given the evidence that a large percentage of students in middle school neither arrive in the seventh grade nor leave the ninth grade having become proficient in inferential thinking abilities (Alspaugh, 1998; Stern and Ahlgren, 2002).

METHODS

PARTICIPANTS

A pre-post, quasi-experimental design, with a designated comparison group, was used for the current study. Experimental study participants were from public middle school seventh and eighth grade classes throughout Dallas, Texas and the surrounding urban and suburban area, with a total of 13 middle schools participating. Various teachers in each school were provided with the opportunity to allow their students to participate in the study, based on school district and/or campus administration suggestions/directives. Thus, the teachers who agreed to allow the research team into their classrooms volunteered to give up their instructional time in order to provide the opportunity for their students to participate in the study. Each school district and each school guided the seventh and/or eighth grade class/teacher selection without our input. Thus, the chosen teacher/classes consisted of students with various abilities and degrees of motivation, or lack thereof. Cumulatively, 1,031 students were offered the opportunity to participate in the cognitive training program. Of this initial pool, 140 students declined, leaving 891 students and their parents who signed informed assent and consent in accordance with our Institutional Review Board at the University of Texas at Dallas. Consent forms and family history questionnaires (FHQs) were proffered in English and Spanish. Of the 891 students with consent, complete pre-and post-cognitive training data were obtained for 741 participants. This initial group of students contained a majority of eighth graders (n = 480; 65%) with gender evenly distributed (48% male vs. 52% female). The average age of the students was 12.95 years (range 12–14 years), and included 32% Caucasian, 43% Hispanic, 17% African-American, and 8% Asian or other race. Students were given a total of $15 in restaurant gift cards for participating in the study. The gift cards were awarded sporadically throughout the data collection and intervention timeframes.

Parents or guardians completed an FHQ, on which they reported information regarding household income, number of family members living in the household, ethnicity, language spoken at home, the student's developmental history, and any diagnosed medical or learning differences, such as a diagnosed brain injury, diagnosed learning disability, neurodevelopmental disorder, ADD or ADHD, or placement in special education courses. On the FHQ, 133 parents reported their child had, singularly or in combination, sustained a brain injury (n = 9), been diagnosed with a learning disability (n = 57), neurodevelopmental disorder (n = 16), or ADHD (n = 79), or been placed in special education courses (n = 38). Filtering out these children and those who had missing information on the FHQ yielded a sample of 556 participants having typical neurological development and on whom data analyses and poverty indexes were conducted; 209 of these participants were seventh grade students and 347 were eighth grade students.

To determine poverty status, we used an income–to-needs metric, using the United States census information to identify the discrete annual poverty level by taking into account the respective number of family members living in the home. This dollar figure was then divided into the respective family's household income. A student's family was defined as living in poverty if [household income]/[needs] < 1.0. Students not falling into this category were considered as living above the poverty line. **Table 1** contains a description of this sample.

We also recruited a separate sample of 357 sixth, seventh, and eighth grade students (176 males; 181 females), from both rural and urban middle schools, to form a comparison group (see **Table 2**). The assessment was extended to sixth grade students as the objective was to ascertain spontaneous development of inferential gist reasoning and fact recall in the absence of cognitive training across the middle schools grades, and eighth grade students matriculated to high schools prior to administration of a second assessment. This group of students formed three cohorts; students who were assessed in sixth grade and then reassessed in seventh grade, students who were assessed in sixth grade and reassessed in eighth grade, and students who were assessed in seventh grade and reassessed in eighth grade. The time points for assessment ranged from 10 to 16 months. This group of students did not provide information about parent income, learning disabilities, grade retention, head injury, or other potential confounding factors. We obtained information regarding ethnicity and SES levels through the participating schools' general data collection and reporting. Thus, the comparison group, is a sample of typical public middle school students from Texas that did not exclude students from the group based upon learning disability, head injury, or any other health factors.

Table 1 | Sample characteristics for experimental group.

		N and percent within grade	
Gender		Grade 7	Grade 8
Male		91 (43.5%)	151 (43.5%)
Female		118 (56.5%)	196 (56.5%)
Poverty Status			
Male	Yes	38 (18.2%)	36 (10.4%)
	No	53 (25.4%)	115 (33.1%)
Female	Yes	44 (21.1%)	62 (17.9%)
	No	74 (35.4%)	134 (38.6%)
Ethnicity			
African-American		43 (20.4%)	59 (17.0%)
Caucasian		33 (16.7%)	105 (30.3%)
Hispanic		121 (56.9%)	146 (42.1%)
Other		12 (6%)	37 (10.7%)
Poverty × Ethnicity			
Poverty	Hispanic	58 (70.7%)	72 (73.5%)
	Non-Hispanic	24 (29.3%)	26 (26.5%)

Table 2 | Sample characteristics for comparison group.

	N and Percent within cohort		
Gender	6th–7th Grade	7th–8th Grade	6th–8th Grade
Male	71 (43.8%)	81 (55.5%)	24 (49.0%)
Female	91 (56.2%)	65 (44.5%)	25 (51.0%)
Economically disadvantaged			
Yes	65%	64%	41%
No	35%	36%	59%
Ethnicity			
African-American	27%	26%	2%
Caucasian	33%	36%	90%
Hispanic	37%	35%	5%
Other	3%	3%	3%

GIST REASONING MEASURES

The Scale of Advanced Reasoning© (SOAR©; Chapman et al., 2006; Gamino et al., 2010) was administered during one 45-min class period preceding and approximately 2 weeks following the cognitive training program to evaluate gist reasoning and fact recall ability for the experimental group. The average length of time between test administrations for the comparison group was 330.2 days ($sd = 69.6$).

The SOAR assesses an individual's ability to spontaneously abstract and convey deeper meaning from a lengthy text, similar to those encountered in the classroom. The SOAR is a pen and paper assessment that consists primarily of three summarization tasks to determine gist reasoning ability and secondarily, probe questions to determine recall of pertinent facts. The SOAR entails three texts of differing lengths, two narrative and one expository, that participants are required to summarize. The students' summaries are scored for the number of abstracted deeper meanings that are produced within the summary. Production of abstracted deeper meanings during summarization reflects the ability to spontaneously utilize gist reasoning to understand and convey unstated underlying ideas derived from information (Chapman et al., 2006; Gamino et al., 2009, 2010). In previous unpublished pilot studies involving samples of children 8–14 years of age, gist reasoning scores from the SOAR showed a significant correlation to scores on the Similarities ($r = 0.57$, $p < 0.001$, $n = 93$) and Vocabulary ($r = 0.60$, $p < 0.001$, $n = 48$) subtests from the Weschler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). However, as the WASI requires individual testing, we did not utilize the WASI for this study.

Prior to taking the SOAR, students were given instructions regarding the qualities of a good summary. Specifically, students were instructed that a summary is a well-organized, shortened version of the original text that conveys the bigger ideas and important information that can be understood from the text, much like summaries in a movie review or on a DVD cover. Additionally, the students were instructed that their summaries should contain enough information so that readers could gain an understanding of the original text. An example of a high-level gist-based summary of a common fairy tale, "Little Red Riding Hood," was presented.

During testing, each passage was projected onto a screen for students to read and/or follow along while a proctor read aloud. After each text was read, students were reminded that they were to write a summary that included the important bigger ideas from the text. Subsequently, the summaries were collected, and the students were given a form with eight questions (i.e., fact recall probes) regarding the factual information that could be gleaned from the texts, and instructed to give short but complete answers to the questions. This process was repeated for each of the three texts. The testing took place at the students' respective schools, during the regular classroom periods.

Summaries were scored via independent raters who were blinded as to whether the summary was baseline, post-cognitive training, or time one or two for the comparison group. The raters scored each idea conveyed in the summaries according to the manualized SOAR scoring rubric, as either a zero or one, depending upon whether it exemplified an abstracted, inferred meaning that was not explicitly stated in the text. Statements that were directly stated in the text were rated zero since the measure assesses the ability to integrate ideas into more generalized statements than originally presented in the text. The fact recall score was based upon the correctness and completeness of answers to probe questions, which were scored zero, one, or two points. Two trained raters independently scored each summary and the responses to the probe questions using the SOAR checklist rubric. The raters conferred to reach a consensus on final gist reasoning and fact scores, achieving inter-rater reliability of 92% and 94%, respectively; disagreements between the raters were subsequently resolved. The highest possible total score for gist-based concepts summed across all three texts was 25. The highest possible total score for fact recall summed across the three texts was 48.

COGNITIVE TRAINING PROGRAM

The cognitive training program used in the present study was the Strategic Memory Advanced Reasoning Training (SMART©) program developed at the Center for BrainHealth (Chapman and Gamino, 2008; Gamino et al., 2010). The SMART program trains students to use specific cognitive processes that foster top-down thinking and the ability to abstract meaning from information (Gamino et al., 2010). The SMART program consists of hierarchical cognitive processes that are explained and practiced through group interactive exercises and pen and paper activities using student instructional manuals. The seven processes entail: (1) deliberate inhibition of extraneous information; (2) chunking and organizing relevant information; (3) inference; (4) paraphrasing; (5) synthesis of important details; (6) interpretation of take home messages; and (7) abstraction of deeper meanings and synthesis of the processes in order to elicit top-down processing.

The instructed processes emphasize the integration of world knowledge with incoming facts in order to capture overarching themes and facilitate higher-order thinking (Mayer, 1989; Chapman et al., 2004, 2006; Gamino et al., 2010). In the first half of the program, students are specifically taught metacognitive aspects of abstracting meaning from information. The core focus includes cognitive skills such as selective attention which trains students to filter out less important information, chunking

important facts into generalized ideas through inferential and interpretive paraphrasing, followed by synthesis of world knowledge to promote depth of understanding (Kintsch and Van Dijk, 1978). After the processes are introduced and practiced, the program emphasis turns to utilizing the foundation provided by the acquired metacognitive awareness to instill top-down processing from the onset of an assignment. Thus, students' preliminary focus is on the deeper meaning of information prior to deliberate processing of isolated details. The texts and materials used within the program to practice the cognitive processes are similar to content that is typically encountered in English literature, social studies, and science texts. The manualized program was administered to students by trained research associates during regular classroom periods consisting of ten 45-min classroom sessions over a one-month period.

ANALYSES

To determine the effect of cognitive training on gist reasoning ability for the experimental group, we applied a standard general linear model (GLM) to baseline and post-training gist reasoning and fact recall assessing the effects of gender, grade level (seventh or eighth grade) and SES. SES was coded as a binary variable determined by a ratio of family income to household needs (number of household members). A score less than 1.0 was designated as "poverty status".

We also examined post-training gist reasoning while statistically controlling for the influences of pre-training gist reasoning and fact recall ability for the experimental group. Moderate pairwise correlations were found among baseline gist reasoning, baseline fact recall, and post-training fact recall, thus we applied a principal component (PC) reduction to derive two orthogonal variables that comprised nearly 88% of the total variability (see **Table 3**). The two derived variables, factor scores for each individual, were included as covariates in the GLM in order to account for their independent influences on post-training gist reasoning means. All two-and three-factor interactions were included in the GLM. PC derivation was implemented in the R statistical computing language[1] and the statistical model was implemented in SAS (Cary, NC).

RESULTS

GIST REASONING SCORES

At the initial assessment, seventh grade students in the experimental group demonstrated significantly higher gist reasoning ability than seventh grade controls, ($F_{(1,360)} = 5.7$, $p = 0.02$, $d = 0.26$). The analyses revealed significant SES and grade-level differences in mean gist reasoning scores prior to training for the experimental group. The students who were not living in poverty had significantly higher mean gist reasoning ability at baseline than students living in poverty ($F_{(1,548)} = 4.98$, $p = 0.026$, $d = [0.19, 0.23]$); in addition, eighth grade students outperformed seventh grade students ($F_{(1,548)} = 6.72$, $p = 0.010$, $d = [0.22, 0.27]$, see **Figure 1**). While no gender differences were found in the experimental group as a whole at baseline ($F_{(1,548)} = 0.32$, $p = 0.57$), eighth grade girls were found to have higher gist reasoning scores than eighth grade boys ($F_{(1,390)} = 7.82$, $p = 0.005$, $d = 0.29$). For the comparison group, no significant differences in gist reasoning ability at the initial assessment were found for gender or grade ($F_{(1,353)} = 0.42$, $p = 0.52$; $F_{(1,353)} = 0.86$, $p = 0.36$; respectively).

Mean gist reasoning scores significantly improved after cognitive training across the set of gender, SES, and grade-level combinations, ($F_{(2,548)} = 58.28$, $p < 0.0001$; $d = 0.479$), in spite of the differences found in baseline scores across SES, grade, and gender. The comparison group demonstrated no significant changes in gist reasoning ability from time one to time two, after controlling for grade level, gender, and number of days between testing ($F_{(1,349)} = 0.73$, $p = 0.39$).

Table 3 | PC loadings to derive adjustment variables in GLM.

	PC1 Loading	PC2 Loading
Baseline GIST	0.459	−0.867
Baseline FACT	0.649	0.179
Post-training FACT	0.606	0.465

Fact recall scores

There were no significant differences in fact recall ability between the experimental and the comparison group at the initial assessment. At baseline for the experimental group, fact recall scores among the students living above poverty were significantly higher than those who were living in poverty ($F_{(1,548)} = 61.69$, $p < 0.0001$; $d = [0.70, 0.79]$). Additionally, grade level contributed to baseline fact scores differentially within SES levels. As shown in **Figure 2**, at baseline eighth grade students living above the poverty line had significantly higher mean fact recall than seventh grade students living above the poverty line, but there was no difference in grade-level fact recall means for the students living in poverty (grade × SES interaction, $F_{(1,548)} = 6.87$, $p = 0.009$, $d = [0.46, 0.53]$). No gender differences were found for baseline fact recall ability, either at grade level or SES ($F_{(1,548)} = 0.42$, $p = 0.51$; and $F_{(1,548)} = 0.17$, $p = 0.68$; respectively) for the experimental group. For the comparisons, sixth grade females demonstrated significantly better fact recall than males at baseline ($F_{(1,209)} = 4.14$, $p = 0.04$), but no gender differences were found for seventh grade students. There were no significant differences between grades for the comparison group ($F_{(1,353)} = 1.31$, $p = 0.25$).

Following cognitive training, the students living in poverty had a comparable increase in mean fact recall scores relative to the higher income group. Seventh grade students demonstrated significantly more fact recall improvement after cognitive training than the eighth grade cohort ($F_{(1,548)} = 12.83$, $p < 0.001$; $d = [0.31, 0.36]$, see **Figure 2**). The comparison group failed to show significant growth in fact recall between time one and time two after controlling for gender, grade level, and time elapsed between assessment ($F_{(1,349)} = 0.26$, $p = 0.61$).

EFFECTS OF GRADE LEVEL, GENDER AND SES ON POST-TRAINING GIST REASONING

To account for pre-existing differences that might otherwise unfairly influence comparisons of post-training means, we

[1]http://r-project.org

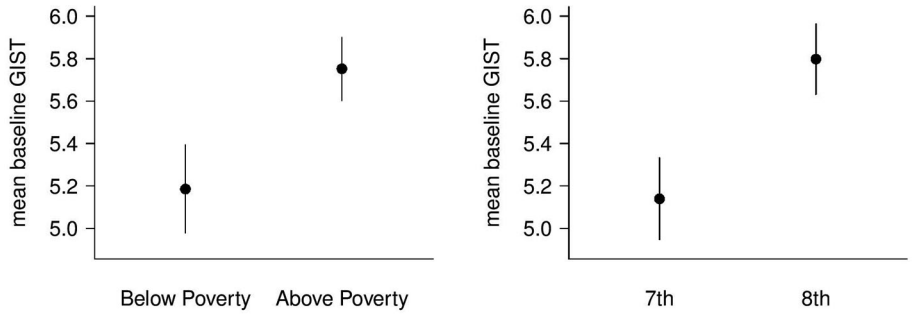

FIGURE 1 | Mean Baseline Gist Reasoning. The figure on the left represents the mean baseline gist reasoning ability for students living below the poverty line and students living above the poverty line. The figure on the right represents the mean baseline gist reasoning ability for seventh and eight grade students.

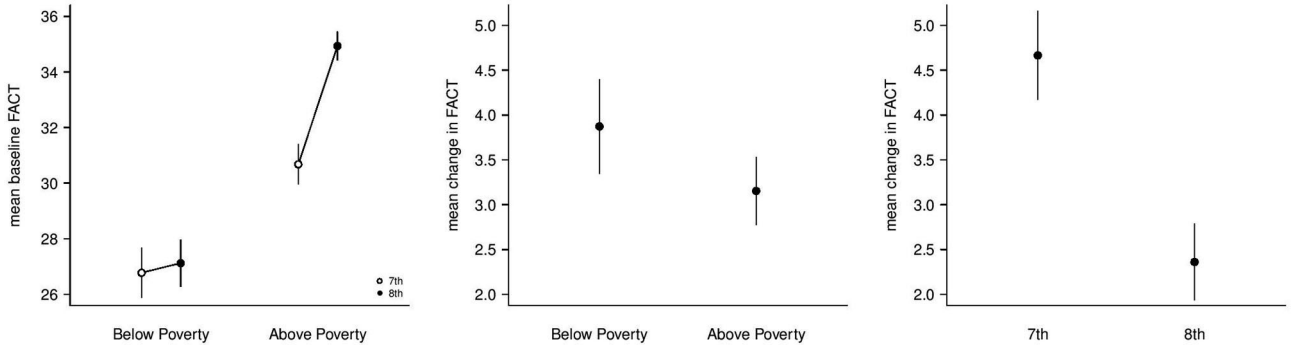

FIGURE 2 | Mean Fact Recall. The figure on the left represents the mean baseline fact learning ability for seventh and eighth grade students living above and below poverty. The middle figure represents the mean change in fact learning ability for students living above and below poverty after cognitive training. The figure on the right represents the mean change in fact learning for seventh and eighth grade students.

adjusted the post-session gist reasoning scores by regressing them on the two PC-derived variables comprised of baseline gist reasoning score, baseline fact recall score, and post-training fact recall score (see **Table 3** for the coefficients corresponding to each of these three variables). Effects of grade level, gender, and SES were assessed on the adjusted mean gist reasoning post-training scores.

Following training, the students living in poverty demonstrated significant gains in gist reasoning scores that were statistically equivalent to the gains made by the students who lived above poverty ($F_{(1,546)} = 0.54$, $p = 0.464$, see **Figure 3**).

Although cognitive training significantly improved gist reasoning scores in both SES groups overall, gender and grade-level differences existed within each of the SES categories. We found that boys had a significantly lower mean post-training gist reasoning score than girls in the poverty level SES category ($F_{(1,546)} = 6.07$, $p = 0.014$; $d = [0.33, 0.43]$), whereas no significant gender difference was found for the group that did not live in poverty ($F_{(1,546)} = 0.89$, $p = 0.345$, see **Figure 3**, above). At the grade level, eighth grade students had significantly higher mean gist reasoning scores after training compared to seventh grade students both in poverty ($F_{(1,546)} = 14.89$, $p < 0.001$; $d = [0.54, 0.65]$) and above poverty ($F_{(1,546)} = 5.02$, $p = 0.025$; $d = [0.22, 0.28]$, see **Figure 3**).

DISCUSSION

The present study is the first known research to specifically examine the efficacy of cognitive training to enhance gist reasoning and fact recall in a large and diverse group of seventh and eighth grade public middle school students as compared to typically developing students who received no specific training. All of our participants were recruited through their respective public middle schools and the assessments and training were performed during the regular school day. The participants came from a rich variety of socio-economic backgrounds, as well as school and home environments, providing ecological validity that exemplifies the melting pot of United States' public school system. The diversity of schools and students who participated in our groups allowed us to examine the effects of poverty, gender, and grade level on the efficacy of cognitive training designed to enhance higher-order thinking skills.

Our study revealed that the gains attained in gist reasoning abilities after less than 10 h of cognitive training were superior to the improvements found in comparison students who did not receive training and who had a year or more to develop

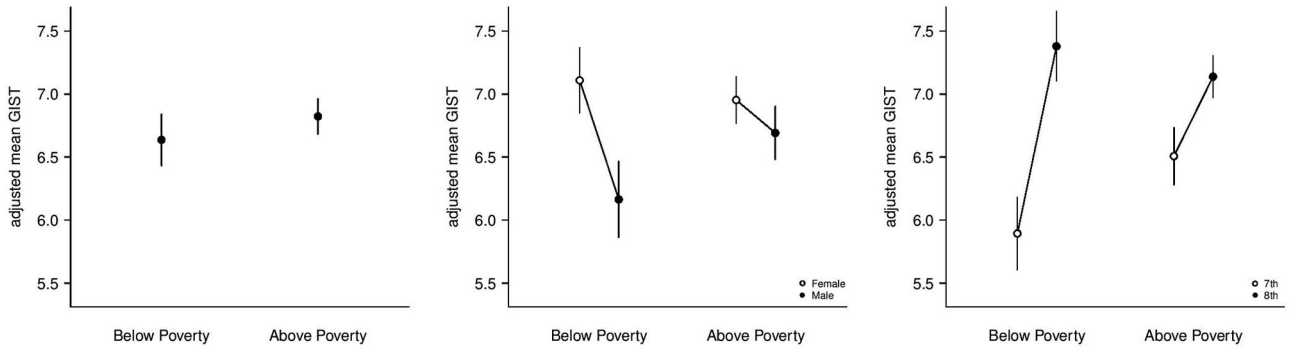

FIGURE 3 | Adjusted Mean Gist Reasoning Comparisons. The figure on the left represents the adjusted mean gist reasoning ability after cognitive training for students living above and below poverty. The middle figure represents the adjusted mean gist reasoning abilities of boys and girls above and below poverty. The figure on the right represents the adjusted mean gist reasoning ability for seventh and eighth grade students living above and below poverty.

and improve gist reasoning through typical classroom teaching. One of the most important findings from this study was that middle school students living in poverty were able to harness cognitive plasticity by showing gains in gist reasoning similar to their more affluent peers. Our findings are similar to Mackey et al. (2011) who found children from a lower SES school demonstrated improved fluid reasoning after a two-month intervention. We postulate that intervening with low SES students with direct cognitive strategies to derive deeper meanings from complex information may attenuate the risk for delayed or stalled developmental trajectory of reasoning skills. Furthermore, we propose that investing time in cognitive training during regular school hours with middle school students regardless of SES could serve to enhance the development of higher-order thinking skills that exceeds the level attained through typical instruction. In particular, measures must be taken to put all students on an even playing field by providing opportunities to enhance academic outcome.

To put a finer point on it, what a child experiences living within a specific economic-level environment must be understood within a larger context that moderates those experiences, and provides opportunities to alleviate deficits in an effort to narrow the achievement gap. A wide variability exists in the presence and influence of mediating and moderating mechanisms within economic levels (Hackman and Farah, 2009). For example, increases in family income among poor families have greater positive impacts on children than increases among middle to high-income families (Raver et al., 2012). Poverty status has been associated with increased vulnerability of multiple brain systems (see Hackman and Farah, 2009 for review; Luby et al., 2013) particularly those involving frontal lobe development (Kishiyama et al., 2009), hindering the acquisition and use of executive control functions which include limitations in problem-solving, decision-making, reasoning, judgment, and planning (Sowell et al., 1999; Bunge et al., 2005). Extant research has found smaller volume in white and gray matter for school-aged children living in poverty (Luby et al., 2013), suggesting a hindrance to brain development that potentially renders children and adolescents limited in their ability to catch up with their more affluent peers. Modifying this previously held poor prognosis, our study found that middle school age students living below the poverty line made significant gains in gist reasoning. Similar to those of Mackey et al. (2011) our findings suggest that remediation of executive control functions is possible and worthwhile.

Our analysis indicated significant gains in gist reasoning ability for eighth grade boys and girls and seventh grade girls after cognitive training regardless of socioeconomic level. The eighth grade students showed significantly greater improvement in gist reasoning than the seventh grade students. The evidence herein suggests that seventh grade girls and eighth grade boys and girls are able to employ inferential processes after short-term, intensive cognitive training designed to improve higher order thinking skills. Specifically, seventh grade girls and eighth grade girls and boys demonstrated that they were able to abstract meaning when presented with new information from a wide variety of text-based information. These cognitive gains suggest that students demonstrated a developmental readiness to employ metacognitive strategies that enhanced understanding and the ability to infer global meanings from texts beyond the explicit facts, including students who were potentially subjected to deprived environments.

Although finding significant gains in gist reasoning across eighth grade students and seventh grade girls from above and below the poverty level was encouraging, we wanted to ascertain the extent to which pre-existing gist reasoning and fact recall abilities provided enhanced prospects for the efficacy of cognitive training. Pre-existing gist reasoning ability could be influenced by opportunities to attend better public schools, have greater access to books and learning opportunities, as well as exposure to positive/educational parental and adult interactions at home, with the resultant greater vocabulary exposure and acquisition. In other words, we sought to determine if the deleterious impact of growing up in poverty (Farah et al., 2006; Luby et al., 2013) would affect the efficacy of cognitive training for boys and girls in middle school. In order to determine if the gist reasoning gains found in students across socioeconomic levels were similar, we statistically co-varied baseline gist reasoning and fact recall ability. By leveling the baseline abilities of the students in our study, we could better determine if the students who lived in poverty were fundamentally disadvantaged and

less apt to experience gains in higher-order cognitive skills with training.

Our analyses found that the students living in poverty showed significant increases in gist reasoning after training comparable to the gains made by their peers living above the poverty line. These results suggest that cognitive training may help reduce the academic achievement gap between socio-economic levels that plagues the United States. With direct training, eighth grade students and seventh grade girls were able to transfer cognitive processing skills learned during training to increase their ability to generate gist-based ideas from a text. In particular, the eighth grade girls who were living below the poverty level in our study showed significant gains in gist reasoning that allowed them to perform comparably to their higher SES peers. It is indeed encouraging to discover that children living in poverty will not necessarily succumb to academic stagnation, but may instead benefit from training to systematically build inferences to generate meanings that enhance understanding. A next step is to determine if cognitive training closes the academic achievement gap beyond the immediate assessment provided in this study, by collecting longitudinal data.

Whereas our findings indicate that the differences in gist reasoning performance between the eighth grade cohorts were not statistically significant, it should be noted that eighth grade boys living in poverty generally performed lower than any of the other eighth grade cohorts. It is possible that childhood poverty has a greater deleterious effect on brain development in boys than girls, such that cognitive training, while efficacious, does not yield the level of improvement of higher order processing at the middle school level in boys as it does for girls. It could be that an increase in the training duration would ameliorate the boys' performance. On the other hand, intervening at an earlier age, especially for boys in poverty, may garner a larger increase in gist reasoning ability by eighth grade, as poor information processing habits might be curtailed with earlier intervention. Earlier intervention may increase boys' confidence, as they could otherwise quietly acquiesce to deficient learning practices.

Failure to develop adequate gist reasoning skills during adolescence may have a profound and lasting effect on the individual in college and throughout adulthood (Willingham, 2009). While fact learning is important, the derivation of meaning by analyzing and synthesizing information, producing abstract concepts, predicting potential outcomes and inferring generalizable relationships and outcomes is absolutely essential for success in school and the workplace (Lehman and Nisbett, 1990; Nisbett, 1993). Theorists and educators recognize that these and other higher-order critical thinking skills typically undergo rapid expansion during adolescence and are refined in complexity and maturity throughout adulthood (Blakemore and Choudhury, 2006; Fischer et al., 2007). Thus, our study focused on middle school students, an age of extensive cognitive development (Bunge and Wright, 2007; Yurgelun-Todd, 2007) and expansion that is concomitant with an incumbent increase in academic demands.

Our findings suggest that seventh grade boys, regardless of SES, did not demonstrate significant gains in gist reasoning after cognitive training. We cautiously postulate that the slower trajectory of brain development in boys (Klingberg et al., 2002; Gogtay et al., 2004; Giedd et al., 2006) impinged transfer of the cognitive skills learned during post-assessment. To be sure, there are substantial individual differences in both age and physical, emotional, and social development among seventh graders that limits confidence in this potential explanation for the null findings. During the training sessions seventh grade boys demonstrated that they understood and could properly use the cognitive processes; however, without direct instruction to use their newly acquired skills, the seventh grade boys did not spontaneously apply what they had learned to the post-training assessment. Our findings are similar to those of Bjorklund et al. (1977), who found a lack of skill/strategy transfer in younger students but not older students after training. It may be that seventh grade boys require cognitive training of longer duration, or additional "booster" training sessions to obtain the benefits found in older children. Potentially, seventh grade boys may require a longer period of time to consolidate the processes acquired with cognitive training to render them useable, as all testing occurred within 2 weeks of the conclusion of the program. Alternatively, beginning cognitive training at an earlier age may prime the development of neural networks relevant to gist reasoning in seventh grade boys. More evidence is needed to determine if seventh grade boys would benefit from earlier intervention or from intervention of longer duration.

Our findings for an effect of gender and grade level on gist reasoning improvement differed from our findings for fact recall gains after cognitive training. We found significant gains in fact recall in both levels of SES, grades, and gender. Although the crux of the cognitive training program was not focused on basic recall, as discovered in previous studies (Gamino et al., 2010; Ryena and Mills, 2014; Wolfe et al., 2014), a focus on top-down processing of textual information positively influenced the ability to remember important details. Our finding supports extant research wherein interventions that utilize training protocols that consist of gist based concepts bolster fact recall (Ryena and Mills, 2014; Wolfe et al., 2014). Of particular interest to this study, the students living below the poverty line made gains in fact recall that were similar to the gains made by the students who did not live in poverty. As a whole, seventh grade students made greater gains in fact recall than eighth grade students. We postulate that when the ability to abstract meaning is purposefully developed, the synthesis of important details leads to greater depth of processing which enhances fact recall.

This study suggests that the deleterious effects of poverty on academic achievement (Farah et al., 2006) and brain volumes (Luby et al., 2013), may be reduced or ameliorated with cognitive training during the early adolescent years, a peak time for important brain development and connectivity refinement (Klingberg et al., 2002; Gogtay et al., 2004; Giedd et al., 2006; Yurgelun-Todd, 2007). Such findings of improved cognitive capacity in gist reasoning during adolescence indicate that the potential to harness cognitive and brain plasticity is preserved despite growing up in impoverished contexts (Mackey et al., 2011). Gist reasoning enhancement has been linked to improved brain function as measured by enhanced synchrony across networks and increased brain blood flow to complex

frontally mediated networks in healthy adults (Chapman et al., 2013). With regard to the adolescent brain, Motes et al. (2014) identified enhanced frontally mediated inhibitory control on EEG measures in a subsample of adolescents who participated in the current study. Future studies should directly investigate the ability to strengthen cognitive capacity and underlying frontal networks during the critical developmental stage taking place in adolescence when the frontal networks and higher-order cognition are undergoing dramatic growth and reorganization. This goal is particularly relevant for youth from low-income backgrounds, to enhance their subsequent potential to succeed.

In an era wherein educational assessment frequently requires merely a regurgitation of facts, students are often more focused on memorizing huge quantities of information, rather than contemplating meaning and applying newly acquired understanding to novel situations (Stern and Ahlgren, 2002). This notion supports our finding that gist reasoning and fact recall abilities in our comparison group had not changed significantly a year or more after our initial assessment. It is likely that memorization does not enhance development of higher order processing, such as gist reasoning nor does memorization equate with understanding information at any depth other than surface level (Ryena and Mills, 2014; Wolfe et al., 2014). Public school curriculum in the United States generally provides breadth rather than depth of core subjects, leaving students with superficial information that has little relevancy in isolation. The evidence gathered herein reinforces the notion that improving gist reasoning in public middle school students, regardless of whether students live in poverty or not, may be attainable in fewer than 10 h of explicit instruction. Thus, the investment of time during the school day to promote direct instruction of higher-order thinking skills may prove invaluable to future academic outcomes that enhance college and career readiness. Unpublished longitudinal evidence gathered after a previous smaller study was published (Gamino et al., 2010) found students who received the cognitive training program graduated from high school on time at a higher rate than the school district average, with more than 70% of the students taking three or more Advanced Placement (AP) classes. Following the students in the present study longitudinally would provide evidence for the longer-term effects of cognitive training, and is a goal of the investigators.

LIMITATIONS

The limitations of the present study include its cross-sectional design. Longitudinal data would provide evidence for the long-term efficacy of cognitive training for middle school students, especially seventh grade male students. In other words, longitudinal data may help to discern if training in seventh grade improves training outcomes for all eighth grade students, such that greater gains are demonstrated with continued cognitive training over two consecutive years. Additionally, collecting supplementary information about students' involvement in early intervention programs, such as Head Start, would help us understand the factors that played a role in the efficacy of cognitive training. Future studies should include longitudinal data of academic markers such as grades and standardized test results to validate correlations of gist reasoning to academic success.

In addition to a lack of longitudinal data, we examined data of groups based on SES, gender, and grade-level, and thus our results are susceptible to design confounds commonly addressed through random assignment to groups. For example, factors associated with strategy acquisition or use, such as motivation or attention, may have influenced the observed differences between groups. Certainly, individual differences in such factors influence children's acquisition and use of the strategies taught, and we attempted to statistically control for aspects of such differences with our covariate analysis. Additionally, for the observed group-level interaction effects, factors such as motivation or attention might have systematically varied with SES, gender, and grade-level (Gottfried et al., 1998) and might mediate differences in gains in gist reasoning. Indeed, SES, gender, and grade level are mere proxies for a host of biological and environmental variables (see, for example, Brooks-Gunn and Duncan, 1997; Bradley and Corwyn, 2002). However, gist reasoning gains on the SOAR, although affected by attention and motivation, show improvement in a student's ability to synthesize the materials with world knowledge (i.e., although necessary, attention and motivation are not sufficient to lead to improved synthesis), and thus our data show synthesis gains following cognitive training even in the low SES groups. Future research should attempt to flesh out the degree to which such gains are mediated by changes in motivation and other factors.

Additionally, our comparison group was neither randomized nor participated in other training outside of their normal classroom activities, which are potential confounds. Likewise, our comparison group came from different schools than the schools that participated in the experimental group and we did not collect information about students' diagnoses that would have enabled us to exclude participation as we did for the experimental group. None of the schools in which students participated in cognitive training enrolled their entire student body in the study, hence we were not given access to other students to recruit them to participate as controls or provide alternative training. The lack of control groups from the same schools as the experimental group was largely due to the disinclination by school administration to have a group of students within their schools that would not have equal access to a potential learning benefit. Therefore, we addressed the issue of a control group by extending an assessment-only option (comparison group status) to schools who did not receive cognitive training for their students immediately, but were assured that should our findings warrant and if funding became available, we would return to provide the program to their students. As such, the students who comprised the comparison group did not provide information regarding family income, learning disorders/differences, brain injury, or other potential confounds. Thus, the comparison group, while indicative of public middle school students, was not precisely matched to the intervention group with regard to those variables, and it is possible that this group lacked the motivation to perform at a higher level. In our previous randomized control study however (Gamino et al., 2010), wherein students in two different control groups were closely matched to the experimental group, we found no significant changes in gist reasoning ability of controls. Thus, we tentatively propose that our comparison group's lack of growth in gist reasoning over

time, may be indicative of many young adolescents in public middle schools wherein teaching students to pass high-stakes standardized tests takes precedence over depth of understanding.

The data presented herein represent the direct assessment of the ability to produce gist-based ideas and recall facts in seventh and eighth grade students who either received cognitive training or did not. Unfortunately, it reflects neither actual academic data nor the academic improvements one would hope to find after cognitive training. From a qualitative standpoint, many of the teachers in whose classrooms we conducted training reported increases in their students' learning performance and standardized test scores. One eighth grade teacher from a low SES school provided data regarding the percentage of "commended" standardized state-mandated test scores from the Texas Assessment of Knowledge and Skills (TAKS) that were received by the students in her class who participated in cognitive training vs. the remainder of the campus. Commended scores represent the highest performance level a student can attain on the TAKS. **Figure 4** compares the percentage of eighth grade students who did not participate in this study and received commended TAKS scores in various content areas compared to the percentage of students from the same low SES campus who received commended scores after participating in the experimental group. Thus, this graph does not represent the comparison group discussed herein but instead represents a cohort of students that is directly linked to a subset of our experimental group as they were all from the same middle school. The campus as a whole was not selected by the administration to participate in this research, thus the majority of the campus was compared only on standardized test results with the small group of students who were in the study. All eighth grade students from the school, the small experimental group, and the student body as a whole where included for this comparison, without excluding any of the students (including the experimental group) for various learning disabilities, head injury, or other factors. The graph indicates that the percentage of students in the cognitive training program who were commended exceeded the percentage of their peers across all content areas tested. While limited and with our acknowledgement that there are potential confounds when comparing these two groups of students, these academic markers of success are encouraging and suggest the necessity for continued study of the efficacy of cognitive training for improving academic performance and advancing career readiness.

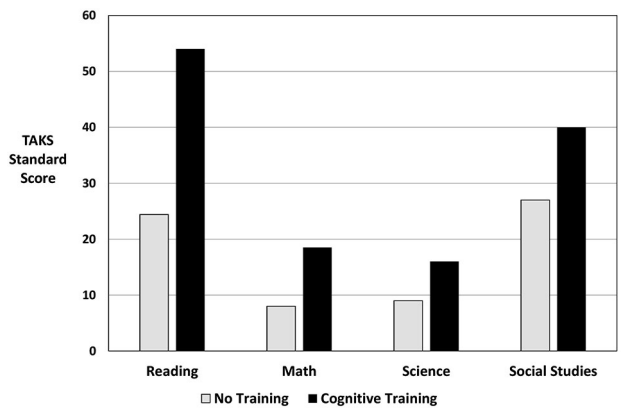

FIGURE 4 | Percent of students commended on the Texas Assessment of Knowledge and Skills from one low SES Dallas area campus; the "No Training" group represents the eighth grade students from the same school who served as a quasi-control group.

In addition to the lack of academic data, our method for ascertaining the SES of our participants entailed using reported family income level and family size; however, additional information could have provided a more accurate portrayal of the students in our study. Poverty levels are frequently indexed through a determination of SES which, in turn, is typically conceptualized as a combination of parental education, income, and occupation (Sirin, 2005). Other studies have relied upon composite SES measures to include parental income, parental education, and parent occupation (Raver et al., 2011). However, there is wide variation in how SES is defined and measured in research and policy contexts (Bornstein and Bradley, 2003). Relying on a needs-to-income ratio may not have yielded a completely thorough appraisal of the poverty status of the students in our study; nevertheless we believe that our method provided a reasonably accurate assessment of our participants' SES level.

CONCLUSION

To be sure, the goal of education is to guide students to become strategic learners wherein they develop the skills to explore and comprehend topics in-depth. The goal-directed behavior to infer global meanings is non-negotiable if one is to be successful in school and the work place (Willingham, 2009). Indeed, memorizing facts does not equate to understanding and represents a formula for failed potential, particularly in children from poverty, who often have limited resources for improving their academic competencies.

Cognitive training in middle school, a time when brain development is at its peak (Giedd et al., 2006), may be the boost students from all income levels need to strengthen their confidence and invigorate their emerging cognitive abilities for the academic rigors that lie ahead in secondary school and beyond. Providing cognitive training at this age in particular, has the potential to take advantage of the brain's plasticity to establish and strengthen the complex frontal networks. This study provides important evidence that, well beyond the early school years, students who have the misfortune of living in poverty can benefit from cognitive training as much as their more privileged peers. The evidence provided herein suggests that utilization of cognitive training within the public school system has the potential to reduce the academic achievement gap, which is underscored by socio-economic disparity.

From a practical perspective, the need for robust gist reasoning skills is readily apparent, for example, when one examines job announcements for entry-level management positions. Such positions routinely call for the ability to rapidly understand, utilize, and apply new knowledge in the conception and execution of tasks and to make flexible decisions on the basis of time constraints and limited resources. Our findings support previous reports that students demonstrate increases in the ability to understand and use information to flexibly problem solve

with guided practice of higher-level cognitive processes (Gamino et al., 2010), perhaps increasing their employability in the future. Likewise the findings in this study support the theoretical position of Reyna (2012), that abstracting gist-based meaning is important for long-term retention of information and efficient learning.

This study may help inform middle school educators, public school administrators, and policy makers of the benefits of directly training top-down cognitive skills as a way to foster high-order thinking in middle school students. Training studies such as this can lead directly to an understanding of dosage and program duration effects to adjust instruction for various grade levels of students. Moreover, the results of studies such as this one have been found to be more influential in motivating educators' attention to and use of research than studies which, at first blush, may not appear relevant to daily classroom practices (Lyon and Esterline, 2007). In essence, treatment studies such as this provide a powerful experimental context to obtain answers to this question: "For which children who vary in economic level are which treatment components and treatment dosages most beneficial and at what ages/grades, provided by which teachers, within which classrooms, within which schools" (Lyon, 1999). More studies are needed to supplant ineffective educational practices with evidence-based remedies.

ACKNOWLEDGMENTS

Funding for this research was provided by the State of Texas, The Meadows Foundation, and The Pickens Foundation. We are also grateful for the support of the AT&T Foundation which provided funding for the expansion of our research.

We are grateful to the research assistants who helped collect data and implement the cognitive training program across the various middle school campuses: Elizabeth Hull, Dr. Katie Croft, Janet Koslovsky, Dr. Amanda Coleman, Courtney Frost, Jeanne Rintelmann, and Phyllis Blanck.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received: 13 July 2014; accepted: 30 October 2014; published online: 09 December 2014.

Citation: Gamino JF, Motes MM, Riddle R, Lyon GR, Spence JS and Chapman SB (2014) Enhancing inferential abilities in adolescence: new hope for students in poverty. Front. Hum. Neurosci. ***8****:924. doi: 10.3389/fnhum.2014.00924*

This article was submitted to the journal Frontiers in Human Neuroscience.

frontiers in Aging Neuroscience

ORIGINAL RESEARCH
published: 09 October 2017
doi: 10.3389/fnagi.2017.00314

Enhancing Innovation and Underlying Neural Mechanisms Via Cognitive Training in Healthy Older Adults

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Non-invasive interventions, such as cognitive training (CT) and physical exercise, are gaining momentum as ways to augment both cognitive and brain function throughout life. One of the most fundamental yet little studied aspects of human cognition is innovative thinking, especially in older adults. In this study, we utilize a measure of innovative cognition that examines both the quantity and quality of abstracted interpretations. This randomized pilot trial in cognitively normal adults (56–75 years) compared the effect of cognitive reasoning training (SMART) on innovative cognition as measured by Multiple Interpretations Measure (MIM). We also examined brain changes in relation to MIM using two MRI-based measurement of arterial spin labeling (ASL) to measure cerebral blood flow (CBF) and functional connectivity MRI (fcMRI) to measure default mode and central executive network (CEN) synchrony at rest. Participants (N = 58) were randomized to the CT, physical exercise (physical training, PT) or control (CN) group where CT and PT groups received training for 3 h/week over 12 weeks. They were assessed at baseline-, mid- and post-training using innovative cognition and MRI measures. First, the CT group showed significant gains pre- to post-training on the innovation measure whereas the physical exercise and control groups failed to show significant gains. Next, the CT group showed increased CBF in medial orbitofrontal cortex (mOFC) and bilateral posterior cingulate cortex (PCC), two nodes within the Default Mode Network (DMN) compared to physical exercise and control groups. Last, significant correlations were found between innovation performance and connectivity of two major networks: CEN (positive correlation) and DMN (negative correlation). These results support the view that both the CEN and DMN are important for enhancement of innovative cognition. We propose that neural mechanisms in healthy older adults can be modified through reasoning training to better subserve enhanced innovative cognition.

Keywords: innovation, cognitive training, aging, creativity, CBF, functional connectivity, reasoning training, randomized trial

OPEN ACCESS

Edited by:
Christos Frantzidis, Aristotle University of Thessaloniki, Greece

Reviewed by:
Daria Antonenko, Charité Universitätsmedizin Berlin, Germany
Hans-Peter Müller, University of Ulm, Germany

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Received: *09 March 2017*
Accepted: *14 September 2017*
Published: *09 October 2017*

Citation:
Chapman SB, Spence JS, Aslan S and Keebler MW (2017) Enhancing Innovation and Underlying Neural Mechanisms Via Cognitive Training in Healthy Older Adults. Front. Aging Neurosci. 9:314. doi: 10.3389/fnagi.2017.00314

INTRODUCTION

Innovative cognition is widely recognized as a vital capacity, undergirding adaptive and flexible thinking. This cognitive domain is of interest in older adults due to its centrality to human cognition, intellect, decision-making, life achievement, resilience and psychological well-being (McFadden and Basting, 2010; Li et al., 2015; Beaty et al., 2016; Heilman, 2016; Palmiero et al., 2016; Saggar et al., 2016). Innovative thinking may be a pivotal cognitive capacity and brain function

allowing one to respond effectively to challenging and constantly changing life demands (Saggar et al., 2016). Cognitive neuroscientists are becoming increasingly interested in elucidating the domain of innovative thinking, its neurobiological underpinnings; and whether this important capability can be enhanced (Fink et al., 2015). Thus, the present study offers one of the first pilot trials: (1) to examine whether innovative cognition can be improved as well as; and (2) to elucidate associated neural changes following cognitive or physical exercise training in healthy older adults.

Innovative thinking purportedly declines even before young adulthood (Kim, 2011) and may worsen with increasing age. Most aging evidence has focused largely on insidious cognitive declines in areas such as executive function, cognitive control and memory as well as losses in both structural and functional aspects of brain systems (Raz et al., 1997; Kennedy and Raz, 2009; Lu et al., 2011). Declines in these domains reportedly accumulate with increasing age even in the absence of frank dementia. The sparse evidence that does exist about age-related changes in innovative cognition is equivocal. Some evidence suggests that innovative thinking may follow the same degradation pattern as other executive functions and memory with a peak in early adulthood followed by accumulating declines starting as young as 30 s to 40 s (Alpaugh and Birren, 1977; McCrae et al., 1987; Reese et al., 2001). Other accounts have challenged this age-related loss pattern, showing preserved innovative cognition with aging (Roskos-Ewoldsen et al., 2008; Greenwood and Parasuraman, 2010). Li et al. (2015) have shown that real life success as reflected in publication productivity in university professors is related to maintaining innovative cognition with increasing age. Other researchers have shown that divergent thinking, one facet of innovative thinking, stabilizes in middle-age and is preserved across the lifespan (Palmiero, 2015) especially when controlling for processing speed (Elgamal et al., 2011).

With regard to age-related decline in brain function, significant changes occur in nodes across two brain networks linked to innovative thinking, namely, the central executive network (CEN) and the Default Mode Network (DMN; Beaty et al., 2016). Specifically, age-related declines are identified on measures of brain function including: (a) reductions in cerebral blood flow (CBF) as measured by arterial spin labeling MRI (ASL MRI) across brain regions (Lu et al., 2011); and (b) reduced functional connectivity in these specific regions (Sambataro et al., 2010; Hafkemeijer et al., 2012; Geerligs et al., 2015). With regard to how brain networks are linked to innovative thinking, the findings are inconsistent. Beaty et al. (2016) reports an inverse correlation between CEN and DMN that is associated with higher performance on innovation (Green et al., 2015; Beaty et al., 2016); whereas Takeuchi et al. (2012) reported increased connectivity between these regions in relation to innovation. Most participants in prior studies were college students. Therefore, it is unclear how the neural and cognitive findings generalize to healthy older adults or to older adults in response to training.

Whether or not innovative cognition can be improved in older adults remains an important issue to address. Clinical trials provide evidence that the neuroplasticity of the aging brain may indeed be harnessed to leverage a perspective shift towards one that refuses to accept the well-documented, insidious age-related loss as a definite outcome of the aging process (Chapman and Mudar, 2014; Rebok et al., 2014). Specifically, research findings reveal that a significant degree of age-related cognitive and brain losses can be halted, reversed or even inoculated against through the building of cognitive and brain reserves to stave off subsequent decline (Mahncke et al., 2006a; Anguera et al., 2013; Rebok et al., 2014; Chapman et al., 2015, 2016; Hohenfeld et al., 2017). Among a variety of opportunities to modify age-related losses, two non-pharmacological intervention-types have been shown to enhance cognition and neural systems, specifically cognitive training (CT) protocols (Levine et al., 2000; Mahncke et al., 2006b; Chapman and Mudar, 2014; Chapman et al., 2015, 2016) and physical exercise regimens (Kramer et al., 1999; Chapman et al., 2013, 2016). We previously reported that reasoning training (SMART©) improved performance on cognitive control measures of complex abstraction and working memory; whereas aerobic exercise improved immediate and delayed memory (Chapman and Mudar, 2014; Chapman et al., 2015, 2016). Linked to these cognitive gains, we also identified corresponding significant increases in resting CBF (Chapman et al., 2016). However, whether the cognitive (SMART©) protocol can improve innovative cognition and neural mechanisms has yet to be investigated in aging populations.

We extend our prior work by addressing whether the CT can also improve innovative cognition, influence brain systems and show correspondence between enhanced innovative cognition and brain changes in the same group of participants. The specific aims of this randomized pilot study were: (a) to determine whether innovative cognition in older adults can be improved through cognitive reasoning training; (b) to compare CBF changes following CT compared to physical training (PT) and wait-list controls; and (c) to elucidate brain mechanisms related to improved innovative thinking in cognitively normal adults (56–75 years of age). We set out to test three questions: would the CT affect: (1) innovative thinking as measured by the Multiple Interpretations Measure (MIM); (2) brain plasticity as measured by resting state CBF; and (3) correspondence between enhanced innovation performance and brain connectivity changes in two prominent brain networks, i.e., DMN and CEN.

MATERIALS AND METHODS

Participants

A total of 140 subjects were screened in a multi-stage screening process comprising online, telephone and in-person questionnaires as well as a physical examination to ensure good health, see Supplementary Figure S1 for the consort chart. Participants were adults between the ages of 56 and 75 years, right-handed native English speakers, with at least a high school diploma, no history of psychiatric or neurological conditions, no history of medication changes or surgery entailing general anesthesia within 3 months, and no more than 20 min of aerobic activity, twice per week. The online questionnaire was followed

TABLE 1 | Baseline subject characteristics and total number of subjects per group, assessments and MRI technique (mean ± SD).

	Control	Physical training	Cognitive training	Range	*p*-value
Age	64.0 ± 3.6	64.0 ± 4.3	61.8 ± 3.3	56–75	0.50
Gender (M/F)	5/15	6/13	8/11	–	0.45
IQ	120.9 ± 10.5	117.5 ± 9.9	121.6 ± 8.0	88–136	0.45
MoCA	28.2 ± 1.4	27.8 ± 1.5	27.9 ± 1.4	25–30	0.72
TICS-M	29.6 ± 2.0	30.7 ± 2.0	29.4 ± 2.2	27–36	0.14
BDI	5.5 ± 4.7	3.0 ± 2.8	3.3 ± 2.4	0–14	0.07
BMI	26.4 ± 3.3	27.7 ± 4.5	25.8 ± 3.6	19–38	0.34
VO_2 Max	19.9 ± 4.0	19.3 ± 3.3	20.8 ± 5.0	13–30	0.52
Participants (*n*)					
MIM cognitive testing	20	19	19		
pCASL MRI	18	18	13		
fcMRI	16	15	15		

Two-sample t-test was conducted to assess potential baseline differences. IQ, Intelligence Quotient; MoCA, Montreal Cognitive Assessment; TICS-M, Telephone Interview of Cognitive Status-Modified; BDI, Beckman Depression Inventory; BMI, Body Mass Index; VO_2 Max, maximal oxygen consumption; MIM, Multiple Interpretations Measure to measure innovation; pCASL, pseudo-Continuous Arterial Spin Labeling; fcMRI, functional connectivity MRI.

up by a telephone interview to answer questions about the study, verify online responses, and screen for cognitive status using Telephone Interview for Cognitive Status-M ≥ 28. The third stage comprised of an in-person Intelligence Quotient (IQ) using Wechsler Abbreviated Scale of Intelligence (WASI) ≥ 80, mood screen using Beck Depression Inventory (BDI) ≤ 14 and cognitive status screen using Montreal Cognitive Assessment (MoCA) ≥ 26. Finally, in the fourth stage, a physician examined each participant's physical ability to comply with the study's exercise requirements through an in-person physical assessment of height, weight, waist circumference, Body Mass Index (BMI) < 40, hypertension screen, basic blood test and graded stress test. Specifically, participants underwent a maximal oxygen consumption (relative VO_2 max: mL/kg/min) exercise stress test to assess maximal exercise capacity as well as blood pressure/ECG responses and rating of perceived exertion (RPE) according to the Borg scale, range: 6–20 (Borg, 1990). A repeat of this rigorous assessment was carried out at all three time points during and following the training.

This study was carried out in accordance with the recommendations of Institutional Review Boards (IRB) of University of Texas Southwestern Medical Center, University of Texas at Dallas and The Cooper Institute. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The participants were then randomized using a block randomization schedule stratified by gender into one of three groups: (CT, $n = 19$), (PT, $n = 19$) and Wait-listed control (CN, $n = 20$). All participants in the PT and CT groups were required to complete at least 90% of the training sessions over the 3-month period. No significant differences in age, gender, estimated IQ, MoCA, Telephone Interview of Cognitive Status-Modified (TICS-M) were noted between groups ($p > 0.05$), as shown in **Table 1**. This study was registered at Clinical Trials.gov, NCT#00977418.

Cognitive Training Program

The CT program used in this study is an evidence-based, manualized program focused on enhancing top-down executive functioning: Strategic Memory Advanced Reasoning Training or SMART© (Chapman and Mudar, 2014; Chapman et al., 2015, 2016). For treatment fidelity, the sessions for all participants in the CT group were led by the same clinician, whose three-stage training process included reviewing literature on the program, observing other trained clinicians and leading non-study SMART© training groups under the supervision of a trained clinician. The SMART© training sessions were comprised of 12 1-h in-person small group ($n \leq 5$) sessions held once a week for 12 weeks. Additionally, each participant was assigned two 1-h pencil and paper assignments to complete at home each week for a total of 24 h of solo work, for a total of 36 h over the course of the study. In addition to completing the independent assignments, each participant kept a log of the assignments, which included the total amount of time spent and task completion.

SMART© trained and provided practice of three metacognitive strategies for each of the complex cognitive functions of Strategic Attention, Integrated Reasoning and Innovation. As stated in Chapman et al. (2016), Distinct Benefits of Cognitive vs. PT, *Strategic Attention* is the ability to filter important information from less relevant data which is routinely necessary in life to efficiently manage time and cognitive resources by prioritizing daily goal setting, blocking distractions, intentionally single tasking, and scheduling regular mental breaks during the day. *Integrated Reasoning* teaches individuals to synthesize information at deeper levels of interpretation by abstracting the essence or extracting key goals for tasks. Strategies for Integrated Reasoning exert cognitive control to "zoom in" on the important details or steps to a goal, then rapidly "zooming out" to synthesize, and abstract big picture ideas/goals, followed by "zooming deep and wide" to construct generalized application of derived ideas, interpretations, or goals-completed. It is a skill that allows one to make informed decisions and solve problems in dynamic and demanding environments. The strategies of Innovation encourage fluid and flexible thinking, perspective taking and problem solving. *Innovation* focuses on flexibly updating ideas and perspectives and continually seeking ways to improve everyday tasks. These three core strategies were trained in the first 3 weeks of in-person group meetings so that participants could understand the basics

of SMART©. The remainder of the training hours, participants practiced generating synthesized ideas and relevant application of the strategies to everyday life. Trainees received feedback from the trainer not only relative to performance on in-session group interactions regarding complex cognitive activities but also regarding their responses to applied activities. SMART trains individuals to approach challenging cognitive tasks with a brain prepared to think deeply, to continually synthesize data encountered daily (e.g., movies, medical information, speeches) and to practice innovative thinking by generating diverse interpretations, solutions and perspectives.

Physical Training Program

The PT program used in the study, similar to the CT program, was comprised of three 1-h exercise sessions per week for 12 weeks. Every exercise session of aerobic activity occurred under supervision of trained personnel, an exercise physiologist and a nurse practitioner, with alternate use of treadmill walking and stationary cycling. By monitoring participants every 5 min, the supervising trainers ensured that they maintained 50%–75% of their VO_2 max during the individual sessions. Sessions were structured to include 5-min warm-up and cool-down periods with specified slower speeds and 50 min at the rate necessary to maintain the required VO_2 max For a complete description of both training protocols employed, interested readers are encouraged to reference "Distinct brain and behavioral benefits of cognitive vs. PT: a randomized trial in aging adults" (Chapman et al., 2013).

Multiple Interpretations Measure (MIM)

A shortcoming of assessment batteries for innovative cognition is the limited ability to measure novelty and relevance of ideas in responses that typify naturally occurring cognitive activities and challenges. Commonly used measures to characterize innovation include a variety of divergent thinking tasks such as Guilford's Alternative Use Task (e.g., list as many different uses of cardboard boxes, a brick, pencil, etc.), other verbal fluency tasks (e.g., list as many words as possible that begin with the letter "d" or exclude the letter "k"), ideational fluency like some of the prompts present in the Torrance Test of Creative Thinking (e.g., ask as many questions as possible regarding a provided image or object, list as many consequences as possible for a given image, list as many improvements as possible for a toy, and as many consequences as possible for impossible scenarios like people no longer needing sleep; Guilford, 1967; Wallach, 1968; Kaufman and Sternberg, 2006; Runco and Acar, 2012; Runco and Jaeger, 2012). Whereas these measures may be informative, these are less common cognitive challenges faced in everyday life in older adults and may lack ecological validity.

For the present study, we utilized The MIM, a subtest of Test of Strategic Learning (TOSL). This test is comprised of three expository texts about an historical person who is unknown but has generalizable life experiences from which distinct high-level themes may be gleaned, e.g., the meaning of success, self-actualization, courage, strength during moments of adversity, etc. One of the three versions was randomly administered at each assessment time point: pre- (T1), mid- (T2) and post-training (T3) periods. The primary scale of the Test of Strategic Learning measures cognitive control of complex abstraction as represented through the ability to understand and synthesize the overall meaning in a synopsis of text, much like you would in the abstract of an article or a synopsis of a movie. The Multiple Interpretation Measure subtest measures an individual's ability to generate multiple interpretations of the expository text, a task motivated by the work of Kaufman and Sternberg (2006). Specifically, participants are asked to construct as many high-level interpretations as possible that can be drawn from the expository texts but which are not explicitly stated.

In this way, the MIM subtest taps the ability to combine presented information with their world knowledge in a multitude of ways. This subtest that solicits multiple interpretations represents a real-life task, similar to what a person could encounter in everyday life when they express a range of ideas and/or solutions. For instance, when engaged in conversation, there are an infinite number of possible interpretations for a movie, political speech, medical scenario dilemma, or future financial advice. These interpretations are self-generated ideas, which are not explicitly conveyed in the texts. Instead, individuals use cognitive control processes to create abstracted responses. Abstracted interpretations require the individual to decipher meanings expressed in the immediate context and combine these meanings with their own experiences and world knowledge to construct plausible and relevant responses.

For scoring purposes, every interpretation was first rated along two dimensions: either high-quality (HQ) or Other-type. Responses were coded as HQ when they were judged to convey generalized/abstracted ideas that showed an ability to combine the meanings from the text within the context of more generalized real world knowledge. In short, HQ responses were those that represented a depth of understanding and synthesis of meaning whereas Other-type responses tended to represent more of a reiteration of literal facts or obvious ideas from the text. To exemplify, one of the texts of the MIM describes the life of a man who was not considered a success during his lifetime in terms of predominant societal measures, who nonetheless in retrospect made incredible contributions to humankind. A specific example of a HQ interpretation is, "Often the perspective of time can redeem a person's ideas and ideals". Or "Empathy can impact the lives of many by creating societal change". Example of Other-type responses would be "He had a lot of jobs and failed at them all" or "He never seemed to be satisfied with his choices". The first examples clearly represent synthesized statements that generalize beyond what is explicitly stated in the text whereas the latter responses relate only to the meaning as conveyed in the text.

Three clinicians, trained in the scoring method for the measure, utilized a coding manual with sample responses to make response judgments. Three raters scored the responses separately and were blinded to the participant's group membership and time interval of test, i.e., whether they were scoring T1, T2 or T3. Disagreements on scores were resolved by consensus. Changes in participants' innovative responses over time were determined by comparing the number of HQ interpretations by training group (i.e., T1 to T2 and/or T3).

MRI Experiment

MRI investigations were performed on a 3 Tesla MR system (Philips Medical System, Best, Netherlands). A body coil was used for radiofrequency (RF) transmission and an 8-channel head coil with parallel imaging capability was used for signal reception. We used different MRI techniques to investigate changes at rest: a pseudo-Continuous Arterial Spin Labeling (pCASL) sequence was used to measure CBF, functional connectivity MRI (fcMRI) was used to assess functional connectivity of the brain. Additionally, a high-resolution T_1-weighted image was acquired as an anatomical reference. The details of imaging parameters and their processing techniques are provided below.

Imaging parameters for pCASL experiments were: single-shot gradient-echo EPI, field-of-view (FOV) = 240 × 240, matrix = 80 × 80, voxel size = 3 × 3 mm^2, 27 slices acquired in ascending order, slice thickness = 5 mm, no gap between slices, labeling duration = 1650 ms, post-labeling delay = 1525 ms, time interval between consecutive slice acquisitions = 35.5 ms, TR/TE = 4020/14 ms, SENSE factor 2.5, number of controls/labels = 30 pairs, RF duration = 0.5 ms, pause between RF pulses = 0.5 ms, labeling pulse flip angle = 18°, bandwidth = 2.7 kHz, echo train length = 35, and scan duration 4.5 min. The sequence parameters for fcMRI were FOV = 220 × 220, matrix = 64 × 64, slice thickness = 4 mm, no gap between slices, voxel size = 3.44 × 3.44 × 4 mm^3, 36 axial slices, TR/TE = 2000/30 ms, flip angle = 70°, 120 image volumes, and scan duration = 4 min. The high-resolution T_1-weighted image parameters were magnetization prepared rapid acquisition of gradient-echo (MPRAGE) sequence, TR/TE = 8.3/3.8 ms, shot interval = 2100 ms, inversion time = 1100 ms, flip angle = 12°, 160 sagittal slices, voxel size = 1 × 1 × 1 mm^3, FOV = 256 × 256 × 160 mm^3, and duration 4 min.

pCASL image series were realigned to the first volume for motion correction (SPM5's realign function, University College London, UK). An in-house MATLAB (Mathworks, Natick, MA, USA) program was used to calculate the difference between averaged control and label images. Then, the difference image was corrected for imaging slice delay time to yield CBF-weight image, which was normalized to the Brain template from Montreal Neurological Institute (MNI). This procedure was carried out using a nonlinear elastic registration algorithm, Hierarchical Attribute Matching Mechanism for Elastic Registration (HAMMER, University of Pennsylvania, PA, USA). The HAMMER algorithm detects and corrects for region-specific brain atrophy which is commonly seen in elderly subjects. Last, the absolute CBF was estimated by using Alsop and Detre's equation in the units of mL blood/min/100 g of brain tissue (Aslan et al., 2010).

For voxel-based analyses (VBA), the individual CBF maps were spatially smoothed (with full-width half-maximum (FWHM) of 4 mm) to account for small differences in sulci/gyri location across subjects. For cluster extent inference, we used *3dClustsim* in AFNI (NIMH Scientific and Statistical Computing Core, Bethesda, MD, USA), which controls false-positive activation clusters over the set of all activation clusters throughout the whole-brain volume. We refer to this procedure in the "Results" Section as family-wise error correction (FWE corrected). For cluster inference, we tested the volume of clusters, which is conditional on two criteria: smoothness of the voxel map and cluster-defining threshold. We estimated the smoothness to be 9.3 mm FWHM (inherent smoothness plus additional smoothness applied—described above) and set the cluster-defining threshold to the 99.5th percentile of *t*-statistic distribution. Then, the minimum cluster size of 98 voxels (784 mm^3) yielded an FWE-corrected significance level of 0.05.

Functional connectivity images were analyzed by using AFNI (NIMH Scientific and Statistical Computing Core, Bethesda, MD, USA). The dataset was preprocessed with slice timing correction, motion correction (realignment), removal of the linear trend, smoothing by a Gaussian filter with a FWHM of 6 mm and band-pass filtering (0.01–0.1 Hz) to keep appropriate frequency fluctuations. Next, images were spatially normalized to MNI template. In the DMN analysis, we correlated the time series of the orbitofrontal cortex (OFC) and posterior cingulate cortex (PCC) regions (an ROI analysis since the regions were significant in the CBF analysis and are part of DMN). Then, a Pearson correlation was conducted between the time series of PCC and OFC; followed by a z-transformed using Fisher's transformation. In the CEN analysis of functional connectivity, the preprocessed images were analyzed using a seed-based approach by choosing bilateral dorsolateral prefrontal [± 45 + 16 + 45] cortices based on MNI coordinates (Chapman et al., 2015). The cross-correlation coefficient between these seed voxels and all other voxels was calculated to generate a correlation map. Next, the correlation maps were converted to a z-transformed using Fisher's transformation. Last, an ROI analysis was performed based on two CEN regions: dorsolateral prefrontal cortex (DLPFC; composed of BA 9 and 46) and inferior parietal cortex (IPC). The functional ROIs were defined as follows: first, each region's anatomical region was defined based on Talairach Daemon database in AFNI. Then, a functional ROI was defined by choosing the top 200 voxels at each time point (i.e., T1, T2 and T3) and the intersection (i.e., common voxels) of the masks was calculated (Chapman et al., 2015). The CEN Z-Score was calculated by averaging the values of the all four nodes of CEN: L/R DLPFC and L/R IPC.

Statistical Analyses

All tests were *t*-statistic contrasts of parameter estimates from a linear mixed model. The computations were implemented in the R computing language[1]. We modeled HQ innovations as additive effects of training type (CT, CN, control and PT), time of assessment (T1—baseline, T2—mid-training and T3—post-training), and the interaction between type of training and assessment period in a standard linear mixed effects model framework. Two variance components—one due to variability across subjects, and one due to variability in the same subject over time—were included to account for the different

[1]http://cran.r-project.org

levels of variability and estimated by restricted maximum likelihood. We were primarily interested in how the groups differed across the training sessions. Thus, we hypothesized that the CT group would show a larger positive change in mean number of HQ innovations by T2 and/or T3, relative to the control and PT groups. This hypothesis led to the following one-sided *t*-statistic contrasts of means from the linear mixed effects model: (1) time contrasts (T23 − T1) for each group, where we define (T23 − T1) = (T2 + T3)/2 − T1 as the "sustained change" following training; (2) interaction contrasts $(T23 - T1)_{CT} - (T23 - T1)_{CN}$ and $(T23 - T1)_{CT} - (T23 - T1)_{PT}$. One additional interaction contrast was also tested as $(T23 - T1)_{CT} - (T23 - T1)_{CN/PT}$, where CN/PT denotes the average of the two control groups. These six contrasts were tested as single degree-of-freedom *t*-tests from the linear mixed effects model without multiple comparisons adjustments.

We modeled CBF similarly. That is, in the VBA, we used the same linear mixed effects model for voxel-level CBF as noted above: training type (CT, CN, PT), assessment period (T1, T2, T3), and their interaction. Our hypothesis for CBF was also similar to that of HQ innovations—we hypothesized that the CT group would show a larger positive change in mean CBF by T2 and/or T3, relative to the control and PT groups. For this hypothesis, we tested only the single interaction contrast $(T23 - T1)_{CT} - (T23 - T1)_{CN/PT.}$ We did not, however, hypothesize specific regions of the brain in which we expected this CBF relationship. Therefore, as noted above in the description of our VBA analysis, we FWE corrected through AFNI's cluster-extent inference.

Last, we used separate linear models to assess the HQ innovations/DMN connectivity relationship and the HQ innovations/CEN connectivity relationship. In the first linear model the dependent variable was (T23 − T1) for HQ innovations, and the independent variable was (T23 − T1) for DMN connectivity on a z-transformed scale (described above). In the second linear model, based on the CEN findings of Chapman et al. (2015), the independent variable was "transient change" (T2 − T1) for CEN connectivity on a z-scale, and the dependent variable was, similarly, (T2 − T1) for HQ innovations. For both models, training type (CT/CN/PT) was also included as an additive term, as well as the interaction of training type with the independent variable DMN or CEN connectivity change, respectively. From these models, we calculated regression coefficients for each group and tested their respective differences from zero as *t*-statistics. Additionally, we tested the single degree-of-freedom interaction contrast $B_{CT} - B_{CN/PT}$, where B denotes the estimated regression coefficient. In the first model our primary hypothesis was that the functional relationship would be restricted to the CT group relative to controls and the PT group, yielding a significant interaction test, but without a directional hypothesis. In the second model, however, our hypothesis was that the HQ innovations/CEN connectivity relationship was positive and restricted to the CT group. This directional hypothesis was also based on the CEN findings of Chapman et al. (2015).

RESULTS

All control (CN, n = 20), physical training (PT, n = 19) and cognitive training (CT, n = 19) participants completed the neurocognitive assessments at each time point. However, several participants in the control (CN), CT and physical exercise (PT) groups were not included in the analysis due to incomplete MRI time points, gross movement of >3 mm, and >3° and/or artifacts. All physical exercise and CT participants were required to complete at least 90% of training sessions over the 3-month training period, which means they completed 32 h or more of the 36 h of training. One baseline-only measurement for the neurocognitive assessment of one CT participant was removed because it had been scored incorrectly. No participant was excluded due to missing too many sessions to meet the 90% criterion.

Neurocognitive Analysis

Figure 1 displays mean HQ innovations for each group and each assessment period, and **Table 2** lists all the relevant contrasts of interest from the linear mixed model. The CT group shows a significant mean "sustained increase" in number of HQ innovations from T1 to T23 (t_{109} = 2.23, p = 0.014); whereas the same contrast for the control and PT groups were not significant (t_{109} = 0.44, p = 0.33 and t_{109} = −0.08, p = 0.53, respectively). Comparing the sustained increase for the CT group with the comparable change in the control group and the PT group (i.e., from T1 to T23), we found that the sustained increase for the CT group is marginally larger than the control group (t_{109} = 1.30, p = 0.098) and, similarly, marginally larger than the PT group (t_{109} = 1.63, p = 0.053). Averaging the sustained change over the two control groups (i.e., CN and PT), we find that the sustained increase for the CT group is also marginally larger than the average change of the controls and PT groups (t_{109} = 1.69, p = 0.047).

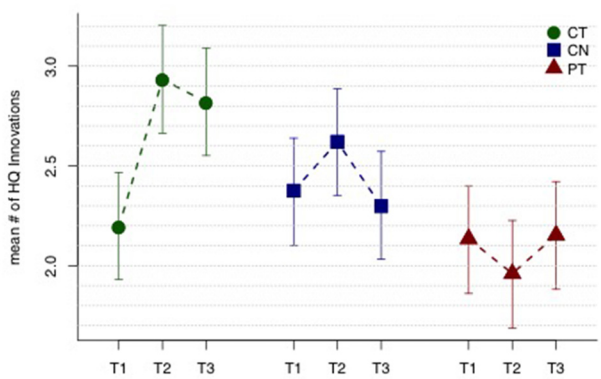

FIGURE 1 | High-quality (HQ) innovation results. Mean number of HQ innovations across three assessment periods T1, T2 and T3 (baseline, mid-training, and post-training, respectively). The cognitive training (CT) group shows a sustained improvement in mean HQ innovations (T23 − T1), while the controls (CN) and physical training (PT) groups do not. See text and **Table 2** for tests of the relevant contrasts. Error bars indicate 95% least significant intervals for contrasts T23 − T1 by group.

TABLE 2 | HQ innovation results.

Mean time contrasts	Estimate	SE	*t*-statistic	*df*	*p*-value
$(T23 - T1)_{CT}$	0.739	0.331	2.23	109	0.014
$(T23 - T1)_{CN}$	0.139	0.316	0.44	109	0.33
$(T23 - T1)_{PT}$	−0.024	0.300	−0.08	109	0.53
Mean interaction contrasts					
$(T23 - T1)_{CT} - (T23 - T1)_{CN}$	0.6	0.462	1.3	109	0.098
$(T23 - T1)_{CT} - (T23 - T1)_{PT}$	0.763	0.468	1.63	109	0.053
$(T23 - T1)_{CT} - (T23 - T1)_{CN/PT}$	0.681	0.403	1.69	109	0.047

Contrasts from the linear mixed model for HQ innovations for cognitive training (CT), control (CN) and physical exercise (PT) groups.

CBF Analysis

Figure 2 shows the results of the interaction contrast described above for the VBA of the CBF maps. That is, we tested whether the sustained increase for the CT was greater than that of the average change between the control (CN) and physical exercise (PT) groups. A significantly larger increase in blood flow was observed at T23 in bilateral medial orbital frontal cortex (mOFC) and bilateral PCC of the CT group compared to the PT/control group, shown in **Figure 2**. Both mOFC and PCC are major nodes of DMN (Fox et al., 2005). **Table 3** summarizes these findings for cluster-level inference as well as descriptive statistics for peak voxel within cluster. Cluster volumes larger than 784 mm^3 (FWE alpha level of 0.05) yield FWE *p*-values less than 0.05. Our observed cluster volumes for PCC and mOFC are 3792 and 992 mm^3, respectively.

Neurocognitive and Regional Connectivity Relationship

Figure 3A shows a scatterplot of the relationship between the sustained change in functional connectivity of the DMN and the sustained change in High Quality innovation scores, coded separately for each group. **Table 4** displays the regression statistics from the linear model. An inverse relationship was found for the CT group ($t_{36} = -4.57$, $p < 0.001$); whereas the control (CN) and physical exercise (PT) groups showed no significant relationship (CN: $t_{36} = 1.15$, $p = 0.25$; PT: $t_{36} = -0.81$, $p = 0.43$). Furthermore, the inverse relationship for the CT group was significant relative to the control (CN) and physical exercise (PT) groups (interaction test in **Table 4**: $t_{36} = -4.36$, $p < 0.001$).

Figure 3B shows a scatterplot of the relationship between the transient change in functional connectivity of the CEN and the transient change in HQ innovation scores, coded separately for

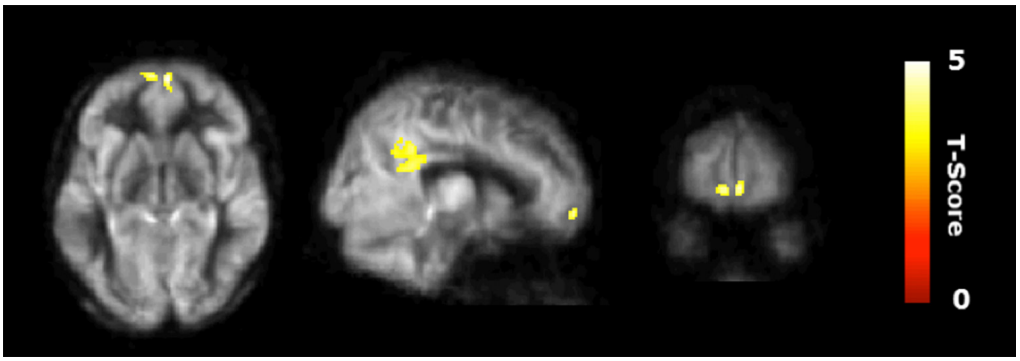

FIGURE 2 | Regional cerebral blood flow (CBF) results. Voxel-based analysis for the interaction contrast described in text, superimposed on an average CBF map of all participants. Both cluster volumes $k = 3792$ mm^3 for posterior cingulate cortex (PCC) and $k = 992$ mm^3 for medial orbitofrontal cortex (mOFC) are significant at an family-wise error correction (FWE) alpha level of 0.05 ($k = 784$ mm^3).

TABLE 3 | Regional CBF results.

			MNI			
Brain regions	**BA**	**Cluster size (mm^3)**	***X***	***Y***	***Z***	***T*-Value**
CT > CN/PT						
L/R posterior cingulate cortex	31/23	3792	−4	−44	36	4.76
L/R medial orbitofrontal cortex	11/10	992	6	64	−8	4.91

Regions that showed significant cerebral blood flow (CBF) increase at rest in cognitive training (CT) compared to control (CN) and physical training (PT) groups. The coordinates depict the peak of clusters.

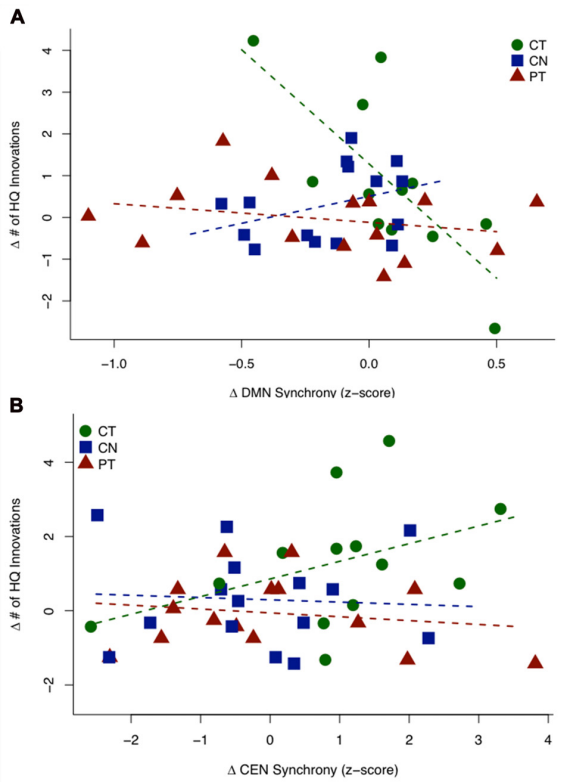

FIGURE 3 | HQ innovation changes in relation to changes in connectivity of default mode network (DMN) and central executive network (CEN). **(A)** Scatterplot of the sustained change (T23 − T1) in HQ innovation scores against the sustained change (T23 − T1) in DMN connectivity z-scores. The CT group shows a significant negative relationship, while the controls (CN) and PT groups do not show significant relationships between behavior and connectivity. **(B)** Scatterplot of transient change (T2 − T1) in HQ innovation scores against the transient change (T2 − T1) in CEN connectivity z-scores (outlier removed, see text). The CT group shows a significant positive association, while the controls (CN) and PT groups show no significant relationship. **Table 4** displays the regression statistics from both linear models.

each group. One subject in the CT group has been removed based on outlier diagnostics (studentized residual = −4.16; outlier test—Bonferroni p-value = 0.010), see Supplementary Figure S2. A positive association was found for the CT group (t_{37} = 1.837, p = 0.037); whereas the control (CN) and physical exercise (PT) groups showed no significant relationship (CN: t_{37} = −0.239, p = 0.594; PT: t_{37} = −0.483, p = 0.684). Furthermore, the positive relationship for the CT group was significant relative to the control (CN) and physical exercise (PT) groups (interaction test in **Table 4**: t_{37} = 1.81, p = 0.039). In **Table 4**, we display the regression statistics from the linear model for ΔHQ innovation as a function of ΔDMN and ΔCEN, respectively.

DISCUSSION

This randomized pilot study evaluated whether innovative cognition was improved in a group of older adults (56–75 years) in response to CT vs. physical exercise training (PT) or a wait-list control group (CN). In previously published research, we showed that CT improved cognitive control on measures of complex abstraction and working memory; whereas physical exercise enhanced immediate and delayed memory (Chapman and Mudar, 2014; Chapman et al., 2015, 2016). In the current article, we used the same cohorts, but compared a distinct measure from that previously reported, to examine this new question as to whether the CT protocol would also improve innovative cognition. The outcome measure was a novel cognitive innovation task intrinsically related to real life demands, i.e., being able to formulate multiple interpretations for a lengthy expository text.

Our preliminary results can be summarized as three key findings. First, we found that the CT group showed significant gains in high quality innovation performance. In contrast, neither the exercise nor the control group showed significant changes in innovation performance over time. Second, we identified mechanisms related to training-induced brain changes, namely increases in CBF within the CT group only. The CT

TABLE 4 | HQ innovation changes in relation to changes in connectivity of default mode network (DMN) and central executive network (CEN).

A	Δ HQ innovation as a function of Δ DMN connectivity				
	Group-specific coefficient	**Estimate**	***t*-statistic**	***df***	***p*-value**
	B_{CT}	−5.46	−4.57	36	<0.001
	B_{CN}	1.31	1.15	36	0.257
	B_{PT}	−0.45	−0.81	36	0.425
	Interaction contrast	**Estimate**	***t*-statistic**	***df***	***p*-value**
	$B_{CT} - B_{CN/PT}$	−5.89	−4.36	36	<0.001
B	**Δ HQ innovation as a function of Δ CEN connectivity**				
	Group-specific coefficient	**Estimate**	***t*-statistic**	***df***	***p*-value**
	B^*_{CT}	0.476	1.837	37	0.037
	B_{CN}	−0.061	−0.239	37	0.594
	B_{PT}	−0.104	−0.483	37	0.684
	Interaction contrast	**Estimate**	***t*-statistic**	***df***	***p*-value**
	$B^*_{CT} - B_{CN/PT}$	0.559	1.81	37	0.039

*Regression statistics from linear model for ΔHQ innovation as a function of (A) Δ DMN connectivity and (B) Δ CEN connectivity (*outlier removed, studentized residual = −4.16, Bonferroni p-value = 0.010) for the cognitive training (CT), control (CN) and physical training (PT) groups.*

group showed significant change from baseline bilaterally in the mOFC and the PCC, major nodes in the DMN. Lastly, we found significant associations between changes in high quality Innovation scores and the connectivity of two major neural networks, the CEN and the DMN using resting state fcMRI in the CT group. Specifically, individuals in the CT group with high quality innovation scores showed increased connectivity in CEN nodes (a positive correlation) as contrasted with decreased connectivity in DMN nodes (a negative correlation) on resting state fcMRI.

Overall, the findings support a potential to harness latent innovative thinking capacity and neuroplasticity in a cognitively normal older adult population (56–75 years) with a short-term cognitive reasoning training protocol, namely SMART©. These results add to growing data showing that older adults benefit from different forms of CTs (Mahncke et al., 2006b; Ball et al., 2010; Greenwood and Parasuraman, 2010; Anguera et al., 2013; Hohenfeld et al., 2017). The current study is one of the first known studies to show gains in innovative cognition and corresponding neural networks linked to reasoning training in older adults. Taken together with prior research showing enhanced neurocognitive effects with reasoning training (Chapman et al., 2013, 2016), the present findings support the potential for such training to have broad-based benefits manifested not only on measures of cognitive control but now these results also implicate a potential to improve innovative cognition in middle-age to older adults. This promise of improved innovative cognition capacity in cognitively normal adults warrants further validation in a larger study.

Our evidence suggests that the CT (SMART©) may be deployed to induce an experience-driven neuroplasticity in cognitively normal older adults. This enhanced innovative cognition performance had a direct association with gains in the CEN regions' connectivity but an inverse association with the DMN regions' connectivity in the CT group. The advantageous patterns of connectivity within the CEN and DMN are reinforced by previous evidence linking such a dynamic relation to innovative cognition (Greicius et al., 2003; Beaty et al., 2016). Further evidence that the neural changes reflect positive brain reorganization with CT is supported by the distinct pattern for the CT group only with no significant innovation or neural changes for the physical exercise (PT) and control (CN) groups. Thus, we propose that the change in connectivity of CEN and DMN following reasoning training may represent a redesigned "healthier neural mechanism" in older adults that is able to better subserve enhanced innovative cognition. Specifically, continued research toward this effort would help determine if reasoning training builds a more resilient system to counteract failure between two major networks; which previously has been linked to inefficient cognitive performance in healthy and compromised brains (Bonnelle et al., 2011, 2012). This interacting neural pattern between networks is consistent with the claim by Beaty et al. (2016) that innovative thinking engages dynamic interactions of large-scale brain networks, especially the CEN and DMN.

The nature of this complex and dynamic interaction of the CEN and DMN in relation to innovative thinking is equivocal. Jung et al. (2013), concluded in their review article that both increased and decreased brain "fidelity" across major brain networks was linked to creative innovation. In contrast, other studies report the opposite inverse innovation-connectivity relation between the two networks in relation to elevated divergent thinking performance, an aspect of innovative cognition (Takeuchi et al., 2012; Benedek et al., 2014; Mayseless et al., 2015; Beaty et al., 2016). Despite the disparity in directionality of CEN and DMN in support of innovative cognition, the consensus supports a dynamic interplay between the two functionally distinct but complementary networks (Jung et al., 2013). We propose that the complex operations of innovative thinking are not isolated to single neural hubs, but rather are supported through the involvement of at least two brain networks of DMN and CEN.

A number of factors may contribute to this seemingly disparate pattern across studies such as: (1) the nature of the innovative paradigm; (2) resting-state vs. task-induced studies; (3) age of participants; and (4) single time point measurement vs. longitudinal measurement in response to an intervention. First, the measure of innovation that we used in the present study is distinct from those used in prior work. Our innovative task taps top-down processes, drawing upon controlled retrieval of information, combining and integrating the selected ideas with world knowledge to generate and create a multitude of abstract interpretations. Second, different mechanisms are tested when comparing resting-state vs. task-induced brain imaging. The majority of studies that have shown increased DMN with higher creativity were task-induced studies whereas ours was resting-state. Third, previous innovation-connectivity patterns were identified in younger adults (ages 19–36 years), which may not necessarily be comparable to an older group (ages 56–75 years). Last, we were interested in neural changes following a 12-week CT protocol whereas many of the prior findings examined a single time point, with a few exceptions involving young adults (Fink et al., 2015; Saggar et al., 2016). We conclude that the functional changes in two neural networks relative to innovative cognition following training leaves a footprint in the resting state networks to better support enhanced innovative cognition in the aging brain.

This pilot study must be interpreted in the context of a number of limitations. First, the present task lacks the degree of validation of prior tasks used to measure divergent thinking, namely tasks which prompt for as many alternative uses of an object, (i.e., a "tissue") as designed decades ago by Guilford (1967). Whereas we recognize this is a limitation and are in the process of establishing its validity; we propose that the task of deriving multiple interpretations for commonly encountered information may be a practical, functional task that is related to higher-order cognitive capacities that may have ecological validity. Other limitations include small sample size and lack of follow-up after training ended to shed light on the persistence of the gains. We were able to address whether this particular sample enhanced their performance from baseline. However, we were not able to evaluate whether individuals regained lost capacity or perhaps may be able to maintain and mitigate declining innovative cognition in the ensuing

years. Addressing these latter issues requires longitudinal studies and quite possibly proactive interventions along the way to test whether declining abilities can be strengthened at life stages where decline emerges. Another possibility to consider for subsequent research is whether this older adult group achieved a level of performance that was superior to how they would have performed as a younger version of themselves. Some evidence suggests that the older mind may be able to take advantage of prior experience to engage in innovative cognition.

CONCLUSION

The objective of the present study was to examine the effects of CT on innovative cognition in older adults. This study revealed that reasoning training via SMART improved innovative cognition which correlated to the key nodes of CEN and DMN networks. In sum, the current findings suggest that short-term and cost effective interventions, such as CT, may be beneficial in enhancing cognitive capacities and supporting neural mechanisms in healthy older adults. The new finding related to improved innovative cognition in healthy older adults is heartening; given innovative thinking is one of the most valued assets and fruitful outputs of the human mind across the lifespan (Kaufman and Sternberg, 2006; Palmiero et al., 2016). The potential to strengthen innovative cognition may tap into a positive and valuable resource of the aging mind that could support an individual's ability to reinforce and retain an active mental lifestyle, engage in complex decision-making, intellect and psychological well-being with advancing age (Baltes et al., 1999; Kaufman and Sternberg, 2006). Much work needs to be done but this feasibility study motivates a continued push to harness the potential and reduce the gap of cognitive brain decline as we age.

AUTHOR CONTRIBUTIONS

SBC designed the study, interpreted the data and drafted the manuscript; JSS performed statistical analysis and drafted the manuscript; SA performed neuroimaging analysis, interpretation of neuroimaging data and reviewed the manuscript; MWK performed cognitive assessments and reviewed the manuscript.

FUNDING

This work was supported by a grant from the National Institute of Health (RC1-AG035954, R01-NS067015, R01-AG033106) and by grants from the T. Boone Pickens Foundation, the Lyda Hill Foundation and Dee Wyly Distinguished University Endowment. Funding to pay the Open Access publication charges for this article was provided by funds from the Dee Wyly Distinguished University Endowed Chair held by SBC.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnagi.2017.00314/full#supplementary-material

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Brain and Cognition

Volume 84, Issue 1, February 2014, Pages 44-62

Inhibitory control gains from higher-order cognitive strategy training☆

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Abstract

The present study examined the transfer of higher-order cognitive strategy training to inhibitory control. Middle school students enrolled in a comprehension- and reasoning-focused cognitive strategy training program and passive controls participated. The training program taught students a set of steps for inferring essential gist or themes from materials. Both before and after training or a comparable duration in the case of the passive controls, participants completed a semantically cued Go/No-Go task that was designed to assess the effects of depth of semantic processing on response inhibition and components of event-related potentials (ERP) related to response inhibition. Depth of semantic processing was manipulated by varying the level of semantic categorization required for response selection and inhibition. The SMART-trained group showed inhibitory control gains and changes in fronto-central P3 ERP amplitudes on inhibition trials; whereas, the control group did not. The results provide evidence of the transfer of higher-order cognitive strategy training to inhibitory control and modulation of ERPs associated with semantically cued inhibitory control. The findings are discussed in terms of implications for cognitive strategy training, models of cognitive abilities, and education.

Introduction

Formal education requires balancing teaching subject content and teaching more general cognitive and learning strategies (Conley, 2008, Dansereau, 1985, Pressley et al., 1990, Rosenshine and Meister, 1992, Weinstein and Mayer, 1986, Weinstein and Meyer, 1991, Weinstein et al., 1989). On the one hand, teaching subject content is necessary for students to develop subject knowledge and competence with subject-specific learning and problem-solving strategies. On the other hand, teaching general cognitive and learning strategies is necessary to facilitate student learning and problem-solving in novel situations, particularly in situations where an expert is not immediately available. Teaching higher-order cognitive strategies aimed at improving reasoning, problem-solving, and comprehending, however, also has the potential to exercise and improve supporting core executive processes. As a test of this broader hypothesis that higher-order cognitive strategy training can improve associated executive processes, the present study examined the transfer of a higher-order, reasoning-based, cognitive strategy training program to an untrained measure of inhibitory control.

The Strategic Memory Advanced Reasoning Training (SMART©) program (Chapman and Gamino, 2008, Gamino et al., 2010) was used as the higher-order cognitive strategy training program in the present study. SMART is a general cognitive strategy program that teaches a hierarchical sequence of steps designed to facilitate inferring essential gist from materials. The findings from a randomized control study have provided validation for SMART as a method for improving the ability to infer essential gist from materials (Gamino et al., 2010). In that study, middle-school students were randomly assigned to either receive SMART, mnemonic training, or lectures about the teen brain. The analysis of summaries written before and after the training showed that the SMART group, but not the other two control groups, made significant gains in inferring overall messages from texts and inferring connections between overall messages and more general world knowledge. The efficacy of SMART for improving the ability to infer the essential gist from materials also has been shown in healthy elderly adults (Anand et al., 2011) and adults who had suffered traumatic brain injuries (Vas, Chapman, Cook, Elliott, & Keebler, 2011).

SMART steps and activities were developed based on models of comprehension and reasoning and were designed to foster the use of comprehension and reasoning processes to facilitate inferring essential gist from studied materials. SMART consists of seven hierarchical steps: (1) identifying and deleting irrelevant information, (2) organizing the remaining relevant information, (3) inferring unstated meanings from the organized information, (4) paraphrasing, (5) synthesizing important information, (6) inferring an overall message or messages, and (7) inferring analogous relationships between the newly inferred message(s) and general world knowledge (e.g., adages, themes, morals). From models of comprehension, these steps were designed to foster the use of processes mediating the transformation of studied materials into more global, abstract representations forming a topic (Brown and Day, 1983, Kintsch and van Dijk, 1978, van Dijk, 1977), including suppressing topic-irrelevant information, substituting superordinate representations (e.g., substituting gardening for weeding, mowing, and trimming), and inserting inferred global facts (e.g., inferring that tools were used in gardening). From models of reasoning, the steps were designed to foster the use of processes mediating inferring relationships between parts of studied materials, including identifying attributes and inferring and comparing relationships between attributes (Green and Kluever, 1991, Pellegrino and Glaser, 1979, Sternberg and Gardner, 1983, van der Ven and Ellis, 2000). Furthermore, the steps were

designed to foster the use of more cognitively demanding *inductive inferencing* or making assertions about relationships between information not explicitly present in the studied materials (Klauer & Phye, 2008).

The present study explored the effects of SMART on inhibitory control, an executive process that should be recruited and exercised during SMART but that was not directly addressed by the training. Inhibitory control has been proposed to affect a range of higher-order cognitive processes (Dempster, 1991, Dempster and Corkill, 1999). In comprehension, inhibitory control mechanisms have been said to eliminate or suppress extraneous encoded information and retrieved inappropriate meanings and inferences (Cain, 2006, Chiappe et al., 2000, De Beni and Palladino, 2000, Gernsbacher and Faust, 1991, Gernsbacher and Robertson, 1995, Just and Carpenter, 1992, Kintsch and van Dijk, 1978, Pimperton and Nation, 2010). Additionally, in reasoning, inhibitory control mechanisms have been proposed to also eliminate or suppress extraneous encoded information (Viskontas, Morrison, Holyoak, Hummel, & Knowlton, 2004) and to eliminate or suppress retrieved strategies, beliefs, examples, memories, and prepotent responses deemed inaccurate (De Neys and Everaerts, 2008, De Neys et al., 2005, Handley et al., 2004, Houdé, 2000, Houdé et al., 2000, Moutier et al., 2002, Moutier and Houdé, 2003, Robin and Holyoak, 1995). Thus, by engaging comprehension and reasoning processes while working through SMART, students also should engage and exercise inhibitory control mechanisms.

Inhibitory control in the present study was measured using a Go/No-Go task (e.g., Luria, 1959, Simpson and Riggs, 2006). Go/No-Go tasks involve building preparatory or anticipatory cognitive and motor responses through frequent and temporally regular presentations of stimuli to which participants are to respond and then involve the attenuation, circumvention, or some kind of "control" of these prepotent responses when shown a less frequently presented No-Go stimulus (Simpson & Riggs, 2006). Thus, the proportion of correct rejections on No-Go trials serves as an index of inhibitory control, and the proportion of correct rejections has been shown to provide a reliable and relatively pure index of inhibitory control (Perner et al., 2002, Simpson and Riggs, 2006).

Research suggests that a general inhibitory control mechanism mediates correct rejections on Go/No-Go tasks (Brocki and Bohlin, 2004, Friedman and Miyake, 2004, Miyake et al., 2000; but see Eagle et al., 2008, Kramer et al., 1994, Shilling et al., 2002). Inhibitory control often has been operationalized using motor control measures like stopping a planned or prepotent response (Barkley, 1997, Bedard et al., 2002, Brocki and Bohlin, 2004, Eagle et al., 2008, Rubia et al., 2001, Schachar et al., 2007, Verbruggen and Logan, 2008, Verbruggen and Logan, 2009, Williams et al., 1999). However, latent variable analyses have provided convergent and discriminant evidence for the presence of a general inhibitory control mechanism (Brocki and Bohlin, 2004, Friedman and Miyake, 2004, Friedman et al., 2006, Miyake et al., 2000). Latent variable analyses have revealed correlations between a range of measures of response inhibition (i.e., stopping planned, prepotent, or automatic motor responses) and of distractor interference (i.e., avoiding the influence of irrelevant distractors), providing convergent evidence for a common inhibitory control mechanism. Latent variable analyses also have shown distinctions in the associations between measures of inhibitory control and prospective memory interference, providing discriminant evidence for involvement of an inhibitory control mechanism in response

inhibition and distractor interference but not resistance to memory intrusions (Friedman & Miyake, 2004).

The Go/No-Go task used in the present study also allowed for the examination of the effects of SMART on semantically cued inhibitory control (Brier et al., 2010, Maguire et al., 2011, Maguire et al., 2009). Research on semantically cued inhibitory control has shown the sensitivity of fronto-central (Fz) EEG markers of response inhibition to requirements of deeper semantic processing (Brier et al., 2010, Maguire et al., 2009). Go/No-Go tasks, in general, have been found to elicit changes in the N2 and P3 ERP components, with the N2 occurring approximately 150–300 ms after the stimulus onset and the P3 occurring approximately 300–600 ms after the stimulus onset (e.g., Hillman et al., 2012, Maguire et al., 2009, Simson et al., 1977). For both components, greater signal change has been observed on successful No-Go trials (i.e., correct rejections) compared to successful Go trials (e.g., Donkers and van Boxtel, 2004, Maguire et al., 2009). However, there has been debate over which component, N2 or P3, over which location actually indexes inhibitory control (Bruin et al., 2001, Donkers and van Boxtel, 2004, Falkenstein et al., 1999, Kopp et al., 1996, Smith et al., 2007). Among young adults, both N2 and P3 inhibitory control effects have been observed over fronto-central electrodes (e.g., Donkers and van Boxtel, 2004, Maguire et al., 2009). However, among young adults, deeper semantic processing requirements have been shown to attenuate fronto-central (Fz) P3 amplitudes and increase P3 peak latencies on No-Go trials (Maguire et al., 2009). Deeper semantic processing requirements also have been shown to decrease EEG frontal theta-band power changes and increase frontal theta-band peak latencies on No-Go trials (Brier et al., 2010).

In addition to showing sensitivity to deeper semantic processing, research on semantically cued inhibition has provided evidence for the sensitivity of P3 to developmental change (Maguire et al., 2011). A developmental study of groups of children 10–11 years of age and 7–8 years of age showed depth of semantic processing modulation of the P3 over parieto-central (Pz) electrodes. The 10–11 year old group showed attenuation of the P3 amplitude at Pz on No-Go trials with increases in the depth of semantic processing requirements, but the younger group showed increases in the P3 amplitude at Pz on Go trials with increases in the depth of semantic processing requirements. These results suggest that there is a shift in the modulatory effect of deeper semantic processing on P3 at Pz as children develop from middle to late childhood. Then when compared with the results from young adults (Maguire et al., 2009), there appears to be another shift toward fronto-central mediated semantically cued inhibitory control.

The present study was conducted to evaluate the transfer of SMART to inhibitory control using the semantically cued Go/No-Go task (Brier et al., 2010, Maguire et al., 2009, Maguire et al., 2011). Participants in the SMART group were recruited from a pool of students enrolled in a broader, in-school administration of the SMART program (see Fig. 1). Thus, importantly, the training was provided in normal school classrooms during school hours. Providing the training in a relevant educational context, rather than a lab setting, increased ecological validity of the study. Ecological validity has been an oft-raised issue regarding generalization of cognitive, cognitive neuroscience, and in particular, cognitive training findings to relevant educational contexts (e.g., Varma, McCandliss, & Schwartz, 2008). A pre-post, quasi-experimental design, including a historical control group, was used (Campbell & Stanley, 1966). The semantically cued Go/No-Go task allowed for the assessment of the transfer of SMART to inhibitory control,

the specificity of the transfer to inhibitory control (i.e., as compared to selection), and the effect of SMART on the potential modulatory effects of deeper semantic processing in inhibitory control.

Section snippets

Demographics

The data for 26 participants (*M* = 13.19 years; 16 males; 11 White, 8 Hispanic, 6 African-American, and 1 Native American) in the SMART group and 30 participants (*M* = 13.07 years; 14 males; 21 White, 4 Hispanic, and 5 African-American) in the control group were analyzed. All were right-handed adolescents between 12 and 15 years of age. Full scale IQ scores (based on WAIS Matrix Reasoning and Vocabulary tests; Wechsler, 1999) were obtained for both groups.

Results

The primary aim of the study was to evaluate training-related effects on inhibitory control. Therefore, for all analyses the Group (SMART; Control) × Time (Pre; Post) and higher order interaction effects involving Group (SMART; Control) × Time (Pre; Post) are reported below, and in the interest of full reporting, the ANOVA tables for all main and interaction effects appear in Appendix A, Appendix B. All ANOVAs used Type III sums of squares yielding more conservative estimates of effects when

Training-related inhibitory control gains

The results provided evidence that higher-order cognitive strategy training can lead to increased inhibitory control. Overall, the group of students who completed the SMART program was more successful at inhibiting prepotent responses after the training, regardless of the depth of semantic categorization required, than the control group. Furthermore, although inhibitory control increased, the group of students who completed the SMART program showed a decision criterion shift from a criterion

Acknowledgments

The authors would like to thank the SMART teachers for administering the program to the students; the SMART data entry and administrative teams; Tiffani Jantz, Monique Salinas, Diane Ogiela, Shreya Goyal, Timothy Meyers, and Monica Yagle for their help with data collection and processing; Ilana Bennett, Ehsan Shokri-Kojori, and Jeffrey Spence for constructive discussions and comments on drafts of this manuscript; and the teachers and administrators at the participating schools for their time

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  Clinical Neurophysiology

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- M.R. Brier *et al.*

  Frontal theta and alpha power and coherence changes are modulated by semantic complexity in Go/NoGo tasks

  International Journal of Psychophysiology

  (2010)

- A.L. Brown *et al.*

  Macrorules for summarizing texts: The development of expertise

  Journal of Verbal Learning and Verbal Behavior

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- K.J. Bruin *et al.*

  Inhibition, response mode, and stimulus probability: A comparative event-related potential study

Clinical Neurophysiology

(2002)

- K.J. Bruin *et al.*

Response priming in a go/nogo task: Do we have to explain the go/nogo N2 effect in terms of response activation instead of inhibition?

Clinical Neurophysiology

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Intrusion errors in working memory tasks: Are they related to reading comprehension ability?

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Inhibitory processes: A neglected dimension of intelligence

Intelligence

(1991)

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  The N2 in go/no-go tasks reflects conflict monitoring not response inhibition

Brain and Cognition

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Cited by (20)

- **The power of appraisals in predicting PTSD symptom improvement following cognitive rehabilitation: A randomized clinical trial**

  2021, Journal of Affective Disorders

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Higher-order cognitive training effects on processing speed–related neural activity: a randomized trial

2018, Neurobiology of Aging
Citation Excerpt :

However, the results from the present randomized training trial support the notion that cognitive training targeting higher-order cognitive processes can alter PFC involvement in processing speed and may serve to mitigate age-related changes in PFC function, in general. The transfer of higher-order cognitive training to only PFC-mediated processing speed–related neural activity, and not to other brain regions associated with processing speed (Rao et al., 2014), suggests that transfer of higher-order cognitive training to lower-order cognitive functions (Baniqued et al., 2015; Basak et al., 2008; Motes et al., 2014; Mudar et al., 2016; Vas et al., 2016; Venza et al., 2016) might occur through higher-order cognitive training indirectly benefiting mediating higher-order common functions served by the PFC rather than indirectly benefiting a host of lower-order supporting functions. Across CT, WLC, and AC groups and assessment periods in

the present study (Supplementary Fig. 1) and in a study of healthy young adults examining intra-individual dynamics in RT-BOLD association on the DSVT (Rao et al., 2014), faster processing speed was associated with reduced brain activation across a host of brain regions, including medial and lateral PFC, parietal, occipital, subcortical, and insula.

• •

“Happy goat says”: The effect of a food selection inhibitory control training game of children's response inhibition on eating behavior

2016, Appetite
Citation Excerpt :

For the AD/HD children, the symptoms were marginally alleviated after training. Motes et al. (2014) used a cognitive strategy-training program to train 12- to 15-year-old children, and the children's performance on a go/no-go task improved after training. Thorell et al. (2009) used an inhibition-training program to train 4- to 5-year-old children, whose performance on the inhibition tasks also improved.

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The field of expertise modulates the time course of neural processes associated with inhibitory control in a sport decision-making task

2022, Scientific Reports

•

Effects of searching for rhetorical relations on university-level text comprehension in L2

2022, Reading and Writing

•

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The role of primary auditory and visual cortices in temporal processing: A tDCS approach

Behavioural Brain Research, Volume 313, 2016, pp. 151-157

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Inhibition of the mirror generalization process in reading in school-aged children

Journal of Experimental Child Psychology, Volume 145, 2016, pp. 157-165

- • Research article

The effect of social observation on children's inhibitory control

Journal of Experimental Child Psychology, Volume 113, Issue 2, 2012, pp. 248-258

- • Research article

The effects of inhibitory control training on alcohol consumption, implicit alcohol-related cognitions and brain electrical activity

International Journal of Psychophysiology, Volume 89, Issue 3, 2013, pp. 342-348

- • Research article

Mindful decision making and inhibitory control training as complementary means to decrease snack consumption

Appetite, Volume 103, 2016, pp. 176-183
• • Research article

Revealing hot executive function in children with motor coordination problems: What's the go?

Brain and Cognition, Volume 106, 2016, pp. 55-64

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☆

This research was supported by Texas Legislature appropriated ARRA Funding for the Middle School Brain Years Program (2009–2011), and ongoing research on SMART is supported by funding from the Texas Legislature and AT&T. A United States patent application has been filed to protect the Strategic Memory Advanced Reasoning Training program (Publication #US20120282578 A1) with the University of Texas System Board of Regents, Dr. Chapman, and Dr. Gamino as the assignees.

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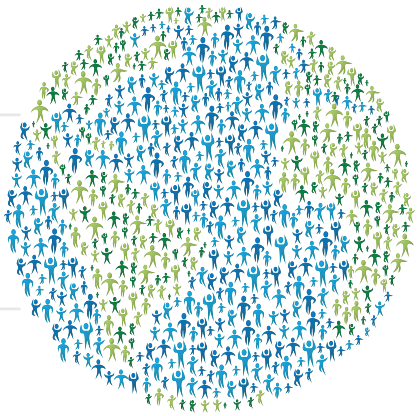

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HIGH SCHOOL EDITION
Journal of Student Research

Volume 10 Issue 4 (2021)

Efficacy of Music Therapy on Adolescents with Depressive Symptoms

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ABSTRACT

Adolescents in the USA are experiencing increasing rates of depressive symptoms each year, resulting in a variety of emotional, social, neurological, and behavioral problems. Current traditional treatments are limited in their ability to reduce symptoms of depression. In the past few decades, music therapy has emerged as a viable treatment for depression and its comorbidities across various age groups and demographics. Music therapy is a unique form of clinical and evidence-based treatment characterized by a relationship between the music therapist and patient to address the patients' needs through various methods such as song-writing, listening, and/or singing. This literature review analyzes a wide range of qualitative and quantitative sources studying various cohorts and contexts to examine the efficacy of music therapy for treating adolescent depression in comparison to traditional treatments. We found that most sources concluded that music therapy is more effective than traditional treatments and can be used as a supplement to such treatments. Music therapy has multiple positive socio-emotional, behavioral, and neurological effects, particularly for adolescents with depressive symptoms. Furthermore, many studies noted improvements in the comorbidities and related disorders of depression. In the future, studies should be conducted with standardized trials focusing specifically on adolescents and music therapy treatments to refine therapeutic applications. In conclusion, we make the case that music therapy should be made more accessible to adolescents as a treatment option.

Introduction

Background

As rates of adolescent depression in the USA continue to rise, music therapy has become increasingly recognized as an effective treatment for depression and depressive symptoms (Mojtabai et al., 2016; Weinberger et al., 2017). Broadly speaking, the current literature in the field of music therapy contains an abundance of qualitative and quantitative studies performed in various contexts and observed through various outcomes, such as emotional, behavioral, and neurological, to demonstrate music therapy's efficacy (e.g., Aalbers et al., 2017; Albornoz, 2011; Algoodkar & Sunitha, 2019; Chang et al., 2008; Erkkilä et al., 2011; Langhammer et al., 2019; Mohammadi et al., 2011; Popa, 2015; Raglio et al., 2015; Ramirez et al., 2018; Sharma & Jagdev, 2012; Shiranibidabadi & Mehryar, 2015; Wu, 2002). From its ability to improve health outcomes and the quality of life of patients diagnosed with myriad physical and psychological disorders to its ability to reduce depressive symptoms, according to the evidence from meta-analyses and systematic reviews, music therapy is accepted as a viable treatment method across the board (e.g., Aalbers et al, 2017; Kamioka et al., 2014; Leubner & Hinterberger, 2017; Stegemann et al., 2019; Tang et al., 2020; Zhao, 2016).

Specifically, in the field of depression, music interventions have shown consistency in reducing depressive symptoms and reducing the effects of common comorbidities (e.g., Kamioka et al., 2014; Leubner & Hinterberger,

2017; Mohammadi et al, 2011; Porter et al., 2017; Ramirez et al., 2018). For adolescents in particular, music therapy may be a viable treatment that reduces the possible side effects of traditional pharmacological treatment and provides adolescents the opportunity to relieve their depressive symptoms by expressing themselves in creative ways (Albornoz, 2011; Porter et al., 2017; Stegemann et al., 2019).

Purpose and Scope

The purpose of this comprehensive literature review is to analyze trends and patterns and identify gaps of knowledge in the literature on the use of music therapy and music medicine for adolescents with depression or depressive symptoms. Among this age group, depression has been a prevalent and significant issue, severely threatening the mental health and livelihoods of youth, and thus, warrants the need to study this disorder and its treatments (Weinberger et al., 2017). Additionally, this review will identify logistical inconsistencies and theoretical disagreements in the included studies and determine areas that need further research and observation.

The scope of the literature discussed in this review extends approximately from the early 90s to the present day, including studies originating from outside of the USA to consider a broader context and specific demographics. This review includes studies on both music therapy and music medicine (further explained in the section "Music Therapy versus Music Medicine"), various measurement scales, diverse study designs, and both significant and null conclusions. We also included studies on traditional treatments to compare the efficacy of these treatments to that of music therapy. Despite the seemingly broad scope of our study, we determined that it was essential to include such diverse literature to fully capture the current understanding regarding the efficacy of music therapy.

Sequence

In this review, we first discuss the background of the literature to establish the context associated with depression and music therapy. Then, we analyze the efficacy of music therapy on the general population before moving on to consider a more specific cohort, adolescents. Throughout the efficacy sections, we compare the studies in terms of the types of music therapy employed, the concerns of the comorbidities of depression, the duration of the music therapy sessions, the format of music therapy sessions, and the results of the studies. We also compare the efficacy of music therapy with the efficacy of traditional treatment on patients with depressive symptoms. Moreover, the review highlights the constraints of music therapy, including critiques and limitations. Finally, we offer conclusions and recommendations for the use of music therapy to treat adolescents with depression.

Adolescent Depression

Depression is a rampant mood disorder that includes symptoms of sadness and a loss of interest in previously enjoyed activities according to the National Institute of Mental Health (2018). It can lead to a plethora of psychophysiological issues that impact daily functioning, such as reduced quality of life, diminished concentration, insomnia or hypersomnia, fatigue, and suicidal thoughts (Algoodkar & Sunitha, 2019; Dere-Meyer et al., 2011; Dong et. al, 2019). Numerous factors could play crucial roles in the development of depression: (1) genetics, which can contribute to the inheritability of depression from parent to offspring, (2) biochemistry, which can result in varying levels of neurochemicals that add to the symptoms of depression, (3) personality, which can cause those with a negative outlook on life or low self-esteem to be predisposed to depression, and (4) environment, which can influence depression through external factors such as poverty, neglect, or abuse (American Psychiatric Association, n.d.; National Institute of Mental Health, 2018).

Though the usual onset of depression is in adulthood, adolescent depression is becoming increasingly common (The National Institute of Mental Health, 2018; Twenge, 2020). Nationally, depression rates in adolescents have

been on an upward trend; between 2005 and 2014, Major Depressive Episodes rose from 8.7% to 11.3% in adolescents (12-17) versus 8.8% to 9.6% in young adults (18-25) (Mojtabai et al., 2016). A 2017 survey showed that approximately 3.2 million adolescents between 12 and 17 in the United States had at least one major depressive episode, which represented 13.3% of all adolescents in the USA (The National Institute of Mental Health, 2019). This makes depression one of the most concerning medical illnesses young people face today. Depression can have significant impacts on long-term mental health as childhood and adolescent depression can lead to persistent and recurring affective disorders in young adulthood (Dunn & Goodyer, 2006). Furthermore, suicide, the most concerning consequence of depression, has become increasingly frequent (Curtin, 2020). "Suicide is the second leading cause of death for children, adolescents, and young adults age 15-to-24-year-olds. The majority of children and adolescents who attempt suicide have a significant mental health disorder, usually depression" (American Academy of Child and Psychiatry, 2018). Thus, this life-threatening possibility further demonstrates the critical importance of analyzing potential treatments for depression.

Despite the increasing rates, more than half of adolescents with depression in the USA did not receive any form of treatment (National Institute of Mental Health, 2019). In their qualitative study, Wisdom et al. (2006) suggested that adolescents may experience pressure to "fit in" and bury their depressive symptoms to stay "normal", which indicates that a stigma surrounds depression. They found that adolescents may perceive depression as a form of weakness or illness that they do not want to be associated with, and, as a result, not seek treatment. Other factors influencing the likelihood of pursuing treatment include parental influences and beliefs, suspicion about prescribed depression medications, and confidentiality concerns (Wisdom et al., 2006). More logistical barriers include the high cost of traditional treatments and the lack of qualified healthcare professionals (Reangsing et al., 2021). In recent decades, one non-pharmaceutical treatment has become more widely recognized for its cost-effectiveness and quality of treatment, music therapy (Algoodkar & Sunitha, 2019).

Limitations in the Research on Adolescent Depression

Many of the sources discussed in this section had a small sample size, which limited the statistical significance and generality of their results (Dunn & Goodyer, 2006; Wisdom et al., 2006). Second, there was wide variability in the samples collected in the studies that may have made it difficult to study a particular factor or aspect of depression in isolation (Mojtabai et al., 2016; National Institute of Mental Health, 2019; Wisdom et al., 2006). Third, the studies had low-response or follow-up rates, which may lead to a lack of a strong correlation or generalizability (Dunn & Goodyer, 2006; National Institute of Mental Health, 2019). Finally, a widely accepted limitation of these studies is the reliance on self-reports that may lead to reduced credibility and validity in the responses due to recall bias and discomfort with exposing confidential information (Dunn & Goodyer, 2006; Mojtabai et al., 2016; National Institute of Mental Health, 2019; Wisdom et al., 2016). Additionally, some adolescents who participated in these studies may not have accurately communicated their depressive symptoms or chose not to disclose them (Wisdom et al., 2006). All of these limitations should be taken into consideration when evaluating the research regarding the background and context of adolescent depression in the USA.

Traditional Treatment for Depression

Currently, a variety of strategies is employed to treat depression, with the most popular treatments being pharmacotherapy (medication) and psychotherapy, which can be used independently or together (Mayo Clinic Staff, 2018). Pharmacotherapy treatments include antidepressants, anti-anxiety medications, or stimulants, which aim to balance neurochemicals associated with depression (National Health Service, 2018; National Institute of Mental Health, 2016). According to the National Institute of Mental Health (2016), the most commonly used pharmaceuticals are antidepressants, which have varying effects on patients. While effective for some, they may lead to adverse side effects including nausea, weight gain, diarrhea, and problems with sleep (National Institute of Mental Health, 2016).

General psychotherapy, on the other hand, is an effective and cost-effective form of treatment that has promising effects: increasing a patient's awareness of their thoughts, helping them understand factors contributing to their depression, and increasing control in their life (American Psychological Association, 2010; Leichsenring et al., 2006). A specific type of psychotherapy, cognitive-behavioral therapy (CBT) is an evidence-based intervention that combines cognitive and behavioral interventions (Leichsenring et al., 2006; March et al., 2007). In their literature review, Leichsenring et al. (2006) described how the cognitive aspect focuses on helping patients become cognizant of their thoughts, situations, and symptoms, while the behavioral aspect aims to help patients learn how to alter their behavior according to conditioning models to address their problems. Ultimately, the authors indicated that the purpose of CBT is to allow individuals to use their learned skills to directly tackle and alleviate symptoms of their mental disorders through collaboration and interaction with a qualified therapist.

Regarding efficacy, the studies included in Leichenring et al. (2006) indicated that CBT may not be effective in alleviating depressive symptoms in the long term. Furthermore, the studies on psychotherapy did not practice universal forms of treatment (they did not use the same models); thus, efficacious results are difficult to generalize. Researchers have also demonstrated that antidepressants may not be as effective as they are often thought to be — possibly even exaggerating the symptoms of depression (Moncrieff & Kirsch, 2005; Pigott et al., 2010).

Antidepressants and CBT are the most commonly used treatments for adolescents with depression (Parquet, 2017). Axelson and Birhamer (2001) suggested that pharmacotherapy and CBT might be effective for pediatric depression and comorbid anxiety. However, Bradley et al. (2009) noted that adolescents seem to prefer psychotherapies to antidepressants, and the National Institute of Mental Health (2016) advised using medications only as a last resort for severe forms of depression if other therapies do not work. Furthermore, another disadvantage of pharmaceutical treatment is that antidepressants can increase suicidal ideations in adolescents, particularly during short-term treatment (National Institute of Mental Health, 2018).

Cook et al. (2017) described how evidence-based psychotherapies, including the most common one, CBT, have their limitations. They tend to base their protocols on controlled trials, which are not completely reflective of the individual needs of adolescents, especially those of minority groups or those with comorbidities. Moreover, they suggested that due to the scientific rigor required for this practice, some levels of evidence become unattainable, and the clinical knowledge of professionals becomes ignored. Consequently, adolescents may lack access to the most suitable form of treatment for them and feel neglected.

Taken together, while these traditional forms of treatment are efficacious to some extent in treating depression, prominent limitations of the most common ones, pharmacotherapy and psychotherapy, necessitate the consideration of an alternative option for treatment. Alternatively, music therapy has been shown to significantly reduce symptoms of major depression and alleviate the symptoms of comorbidities when used in conjunction with these traditional forms of treatment (Aalbers et al, 2017, Kamioka et al., 2014; Stegemann et al., 2019).

Limitations of the Research on Traditional Treatments for Adolescent Depression

Archer et al. (2012), Leichsenring et al. (2006), Moncrieff & Kirsch (2005), and Pigott et al. (2010) conducted meta-analyses and/or reviews. They noted a lack of literature in their respective research areas, a considerable lack of quality in the studies, a lack of standardization in measurement methods and collection, a failure to report negative results, and a sizable amount of bias. All of these limitations should be considered when evaluating the efficacy of traditional treatments for adolescent depression.

Music Therapy Treatments

Music Therapy versus Music Medicine

In the field of music therapy research, some studies make use of a licensed music therapist, while other studies do not (e.g., Eren, 2015; Jasemi et al., 2016; Porter et al., 2016; Shuman et al., 2016). Some literature uses the term "music

therapy" to classify the former and the term "music medicine" to classify the latter (Bradt et al., 2014; Gold et al., 2011).

Music therapy differs from music medicine in important ways. For instance, in music therapy, the therapist-client relationship is crucial to the client's progress. The therapist helps improve the client's health and attain the client's personal aspirations by forming a therapeutic relationship and addressing emotional, social, cognitive, and behavioral needs (Raglio et al., 2015). If an intervention does not have this therapist-client relationship, even if it involves other healthcare professionals, it does not qualify as music therapy, but is instead considered music medicine (Gold et al., 2011; Leubner & Hinterberger, 2017). Furthermore, music therapy is defined as a process, where therapists are trained to improve the client's health by using music as a tool instead of as a passive intervention. Music medicine, however, does not include a "systematic therapeutic process" (Bradt et al., 2014). While music medicine does not require active interaction from the client, in a typical music therapy session, patients have the opportunity to take part through dialogue and active music-making (Rafieyan & Ries 2007). Interestingly enough, in a meta-analysis, Bradt et al. (2014) found that there was not a significant difference in the efficacy of both treatment types, although participants tended to prefer music therapy. This suggests that music has inherent strong therapeutic qualities.

The American Music Therapy Association (AMTA) clearly defines music therapy as requiring "a credentialed professional who has completed an approved music therapy program" (American Music Therapy Association [AMTA], n.d.-a). Any intervention outside this definition would be classified as music medicine. Zanders (2018) makes an accurate comparison when addressing the dissimilarity between the two by stating, "just because going to a music concert may be therapeutic, it does not make it therapy" (p. 219). For this review, studies that use both music therapy and music medicine are included. References to both at the same time are typically referred to as "music interventions", and studies with ambiguous terminology are classified as music therapy.

History of Music Therapy

Music therapy is a clinical and evidence-based practice that draws on the theory that music can have therapeutic effects (AMTA, n.d.-a). Throughout history, music has been recognized in various cultural contexts for its rehabilitative capacity and effectiveness in addressing the various psychological, behavioral, and physiological needs of individuals, according to the AMTA (n.d.-b).

Scholars including Plato and Aristotle (AMTA, n.d.-b) recognized music as a form of healing millennia ago. Meymandi (2009) stated, "Greek physicians used flutes, lyres, and zitters to heal their patients. They used vibration to aid in digestion, treat mental disturbance, and induce sleep… Ancient Egyptians describe musical incantations for healing the sick" (p. 43). Yet, music therapy was only explicitly referred to in 1789 (AMTA, n.d.-b). More light was shed on this newly recognized field with the first record of music therapy intervention and music therapy-related experiments in the early 1800s (AMTA, n.d.-b). However, the AMTA clarifies that it was not until the mid-1900s that there was any notable development of music therapy as a professional field (n.d.-b). With the contribution of E. Thayer Gaston, often known as the "father of music therapy", and others, music therapy flourished in terms of education, funding, and popularity (AMTA, n.d.-b). In 1998, the AMTA was formed for "the advancement of education, training, professional standards, credentials, and research in support of the music therapy profession" (AMTA, n.d.-c). Since then, multitudes of studies have been conducted to better understand the efficacy of music therapy. Altogether, through centuries of development, music therapy has evolved into an effective treatment for depression.

Different Types of Music Therapy

In the field of music therapy, there are two primary types of treatment techniques: passive music therapy and active music therapy (Prakash, n.d.). Prakash states that passive music therapy, also referred to as receptive music therapy, is defined as an intervention where individuals listen to live or recorded music as a form of therapy, with no discussion or active participation. Aalbers et al. (2017) states that the purpose of passive music therapy is typically to create

certain moods, encourage relaxation, or decrease anxiety through silent or verbal response to the music. They indicated that passive music therapy is mostly influenced by humanistic, cognitive-behavioral, or psychodynamic beliefs. In contrast, active music therapy is defined as an intervention that actively engages clients through various participatory activities, such as singing, music composition, and instrument playing (Aalbers et al., 2017). They also suggested that the purpose of active music therapy is to help patients express and ultimately better understand their thoughts and emotions, elevate their self-esteem, and reduce stress and anxiety. Passive and active music therapy are often used together in treatment to target all the needs of patients (Aalbers et al., 2017).

Neurologically, passive music therapy engages the amygdala, the thalamus, and the auditory cortex (Prakash, n.d.). In addition to these areas, active music therapy also stimulates the cerebellum, basal ganglia, and cortical motor area (Prakash, n.d.). While there is a considerable lack of literature on direct comparisons between the efficacy of active and passive music therapy, research suggests the optimal type of therapy is dependent on the individual, a statement that drives music therapy (Aalbers et al., 2017).

Music Therapy with Adolescents

Music therapy with adolescents is a more dynamic experience compared to its use with other age groups. Since adolescents undergo changes in both their physical and mental states, it is important to administer music therapy in a way that can accommodate their nature (McFerran, 2010).

The choice of music plays a significant role in capturing the attention and prompting the self-reflection of adolescents. Music that emphasizes the idea of youth culture and self-expression, such as rock and pop music, are popular genres for adolescents (Tervo, 2001). However, it is important to note that Tervo's (2001) study is relatively dated and based on adolescents in Finland, which may not completely reflect the preferences of adolescents in the USA. In fact, recent data suggests that among adolescents between 16 and 19 in the USA, pop and *hip hop* are the most popular music genres (Statista Research Department, 2021). Regardless, the choice of music is essential in helping the music therapist fully understand the individuality of each adolescent, their connection to and preference for certain types of music, and the cultural and social context that they function in to better tailor their music therapy experience and address their needs (Halverson-Ramos et al., 2019).

In addition to the type of music, there are other considerations as well. Practically speaking, music therapy sessions for adolescents should be routine, long-term, and rigorous to ensure beneficial outcomes and establish a stable connection with the adolescent (Tervo, 2001). It is also suggested that music therapy should be performed in group sessions to encourage and bolster social connections between adolescents and their peers (Halverson-Ramos et al., 2019). Furthermore, adolescents may be defensive at first when it comes to intervention. Therefore, tremendous attention, support, and praise from the music therapist and others are one of the most instrumental aspects in bringing out energy within the adolescent (McFerran, 2010).

Finally, a significant difference between music therapy with adolescents and other age groups is the purpose of music therapy for each individual. With adolescents, music therapy intervention often addresses goals related to self-regulation, coping skills, self-expression, and social interaction on top of treating the adolescent's specific problem (Halverson-Ramos et al., 2019). The common techniques in music therapy used to address these goals are listening to music, lyrical analysis, musical re-creation, improvisation, and songwriting. These tools of music therapy can improve mental and behavioral problems in adolescents across various empirical studies (e.g., Albornoz, 2011; Hendricks et al., 1999; Porter et al., 2017; Shuman et al., 2016).

Efficacy of Music Therapy

Music therapy can be a suitable option for quality care, regardless of context (Wakim, et al., 2010). The literature extensively demonstrates the efficacy of music therapy in the "diminishing of pain, agitation, disruptive behavior, depression and improving communication and quality of life" across various populations and contexts (Popa, 2015,

p. 1062). For example, Gutgsell et al. (2013) show that music therapy can significantly reduce pain in palliative care patients. Aalbers et al., (2017) demonstrate that music therapy can effectively treat depression. Lim et al. (2013) and Thaut et al. (2009) indicate that music medicine and therapy respectively can help develop language and speech ability in stroke patients and traumatic brain injury patients. Music interventions have also contributed to the improvement of global, social, cognitive, and behavioral functioning in severe cognitive and neurological disorders including, but not limited to depression, anxiety, dementia, schizophrenia, sleeping disorders, autism, stroke, multiple sclerosis, Parkinson's Disease, and Alzheimer's (Kamioka et al., 2014; Khyzhna & Shafranska, 2020; Leggieri et al., 2019; Mahdipour & Nematollahi, 2012; Matthews, 2015; Raglio et al., 2015). Music therapy has been well received by most patients in several circumstances and has no known harmful repercussions (Kamioka et al., 2014). However, in their meta-analyses, Aalbers et al. (2017), Kamioka et al. (2014), Leggieri et al. (2019), discussed how the lack of studies led to insufficient data and how the lack of standardization in the methods in the studies they included led to the lack of generalizability of the results to a larger population. These challenges they describe are unfortunately a prevalent issue across the field of music therapy that, to some extent, compromises the evidence of music therapy's efficacy.

Cost-Effectiveness of Music Therapy

The cost-effectiveness of virtually any treatment should be considered as a factor of its overall efficacy; if the patient cannot afford it, then it is not of value to that patient. Though research is relatively scarce regarding the cost-effectiveness of music therapy for adolescents with depressive symptoms, there are data from other populations that suggests that music therapy is an economical treatment. In a cost-benefit ratio analysis of a small sample of hospice care patients, Romo & Gifford (2007), found that "the total cost of patients in music therapy was $10,659 and $13,643 for traditional care patients, resulting in a cost savings of $2984. The music therapy program cost $3615, yielding a cost-benefit ratio of 0.83. When using cost per patient day, the cost-benefit ratio is 0.95" (p. 353). This analysis clearly shows significant cost reductions in using music therapy as opposed to traditional treatment despite being difficult to generalize due to the small sample size. Furthermore, after conducting empirical studies on patients diagnosed with cancer and depression, Jasemi et al. (2016) and Algoodkar and Sunitha (2019) claimed that music therapy is an inexpensive and simple treatment method — though they do not offer much detail. Despite the limited evidence to support this, the existing research and findings in the field indicate that music is financially beneficial to patients compared with other treatment types.

Efficacy of Music Therapy on Depression

A plethora of studies regarding music therapy focuses on its efficacy in improving mood disorders such as depression. The majority of studies reviewed indicate that music therapy and music medicine are effective in ameliorating depressive symptoms and improving overall quality of life (Raglio et al., 2015). In a variety of cohorts, including heart surgery patients, older adults, substance abusers, adolescents with psychiatric disorders, terminally-ill cancer patients, and depressed women, music therapy has been proven to be beneficial in elevating mood and emotional states or alleviating depressive symptoms (Albornoz, 2011; Hamid & Biat, 2019; Mahdipour & Nematollahi, 2012; Ramirez et al., 2018; Shuman et al. 2016; Zhao et al., 2016). For nursing home residents, music therapy has been shown to play a crucial role in the cultivation of an encouraging and stimulating environment to catalyze improvements in emotional well-being (Mohammadi et al., 2011). For heart surgery patients, music therapy creates a soothing environment which can lead to a decrease in depression-related comorbidities such as stress and anxiety (Mahdipour & Nematollahi, 2012). Leubner and Hinterberger (2017) concluded in their meta-analysis that across multiple age groups, music therapy could improve quality of life and decrease symptoms of depression. Logistically speaking, Jasemi et al. (2016) suggested that music therapy is a cost-effective, convenient, and reliable form of treatment for both depression and its comorbidity, anxiety. However, it was unclear whether their study examined music therapy or music medicine. Regardless, music therapy overall demonstrates its efficacy both in terms of the treatment and logistics.

Neurological Effects

Although music therapy has demonstrated significant efficacy in improving external behavioral and observable emotional changes, understanding the mechanisms that music therapy arouses within the brain is also crucial to gaining a full comprehension of the viability of this treatment. Breakthroughs in the past few decades have shown that the brain is characterized by plasticity, or the ability to restructure synaptic connections due to environmental and internal factors (Raglio et al., 2015). In certain instances, this may lead to the development of neurological disorders including depression. Over the years, studies on music intervention have shown efficacy from neurochemical, psychological, and rehabilitative standpoints to improve some of these neurological disorders (Raglio et al., 2015). From a neurochemical standpoint, music stimulates almost all limbic and paralimbic structures that regulate emotion (amygdala, hippocampus, nucleus accumbens, etc.) which may act atypically in patients diagnosed with depression (Koelsch, 2010; Koelsch, 2014; Raglio et al., 2015). From a psychological standpoint, music, particularly active music therapy, engages various social areas in the brain that strengthen interaction, relationships, and social solidarity. Lastly, from a rehabilitative standpoint, music induces the proper functioning and regulation of motor areas in the brain, which then results in contentment and positive mood in patients.

Music's aptness in engaging the brain has been shown to improve patients' social, neurological, motor, cognitive, and emotional skills (Raglio et al., 2015). In a study where participants listened to rock music for 23 minutes, the researchers noted that the right lateral EEG activity was minimized for female adolescent patients diagnosed with chronic depression (Field et al., 1998). Since high levels of right lateral EEG activity are associated with negative mood and emotions, the study reveals the notable efficacy of music interventions for reducing depressive symptoms. Even though the authors noted that the visible and self-reported mood of the patients at the end of the treatment did not change, the EEG results indicated that music therapy reduced the neurological effects of depression. In sum, the neurological perspective adds more concrete evidence to the claim that music therapy is effective.

Socioemotional Effects

Music therapy is a form of psychotherapy that brings meaning to life by creating an artistic experience. This psychotherapeutic treatment can allow the participant to make strides towards behaving and thinking in a new way as a result of getting satisfaction from their music therapy sessions. In addition, music therapy has been shown to improve aspects relating to mood including emotional communication, self-assurance, and interpersonal skills (Raglio et al., 2015). Specifically for elderly cohorts, according to Mohammadi et al. (2011), music therapy can act as an instrument for emotional catharsis, and subsequently allow them to cope with depression. Two separate studies, an EEG-based analysis on palliative care patients and a semi-experiment on depressed women note that music therapy or medicine respectively can increase positive emotions such as happiness (Hamid & Biat, 2019; Ramirez et al., 2018). This is likely because music can "induce strong emotions," particularly positive emotions (Ramirez et al., 2018, para. 1).

Music therapy can improve social skills as well by directly influencing personality and emotions without first being processed by cognition (Eren, 2015). Active music therapy particularly, allows patients, regardless of age, to express their emotions, develop a deeper understanding of their emotional and socio-emotional issues, and strengthen their emotional competencies (Aalbers et al., 2017). The active techniques use a variety of musical activities, such as musical improvisation or composition, to build a musical bond between the therapist and patient as they communicate. Passive techniques involve the patient listening or inactively responding to music to stimulate certain moods and emotions, induce relaxation and reflection, or reduce stress and anxiety. Therefore, music therapy has strong positive effects on socioemotional functioning.

Behavioral Effects

Symptoms of depression are often very nuanced, individualized, and difficult to differentiate from sadness (Maj, 2011). However, recognizable symptoms include anxiety (one of the most pronounced comorbidities that is discussed later), aggression and anger, insomnia, reduced self-esteem, and the development of eating disorders (Mayo Clinic Staff, 2018). Music therapy has demonstrated efficacy in alleviating the various symptoms and comorbidities of depression by positively influencing individuals in ways that benefit both their physical and emotional well-being. For specific cohorts such as dementia patients and pregnant women, music therapy has been shown to reduce anxiety, irritability, aggression, and stress (Chang et al., 2008; Langhammer et al., 2019). In addition to reductions in anxiety and stress, Hwang and Oh (2013) found that music therapy reduced anger in alcoholic-dependent participants with depression. Hakvoort et al. (2013) showed that music therapy enhanced anger management skills and eliminated aggressive behaviors in forensic psychiatric patients. Choi et al. (2010) also noted that the use of music therapy is correlated with both a significant decrease in aggression and an increase in self-esteem for aggressive children. Other studies point to the effectiveness of music interventions in promoting self-esteem in young adults with depression and stressed adolescents (Sharma & Jagdev, 2012; Wu, 2002). Chen et al. (2015) determined that for male prisoners, improvements in self-esteem in addition to reductions in depression and anxiety were most prominent among the younger population, thus supporting the substantial effect music therapy can have for adolescents with depression. Several researchers, largely using meta-analyses, identified passive music therapy and music medicine, particularly listening to calming music, as a useful tool in improving sleep quality and minimizing insomnia symptoms (Amiri et al., 2019; Chang et al., 2008; Feng et al., 2018; Harmat et al., 2008; Jespersen et al., 2015; Levin, 1998; Wang et al., 2014). Finally, Pasiali et al. (2020) and Bibb et al. (2015), concluded that music therapy reduced anxiety and helped with self-esteem problems among individuals with eating disorders. Lejonclou and Trondalen (2009) suggested that this is likely a result of the musical experience allowing participants to express their inner selves free of shame. As Leubner and Hinterberger's (2017) meta-analysis concisely confirmed, music interventions have beneficial effects that improve self-esteem, confidence, motivation, anxiety, and sleep concerns. Overall, the myriad benefits that music therapy is capable of when addressing the behavioral effects of depression are significant.

Efficacy of Different Therapies to Improve Depression

According to corroborating studies across different contexts, music therapy is highly effective when used in conjunction with traditional treatments such as pharmacotherapy. Music therapy has a greater effect on reducing depressive symptoms than traditional treatment alone (Aalbers et al., 2017; Erkkilä et al., 2011; Shiranibidabadi & Mehryar, 2015). In some cases, the combination of music therapy (or music medicine) and traditional treatment has also been shown to reduce anxiety, a common comorbidity of depression (Erkkilä et al., 2011; Shiranibidabadi & Mehryar, 2015).

Concerning music therapy types, active and passive music therapy differ in fundamental ways. However, corroborating evidence shows that their effect on depression is similar (Aalbers et al., 2017). Active music therapy, specifically improvisational music therapy, has been shown to have a clinically significant effect on reducing clinical depression for substance abusers (Albornoz, 2011). Engaging with music in the form of dancing, clapping, or playing an instrument has also been shown to improve motor function, regulation, and feelings of self-control (Ghasemtabar et al., 2015). This additional engagement with music during therapy sessions can improve the rehabilitative process by promoting emotional regulation (Mohammadi et al., 2011; Raglio et al., 2015). However, some researchers observed that active music participation could cause high initial anxiety, likely because participants may at first feel uncomfortable and embarrassed about engaging in music-making methods (Carr et al., 2017). Therefore, it is crucial for music therapists to provide support and meet individual needs while employing active music therapy. Passive, or receptive, music therapy has also been shown to reduce depressive symptoms. Even though it may produce a quicker response from the patient, the effect may be less potent than that of active music therapy (Atiwannapat et al., 2016).

In other words, passive music therapy may work faster, but active music therapy has a more significant therapeutic effect (Atiwannapat et al., 2016).

Treating Anxiety as a Comorbidity of Depression

Anxiety is a prevalent comorbidity of depression in which an individual is triggered in response to a perceived threat (Leubner & Hinterberger, 2017). Thus, it is pertinent to examine the efficacy of music therapy as a treatment for anxiety. Leubner and Hinterberger (2017) suggest in their meta-analysis that music therapy is associated with alleviated symptoms of anxiety, though they express concern that the studies included in their meta-analysis did not have a standard interpretation of "anxiety disorders." Similarly, Aalbers et al. (2017) conducted a meta-analysis and determined that music therapy used in parallel with traditional care significantly reduced anxiety symptoms, although the findings were of low quality. Across various cohorts, music therapy has demonstrated effectiveness in alleviating anxiety as a comorbidity of depression. For adult and adolescent substance abusers, music therapy, along with traditional treatment, has demonstrated efficacy in reducing anxiety as a depressive symptom (Albornoz, 2011). For nursing home residents, after 10 weeks of music therapy, results show that anxiety and depression were both significantly reduced (Mohammadi et al., 2011). Cancer patients also experienced a significant decrease in both depression and anxiety following music medicine sessions (Jasemi et al., 2016). Music therapy also reduced both anxiety and depression as comorbidities of obsessive-compulsive disorders (Shiranibidabadi and Mehryar, 2015). Finally, Erkkilä et al. (2011) find that music therapy accompanying traditional treatment is more effective than traditional treatment alone in alleviating anxiety symptoms in adults with depression.

Efficacy Regarding Practice Elements of Music Therapy as a Treatment for Depression

Duration

Much of the literature on using music therapy to treat depression examined treatments that were 8 weeks long or had 12 therapy sessions (Algoodkar & Sunitha, 2019; Atiwannapat et al., 2016; Castillo-Pérez et al., 2010; Chen, 1992; Hanser & Thompson, 1994; Hendricks et al., 1999; Leubner & Hinterberger, 2017). Tang et al. (2020) suggest that shorter and medium-length treatment periods between 1 to 12 weeks may be more effective than longer interventions, thus, most studies fall into the ideal range. The length of each session was approximately 1 hour long (Algoodkar & Sunitha, 2019; Atiwannapat et al., 2016; Chen, 1992; Erkkilä et al., 2011; Hanser & Thompson, 1994; Hendricks, 2001; Leubner & Hinterberger, 2017; Zerhusen et al., 1991). However, some of the studies varied in length and duration, while still falling within the 30 minutes to 2-hour duration (Albornoz, 2011; Atiwannipat, 2016; Harmat et al., 2008; Hendricks, 2001; Jasemi et al., 2016; Mohammadi et al., 2011; Radulovic, 1996; Ramirez et al., 2018).

Individual vs Group Sessions

Both individual and group music interventions provide patients with appropriate environments to alleviate depressive symptoms. Leubner and Hinterberger (2017) found no significant differences between the therapeutic formats. Studies have found that individual music therapy in addition to traditional care is effective in ameliorating depressive symptoms (Erkkilä et al., 2011; Ramirez et al., 2018). Furthermore, individual music therapy effectively complements traditional care when regularly used to improve participants' motivation. (Gold et al., 2013; Leuber & Hinterberger, 2017; Wheeler et al., 2003). Group sessions, on the other hand, center on social interaction and improving interpersonal skills (Leubner & Hinterberger, 2017). Research demonstrates that group music therapy can improve individuals' communication, social skills, and self-expression (Leubner and Hinterberger, 2017; Shuman et al., 2016; Wheeler et al. 2003). Moreover, Chu et al., (2014) point to the practicality of using group therapy as an unobtrusive and cost-effective form of treatment for depressed older adults with dementia. However, when comparing individual and group

music intervention, it appears that individual music therapy is a more effective treatment format because of the increased intimacy and individualization of the intervention (Aalbers et al., 2017).

Limitations of the Literature on Efficacy of Music Therapy to Treat Depression

Certain limitations warrant a statement here when drawing conclusions about the efficacy of music therapy on depression. For instance, most studies mentioned above conclusively agree that more methodological rigor, larger sample-sizes, representative demographics, high-quality trials evaluating efficacy, long-term observations, and in general, accounting and testing for more variables should be factored into future studies (Albornoz, 2011; Algoodkar & Sunitha, 2019; Amiri et al., 2019; Atiwannapat et al., 2016; Bibb et al., 2015; Carr et. al., 2017; Chu et. al., 2014; Jasemi et al., 2016; Leubner & Hinterberger, 2017; Mohammadi et al., 2011; Raglio et al, 2015.;_Shiranibidabadi & Mehryar, 2015; Shuman et al., 2016; Wheeler et. al., 2003; Zhao et al., 2016). Particularly, when discussing the overall efficacy of music therapy, we must be careful in concluding that many different cohorts of people benefit from music therapy. Although the effects were generally positive, effectiveness varied based on the individual (Shuman et al., 2016; Leubner & Hinterberger, 2017). Several studies also expressed concern over the lack of statistically significant differences when measuring the efficacy of music therapy (Chang et al., 2008; Hwang & Oh, 2013; Wang et al., 2014). Another concern is the inconsistency in studies regarding the presence (or lack thereof) of a licensed music therapist. This section includes studies that utilize both music medicine and music therapy (e.g., Jasemi et al., 2016; Algoodkar & Sunitha, 2019). Finally, all studies in this section possessed a lack of blinding for participants due to the nature of music therapy as an intervention.

Efficacy of Music Therapy on Adolescents with Depressive Symptoms

Music therapy can be considered a safe and effective intervention in alleviating symptoms and enhancing well-being in children and adolescents. Specifically, researchers have found that both music therapy and music medicine reduce depressive symptoms in children and adolescents with behavioral and emotional problems, including depression (Geipel et al., 2018; Naylor et al, 2010; Parquet, 2017; Porter et al., 2017; Rahmani et al., 2016; Shuman et al. 2016; Stegemann et al., 2019). Positive effects indicating improvement in motivational and emotional competencies of people with depression were also observed (Hendricks et al., 1999; Porter et al., 2017; Stegemann et al., 2019). Adolescents experienced significant increases in hope and subjective happiness with music therapy intervention (Hendricks et al. 1999; Kwok, 2018). Additionally, Hendrick et al. (1999) conducted a study on the effectiveness of music therapy on high school students and suggested that group music interventions were significantly more effective than cognitive-behavioral therapy. It is also important to note that according to Stegemann et al. (2019), almost none of the systematic reviews concerning music therapy have reported any harmful effects of music therapy on adolescents.

Emotional and Behavioral Effects

Music therapy and music medicine give adolescents with depressive symptoms the opportunity to improve their quality of life and socialization in addition to reducing depressive symptoms and anxiety (Hendricks et al.,1999; Porter et al., 2017; Stegemann et al., 2019). For instance, Shuman et al. (2016) have documented mood improvements in adolescents in a spectrum of psychiatric disorders through music therapy. More specifically, Stegemann et al. (2019) indicated that music interventions improved adolescents' mood recognition, regulation, and awareness, which suggests that it can help adolescents perceive their depressive state and take conscious steps to alleviate it. Hendricks et al. (1999) added that music therapy fosters positive emotions in adolescents with depressive symptoms, thus, combating the negative emotions and mood states associated with depression. Furthermore, researchers have identified music medicine as a successful means of improving self-esteem, whether for adolescents with depression or general emotional disturbances (Sharma & Jagdev, 2012). However, Porter et al. (2017) noted that the effects of their study were temporary and minimal, meaning the results are not decisive enough to warrant major changes in the field (Porter et

al., 2017; Sharma & Jagdev, 2012). Given the evidence, music therapy and medicine can be assumed to be effective in creating a positive experience for adolescents.

In addition to increasing positive effects, music therapy reduced the negative consequences of depressive symptoms. Geipel et al. (2018) suggested that music-based interventions decrease internalizing symptoms in children and adolescents. These are symptoms that are typically not expressed outwardly but stem from depression and anxiety (Brumariu & Kerns, 2010). Naylor et al. (2010) found that adolescents suffering from grief, which possesses certain similarities to depression, experienced a reduction in internalizing symptoms related to coping through music medicine, although this was not consistent across all measurement tools. Regarding behavioral effects, they added that music interventions correlate with a decrease in problematic behavior associated with grief and distress. Hilliard (2007) identified similar results, finding that children with grief were alleviated of symptoms to some extent through music therapy; symptoms include withdrawal, disruptive behavior, distress, physiological effects, poor academic performance, mood or behavior swings, and emotional problems.

Music Therapy Compared to Traditional Treatment for Adolescents with Depressive Symptoms

The efficacy of music interventions is comparable to that of traditional forms of treatment for depression, including pharmacotherapy, collaborative care, occupational therapy, electric-convulsive therapy (ECT), hospitalization, and psychotherapy, and can be used in conjunction with them to effectively alleviate depressive symptoms across all age groups (Aalbers et al., 2017; Mayo Clinic Staff, 2018). Hendricks et al. (1999) suggested that music therapy may be more effective than traditional treatments in reducing depressive symptoms in adolescents. Rahmani et al. (2016) came to the same conclusion using music and art therapy for Iranian adolescent girls with depression. Instead of suggesting that music therapy can be used independently as a substitute for traditional treatment, many propose that music therapy and medicine enhances the outcomes of traditional treatment when used in conjunction (Aalbers et al., 2017; Albornoz, 2011; Porter et al., 2017; Stegemann et al., 2019). This is likely because music therapy adds a positive, interactive form of treatment that can elevate the mood of adolescents suffering from depression while minimizing the negative side effects of traditional treatments.

Limitations of the Literature on the Efficacy of MT on Adolescents with Depressive Symptoms

Several limitations were common among the studies and should be noted. First, most studies used a self-reported measurement, which can reduce the reliability of the results and introduce possible participant bias (Hendricks, 1999; Parquet, 2017; Porter et al., 2017; Rahmani et al., 2016; Sharma & Jagdev, 2012). Second, there were problems with the samples of numerous studies, including small sample sizes and samples containing participants of a specific geographic location or demographic (Erkkilä et al., 2011; Hendricks et al., 1999; Hilliard, 2007; Kwok, 2018; Parquet, 2017; Porter et al., 2017; Rahmani et al., 2016; Sharma & Jagdev, 2012; Stegemann et al., 2019). We believe that these limitations with the samples may lead to difficulty in the ability to generalize the results of the studies. Third, there was a significant lack of standardization among the studies in their definitions of music therapy and depression, in measures, and in methodology (Aalbers et al., 2017; Geipel et al., 2018; Hendricks et al., 1999; Kwok, 2018; Naylor et al., 2010; Parquet, 2017; Shuman et al., 2016). Lastly, some studies deviate from the focus of our review, such as not addressing the adolescent population or depression specifically but were important to include (e.g., Aalbers et al., 2017; Hilliard, 2007; Naylor et al., 2010; Sharma & Jagdev, 2012; Shuman et al., 2016; Stegemann et al., 2019;). Many studies conducted their review on a wide range of physical and mental illnesses, which made it difficult to consider whether a study's effectiveness specifically applies to depression. In response to some of these limitations, several authors critiqued themselves and provided implications for future studies based on the lacking aspects of their studies, such as the need for more studies in inclusive music settings (Porter et al., 2017; Stegemann et al., 2019).

Conclusion

Throughout this comprehensive review, we analyzed the literature on music therapy in several contexts to assess the effectiveness of this treatment modality for depressive symptoms, particularly in adolescents. Overall, the existing body of literature on music therapy contributes an expansive range of qualitative and quantitative studies investigating music therapy's effectiveness in treating depressive symptoms and common comorbidities. This range included studies with varied participant demographics, depressive symptoms and comorbidities, measurement scales, treatment formats, study methods, clinical beliefs, and conclusions.

Regarding demographics, despite an attempt to focus on studies that originated from the USA, we realized that there was not enough USA-based research in this area to address our inquiry fully. Thus, we included many studies originating from other countries (e.g., Algoodkar & Sunitha, 2019; Atiwannapat et al., 2016; Chen, 1992; Erkkilä et al., 2011; Hakvoort et al., 2013; Hamid & Biat, 2019; Jasemi et al., 2016; Kwok, 2018; Leubner & Hinterberger, 2017; Mohammadi et al., 2011; Porter et al., 2017; Rahmani et al., 2016; Sharma & Jagdev, 2012; Stegemann et al., 2019).

In our review, some researchers studied the improvement of the symptoms of depression to examine music therapy and music medicine's efficacy. Others studied the improvement of comorbidities and related disorders of depression either in conjunction with or independent from depression (e.g., anxiety, anger and aggression, substance abuse disorders, grief, obsessive-compulsive disorder, internalizing symptoms, and eating disorders) (e.g., Aalbers et al., 2017; Albornoz, 2011; Bibb et al., 2015; Chang et al., 2008; Erkkilä et al., 2011; Geipel et al., 2018; Hakvoort et al., 2013; Hendricks et al., 1999; Leubner & Hinterberger, 2017; Mohammadi et al., 2011; Naylor et al., 2010; Shiranibidabadi & Mehryar, 2015; Stegemann et al., 2019). For example, Algoodkar and Sunitha (2019) solely studied the positive effects music medicine has on alleviating depressive symptoms with almost no reference to comorbidities. On the contrary, Shiranibidabadi and Mehryar (2015) investigated music medicine as a potential treatment for a trio of comorbid disorders: obsessive-compulsive disorder, anxiety, and depression.

Regarding measures represented in the studies reviewed, there was wide usage of multiple self-report scales, which varied on a study-by-study basis. The literature also included meta-analyses, literature reviews, empirical research, academic texts, and other formats.

Some studies used only passive music therapy or active music therapy while others incorporated both into the treatments offered to participants. Additionally, the research community was divided on whether or not music therapy requires the presence of a professional music therapist. Researchers including Jasemi et al. (2016) and Hamid and Biat (2019) disregarded the need for a music therapist whereas researchers including Hendricks et al. (1999) and Aalbers et al. (2017) strictly defined music therapy as requiring a qualified therapist. Some researchers, in an effort to provide comprehensive information, recognized the discrepancy between music therapy and music medicine, but still included both in their reviews or analyses (Kamioka et al., 2014; Leubner & Hinterberger, 2017; Naylor et al., 2010; Raglio et al. 2015; Stegemann et al., 2019; Tang et al., 2020). Furthermore, the definition of depression depended on the researchers. Some studied participants with "depressive symptoms" based on different evaluative scales (e.g., The Beck Depression Inventory, the HAM-A, the MADRS), while others studied patients diagnosed with Major Depressive Disorder.

Among the literature included in this review, several authors concluded that music therapy is an efficacious supplement to traditional treatment (e.g., medication, psychotherapy) rather than a replacement thereof for reducing depressive symptoms and increasing overall well-being (Aalbers et al., 2017; Albornoz, 2011; Atiwannipat, 2016; Erkkilä et al., 2011; Porter et al., 2017; Shiranibidabadi and Mehryar, 2015, Stegemann et al., 2019). In short, despite the overall limitations seen in the literature, our consensus is that music therapy is an effective treatment option for reducing depressive symptoms in adolescents.

Limitations

While this review is comprehensive, several overall limitations should be considered. First, a lack of standardization in the methods, measures, and definitions was a consistent concern in much of the reviewed literature. A major inconsistency was the definition of what qualified as music therapy. Many researchers also expressed concerns over their studies' short durations and suggested the need for observation of long-term effects of music therapy (e.g., Mohammadi et al., 2011; Porter et al., 2017). Furthermore, while some researchers included extremely homogenous groups (e.g., similar age, culture, gender, and depressive symptoms), others studied a broad range of diverse demographics, creating difficulties for us in drawing generalizable and reliable conclusions. In some cases, studies did not directly relate to our thesis (i.e., studies not solely focused on depression) but possessed important information relevant to our inquiry that ultimately led us to include them in our review (e.g., Geipel et al., 2018; Ghasemtabar et al., 2015; Khyzhna & Shafranska, 2020). Overall, we found that there was a lack of research on the efficacy of music therapy on adolescents with depressive symptoms.

Regarding the literature's consensus, while the majority of studies concurred that music therapy is efficacious; some studies acknowledged that there were nonsignificant results and/or negative results (e.g., Leubner & Hinterberger, 2017). These instances of non-uniformity garnered a concern for a decisive conclusion regarding the effectiveness of MT. Second, researcher and participant bias was present in the majority of the studies reviewed due to a lack of blinding, unrepresentative samples, and self-reported results. Third, small sample sizes were a recurring issue as they contributed to the lack of generalizability (e.g., Albornoz, 2011; Hendricks et al., 1999; Mohammadi et al., 2011; Rahmani et al., 2016). Lastly, we observed an inherent problem in the research of music therapy: while research demands standardized measurement scales and therapeutic processes, music therapy demands flexibility to address individual client needs appropriately.

Future Research

Future research should aim to conduct more standardized trials focused on the use of music therapy specifically for adolescents with depressive symptoms without the inclusion of comorbidities (e.g., anxiety, pregnancy, substance abuse, OCD, etc.) to directly investigate the link between depression and music therapy in this cohort. There should be a universal system of standards for defining music therapy, measuring depressive symptoms, and having larger and randomized samples. Furthermore, the cost-effectiveness of music therapy as a treatment should be directly compared to traditional treatments, such as pharmacotherapy and psychotherapy to confirm or refute the effectiveness of using music therapy in monetary terms. Finally, more studies focusing on the efficacy of music therapy alone versus music therapy in conjunction with traditional treatments should be conducted to explicitly compare the efficacy of both.

Implications

Our review of music therapy and its efficacy in adolescents with depressive symptoms provides a fuller picture of the current research in this area, tying together a multitude of studies with various implications. Based on our findings, music therapy can indeed be used as a viable treatment option and should, therefore, be actively implemented for adolescent depression. Since adolescents today are heavily influenced by music and listen to it frequently, the availability of a music therapist could give them access to a more desirable and suitable form of treatment (Council on Communications and Media, 2009). Throughout this literature review, we asserted that music therapy is an evidence-based practice and can be implemented in many contexts, particularly school systems, in hopes of treating adolescents. Currently, counseling programs seen in schools are generally traditional in their approaches to therapy. Implementing music therapy programs that work in tandem with existing counseling programs in schools would be beneficial for students experiencing depressive symptoms (Swanson, 2020). Music therapy has been proven cost-effective, so it would not be detrimental to implement in schools (Romo & Gifford, 2007). Outside of school, music therapy should be promoted as a potential ancillary treatment option for medical professionals (e.g., psychologists, psychiatrists) to

use when treating their adolescent patients with the assistance or direction of a professional music therapist. Moreover, music therapy programs can be created within medical facilities to engage adolescents and effectively treat depressive symptoms and other comorbidities. These suggested actions would help to establish music therapy as a practical and ubiquitous method to treat depression and depressive symptoms. In closing, music therapy can be considered an efficacious supplement and/or alternative for treating general and adolescent depression and should continue to be studied and implemented.

Acknowledgments

We would like to thank our advisor Dr. M. Cherie Clark for guiding us in this project.

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HIGH SCHOOL EDITION
Journal of Student Research

Volume 9 Issue 2 (2020)
AP Research

Meditation for Increased Mindfulness and Memory: An Analysis on the Impact of Meditation on Mindfulness and Working Memory Capacity in High School Students

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ABSTRACT

Zero percent of high school students see anxiety and depression as a "major problem" among their peers (Pew Research Center). Meditation decreases anxiety and stress according to Harvard researchers. Stress and memory are very much connected as a recent study concluded that non-stressed people remember more items on average than stressed people. Although several studies have been done on the impacts of meditation, there has been no research done specifically on the impact of meditation on high school students' working memory. This study utilized a pre-post survey design and a running control group to determine whether mindfulness and working memory capacity increased as a result of a week of daily meditation. Students were randomly assigned to the mindfulness meditation group or to the running control group. Both groups took The Human Benchmark memory test and the Mindfulness Attention Awareness Scale (a Likert scale) before and after a week of meditation or running. The results proved to be significant, showing that mindfulness increased on average by .8 points, while the control only increased by .03 points on average. In addition, memory test scores increased by 40.3% for the meditation group compared to 8.3% for the control group.

Introduction

Meditation has existed since the Vedas around 1500 BCE and remains a vital part of daily life in several cultures (Wynne, 2007). Meditation is a mind and body practice that has been shown to increase calmness and enhance overall well-being (Sedlmeier, 2012). Meditation can be done in a variety of ways, through focusing on one's breath or repeating a mantra. Mindfulness is a state of consciousness attained through one's meditation practice. According to the American Psychological Association (Davis, 2012), mindfulness is: "…a moment-to-moment awareness of one's experience without judgment."

Teenagers are now more stressed than ever before; a 2014 APA's Stress in America™ survey revealed that teen stress rivals that of adults. A recent study from the international science journal, *BMJ Open*, conducted by the Finnish Institute for Health and Welfare found a correlation between stress and lifespan: the more one stresses, the

shorter their lifespan (Härkänen, 2020). Meditation improves emotion regulation, and lessens stress responses according to Harvard researchers (Sevinc, 2019). Therefore, meditation helps us live longer and is especially beneficial for the age group who stress the most: teenagers. In addition to living longer, there are numerous other positive impacts on teens, especially on their brains. Several studies have been done on the impacts of meditation on teens, such as the study conducted by Dianna Quach (2016), professor of psychology at Alliant International University, which found that meditation improved memory in middle schools (Biegel, 2009; Greenberg, 2019; Quach, 2016). However, there has been no research done specifically on the impact of meditation on high school students' working memory.

Literature Review

In addition to decreasing stress and anxiety, a common goal of many is to find happiness in one's life. While happiness is partially determined by factors such as our genes and our evolution, 50 percent of happiness is within our control (Lyubomirsky, 2005). Psychologist William James puts it as "If you can change your mind, you can change your life" (Taylor, 2011). The secret to happiness is as simple as becoming more mindful. Richard Davidson (2003), Professor of Psychology at the University of Wisconsin, found in his research that meditation redistributes the balance between the left and right frontal areas, sparking more left-brain activity and thus positive emotion. High levels of activity in the left frontal area of the cerebral cortex occurred at the same time with feelings of joy, enthusiasm, happiness, alertness, and high energy. Moreover, high levels of activity in the right frontal area coincided with feelings of sadness and anxiety.

M. Ramesh (2013), Professor of Physiology at Melaka Manipal Medical College, conducted a study on the effect of Brahma Kumaris Rajayoga Meditation (BKRM) on positive thinking. The study from the peer-reviewed publication, *The Journal of Clinical and Diagnostic Research*, compared two groups, meditators, and non-meditators, doing BKRM, a type of breathing meditation. The researchers administered the Oxford happiness questionnaire to subjects. Ultimately, they found that BKRM significantly promotes self-satisfaction and happiness in life by increasing positive thoughts notwithstanding of age and experience in one's meditation practice. A similar perspective is found in a study by Daniel Campos (2016), Professor of Psychology at Jaume I University. He examined the relationship between mindfulness skills formed by meditation and happiness. Almost 400 participants took the Self-Compassion Scale-short form (SCS), the Five Facets of Mindfulness Questionnaire (FFMQ), and the Pemberton Happiness Index. He utilized hierarchical regression analysis to determine which particular traits correlated the most with one's measured happiness score. This analysis revealed that two FFMQ components (Observing and Awareness) and two SCS facets (Self-kindness and Common humanity) were statistically significant predictors of happiness. The researchers also found that mindfulness and self-compassion qualities that result from a daily meditation practice are the bridge that connects meditation and happiness.

Anat Shoshani (2013), Professor of Psychology at IDC Herzliya College, highlights the need for a program to help middle school students feel happier. Shoshani discusses how the transition to middle school is very difficult for adolescents, which is evident in their low happiness ratings. A viable solution to improving middle school students' happiness was examined in a study by David Viafora (2015), Professor of Social Work at San Diego State University. He found that many middle school students enrolled in an 8-week meditation course reported feeling less stress and had increased resilience and positive risk-taking.

In another study on the impacts of meditation on students, forty-five African American teenagers were randomly assigned to either a health education group or Transcendental Meditation (TM) group. Dr. Barnes (2003), a professor of psychology at the Georgia Institute for Prevention of Human Diseases and Accidents, Medical College of Georgia, an expert in the field of behavior, led this study. For four months, the TM group meditated for 15 minutes at home and school, while the health education control group engaged in 15-min sessions of health education at school. Students who participated in the TM program missed fewer days of school, had reduced rule infractions and suspensions compared to the control group. This study also found that students were less stressed, meditation decreased negative behavior, and corroborates the previous study.

Another randomized clinical trial was created to examine the impact of the mindfulness-based stress reduction (MBSR) program for 102 high school students with several diagnoses in a psychiatric facility. Dr. Gina M. Biegel and Shauna L. Shapiro (2009), the researchers, are experts in the field of psychology. Compared to control participants who received care as usual at the facility, those in the MBSR program reported fewer symptoms of anxiety, depression, and somatic distress, and improved self-esteem and sleep quality. Additionally, over the 5-month study period, the MBSR group revealed a greater percentage of diagnostic improvement and significant gains in the global assessment of functioning scores relative to controls. This study furthered the work of Barnes (2003) by finding that anxiety and depression were lessened and self-esteem increased.

Building off of the aforementioned study, the authors of *A school-based mindfulness pilot study for ethnically diverse at-risk adolescents* designed a randomized pilot study of a school-based mindfulness program called Learning to BREATHE with a diverse population of at-risk adolescents. Karen Bluth (2015), the lead researcher of this study, is a professor of psychiatry at the University of North Carolina at Chapel Hill and is a certified instructor of mindfulness. Twenty-seven students participated in either a mindfulness course or a substance abuse control class for 50 minutes, once a week, for half of a school year. Students found that the mindfulness class alleviated their stress and lessened their depression and they favored continuing the class.

A randomized controlled study published in *Developmental Psychology* explored the impacts of a 12-week mindfulness-based Kindness Curriculum (KC) on 68 preschool children. The lead researcher of this study was Simon B. Goldberg (2015), a professor of psychology at the University of Wisconsin-Madison and an expert in the field of mindfulness. The KC intervention children revealed significant improvement in their social skills and grades in school compared with their control group counterparts. Researchers discovered that the mindfulness program had a direct positive impact on the preschoolers' health, ability to learn, and cognitive flexibility in contrast to the control group. Moreover, the KC preschoolers who initially scored lower in social abilities and executive functioning surprisingly showed the greatest improvements in social skills compared to the control group. Although research on meditation shows that it helps learning, health, and emotional development, there is a gap in researching meditation's impact on mental development.

Prior research illustrates that meditation may be well suited to reduce anxiety and promote social skills. A study conducted by Jay Beauchemin (2008), professor of medicine at the University of New England, and his team utilized pre and post surveys to look into the feasibility of, feelings toward, and outcomes of a 5-week mindfulness meditation intervention. This study's sample consisted of 34 adolescents dealing with a learning disability. Post survey responses revealed positive feelings toward the program. All survey results showed significant improvement. Participants who finished the program showed decreased anxiety, greater social skills, and improved academic performance.

In addition to helping some social and behavioral aspects of high school students' lives, research has recently illuminated meditation's positive effects on one's health. Dr. James E. Stahl (2015) and his group of Harvard researchers examined an eight-week mind-body program provided through the Benson-Henry Institute for Mind Body Medicine at Massachusetts General Hospital. For the duration of the program, participants were taught meditation, yoga, mindfulness, cognitive behavioral skills, positive psychology, and various other mind-body approaches. At the hospital, the researchers held meditation sessions each week, and participants were asked to continue the practice at home. Program participants used 43% fewer medical services than they had in the prior year. Consequently, each participant saved about $2,400 per year in emergency room costs. The researchers concluded that mind-body programs have the potential to help each participant save health care costs from $640 to $25,500 each year. This study sheds light on how meditation programs could translate into thousands of dollars saved each year by providing immense health benefits to participants.

Another example of how meditation can improve one's health is shown in a study conducted by the aforementioned Dr. Barnes (2001). This study investigated the effects of Transcendental Meditation (TM) on cardiovascular reactivity in high school students with high normal blood pressure. Thirty-five teenagers were randomly placed in the TM group or the health education control group. In the TM group, students meditated for 15 minutes twice each day for two months. Researchers found that the TM program had a favorable impact on cardiovascular functioning at rest as well as during acute laboratory stress in high school students at-risk for hypertension. This beneficial impact on the heart for TM program participants was likely due to larger decreases in resting blood pressure in addition to other various improvements compared to the control group.

As this study by Barnes (2001) reveals that meditation has advantageous effects on one's heart or more broadly on one's health as a whole, these positive consequences on one's health led the researcher to question what impact meditation has on the brain. The author of a study on this topic is Richard J. Davidson (2012), a renowned professor of psychology and psychiatry at the University of Wisconsin–Madison and the chair of the Center for Healthy Minds, which researches well-being and mental health. His article on the current neuroscience research on meditation found several positive effects, including improved social skills related to emotion, attention, empathy, and compassion. He found that a consistent meditation practice creates plastic changes in brain function and structure, promoting social behavior and academic success in adolescents.

In another study contributing to the existing body of cognitive neuroscience research, Sara Lazar (2005) and her team at Harvard found that eight weeks of Mindfulness-Based Stress Reduction (MBSR) transforms the structure of the brain. This mindfulness meditation program thickens the hippocampus, the part of the brain which regulates memory and learning processes. Also, MBSR enlarged areas of the brain that are involved in emotion regulation and self-referential processing. It also decreased cell volume in the amygdala, which processes emotions of fear, anxiety, and stress. Both of these structural transformations correlated with the lowered stress levels of participants. This groundbreaking research uncovered that mindfulness meditation both changes the structure of the brain and impacts our subjective perception and feelings.

In a different randomized controlled study regarding the impact of mindfulness meditation on the brain, researchers examined whether a two-week mindfulness-training course would reduce distracting thoughts and boost cognitive performance. Michael D. Mrazek (2013) and his team of researchers who conducted this study are professors at the University of California Santa Barbara. Furthermore, this source was a peer-reviewed journal, published in the

well-known journal *Psychological Science*. Mrazek and his team examined a population of college students taking the Graduate Record Examination (GRE) and wondered if mindfulness meditation could improve their scores on the GRE test by aiding their memory and helping students to have a clearer mind. The researchers discovered that mindfulness training increased both working memory capacity and GRE reading-comprehension scores (on average by 16%). Moreover, at the same time, mindfulness training decreased the amount of distracting thoughts experienced during the completion of the GRE, allowing students to completely focus on the task at hand. Overall, the researchers found that college students performed better on the GRE by practicing mindfulness and added to the body of meditation research that mindfulness increases cognitive function.

In another study, researchers investigated the efficacy of a mindfulness meditation intervention on improving working memory capacity (WMC) in adolescents. In this randomized controlled trial, researchers compared a mindfulness meditation group to a hatha yoga group and a waitlist control group. Dianna Quach (2016), the main researcher, is a professor of Professional Psychology at Alliant International University in San Diego, California. Quach is an expert in the field of psychology with decades of experience in research. This source was a peer-reviewed journal, published in a well-known journal *Journal of Adolescent Health*. To conduct the study, one hundred and ninety-eight middle school students from a large public middle school in the southwest United States were randomly assigned to one of the three groups of mindfulness meditation, hatha yoga, or a waitlist control condition. Before and after the intervention, participants completed a computerized measure of WMC (Automated Operational Span Task) and self-report assessments of perceived anxiety (Screen for Childhood Anxiety Related Emotional Disorders) and stress (Perceived Stress Scale). Researchers discovered that meditation increased the working memory capacity in middle school students. This was the first study to provide support for the benefits of a mindfulness practice that was completed in a short time in improving WMC in adolescents. Although research has been done on how meditation improves behavior, health, happiness in all age groups, and how it improves memory in middle school students, there has been nothing done on how meditation impacts working memory in high school students. Reviewing the current research led to the research question: To what extent does a week of daily mindfulness meditation improve the working memory and mindfulness of teens in a Connecticut high school? The researcher hypothesized that a week of daily meditation would increase both the working memory and mindfulness of Connecticut high school students.

Methodology

After reviewing the literature, it became evident there was a gap in the field regarding the impact of mindfulness meditation on the working memory of high school students. The gap in the body of meditation research is addressed in this study by surveying high schoolers' mindfulness and testing their working memory before and after a week of mindfulness meditation and running in a high school in Hartford County, Connecticut. After completing the research and obtaining data, administrators in the selected school were informed of the results for them to consider implementing a mindfulness meditation program. The study was inspired by several studies in which people's working memory was assessed before and after meditation (Van Vugt, 2011; Quach, 2016; Buttle, 2011). I used these studies because they were validated, but I had to tailor my research to the high school population and thus, created an original method for this study.

Participants

A school in Hartford county was selected under careful consideration due to its proximity to the researcher and the ability to reach a large sample size that is representative of the student population in the local region. For research participation, the high school required that the name of the school and the identities of the participants be kept confidential. The population examined in the study were students from the ninth, tenth, eleventh, and twelfth grades.

Mindfulness Survey

A mindfulness survey was sent out to the whole school using a Google Form and was administered to high school students during the school day. The Mindful Attention Awareness Scale (MAAS) was utilized, which asks fifteen specific questions to assess mindfulness, such as "I find myself doing things without paying attention." The MAAS asks participants to rate each question on a six-point Likert scale, labeled as: almost always, very frequently, somewhat frequently, somewhat infrequently, very infrequently, or almost never (Brown & Ryan, 2003). To take into account "socially desirable responding," participants are requested to answer based on what "really reflects" their experience instead of what they believe their experience should be. The questions range in a variety of domains including cognitive, emotional, physical, interpersonal, and general ones. The first seven questions assess the ability of the individual to be aware of their surroundings, through asking questions, such as "I tend not to notice feelings of physical tension or discomfort until they really grab my attention." The second group of eight questions determines to what extent are the participants conscious of their actions in the present moment, rather than focusing on their emotions about the past and future, such as "I find myself preoccupied with the future or the past" and "I do jobs or tasks automatically, without being aware of what I'm doing."

The MAAS was chosen for multiple reasons. First, the survey quantifies mindfulness, allowing the researcher to compare and interpret the data with ease. Moreover, researchers have tested its validity, and according to Drs. Kirk Brown & Richard Ryan, the MAAS was found to have good internal consistency, with an alpha of .82 in student samples, which reveals its high reliability (Brown & Ryan, 2003). It was found to be "one of the most effective methods of assessing mindfulness in adolescents" (MacKillop & Anderson, 2007). Lastly, due to its short length of only 15 questions, participants can fill it out easily. The research subjects completed the MAAS before and after a week of daily mindfulness meditation. The MAAS can be found in Appendix A.

Memory Test

Students took a memory test before and after the meditation intervention to determine if their working memory changed as a result of meditation. The researcher found several credible and reliable instruments to measure memory, such as the Automated Operation Span Task (AOSPAN), which was utilized in previous studies (Greenberg, 2019; Quach, 2016). In a recent study by Jonathan Greenberg (2019), professor at the University of California Berkeley, and his team, participants were asked to begin by taking a memory test. First, each participant watched as a group of letters flashed on a computer screen. Then, the screen went blank for a few seconds. Following the blank screen, participants

were shown a single letter and probed to identify if they had seen that letter before. A memory test is essential to this experiment as it quantifies memory, which can be then utilized to compare each participant's mindfulness score with and determine if there is a correlation between mindfulness meditation and one's working memory capacity. A limitation to the research for the memory evaluation was that after contacting several professors and authors of the aforementioned memory test, the researcher was unable to obtain a usable copy of the memory evaluation. In lieu of using AOSPAN, the researcher utilized the "Human Benchmark Test" specifically, its Verbal Memory Test to accomplish the same purpose. This memory test shows the participant one word at a time, such as "grandeurs," and prompts them to determine if they have or have not seen it before during the test on the screen. Similar to the aforementioned study by Greenberg (2019), this study relies on a credible method of measuring how many words one can keep in short term memory at once. The Human Benchmark Verbal Memory Test was also chosen because of its proven reliability and validity in past experiments examining the impact of meditation on adults' short term memory (Butola & Chauhan, 2014; Tenney, 2006).

Control Group

Participants were randomly assigned to the experimental group or the control group in order to increase confidence in the validity of the results. Both groups were measured utilizing the same mindfulness survey and memory test before and after a week of their respective activity. The control group participants ran on their own for 10 minutes a day and communicated with the researcher each day through text, email, or in-person to confirm their participation. No particular speed, distance, or incline was specified to the participants; they were only required to keep track of their time. Participants ran every day for seven consecutive days, which was the same duration assigned for the meditation group.

Mindfulness Meditation Practice

Meditation group participants followed their breath with a meditation YouTube video created by Diana Winston, Professor at the UCLA Mindful Awareness Research Center. This video has been utilized in several studies conducted by the UCLA research group and researchers on a global scale (Zylowska, 2008; Flook, 2010). Participants watched this five-minute video for seven consecutive days and each person checked in with the researcher every day through text, email, or in-person to confirm their participation. In order to practice proper meditation, Professor Zylowska (2008) directed participants to maintain good posture during their meditation practice, in a quiet and distraction-free place. The researcher also had participants follow these same instructions. Flook (2010) mentioned the importance of having a consistent time for meditation each day. The time of day does not matter, as long as participants stay consistent in their meditation practice. Participants were instructed to meditate at the time they felt most comfortable. For example, some participants meditated right before bed, while others did so before school. Prior to a week of meditation, participants completed the pre mindfulness survey and pre memory test. Directly following a week of meditation, they completed the post mindfulness survey and post memory test.

Results and Analysis

Before and after a week of meditation, in addition to the memory test, participants in the meditation group filled out a Google Forms survey that analyzed their mindfulness. Additionally, the running control group completed the same assessments before and after running each day for 10 minutes. Averages were determined for each item and then, a total average of mindfulness was found from these initial averages. According to Table 1, the overall pretest mindfulness average was found to be 3.5 and the overall post-test mindfulness average was found to be 4.0. The net increase in mindfulness as a result of a week of daily mindfulness meditation was .5. Therefore, results reveal that mindfulness meditation does increase one's mindfulness score.

Table 1: *Overall Averages and Net Increase In Mindfulness for Each Survey Item for Meditation Group*

Item	Pretest Average	Posttest Average	Net Increase
I could be experiencing some emotion and not be conscious of it until sometime later.	3.6	3.9	0.4
I break or spill things because of carelessness, not paying attention, or thinking of something else.	4.0	4.5	0.4
I find it difficult to stay focused on what's happening in the present.	3.3	3.8	0.5
I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.	3.4	3.6	0.3
I tend not to notice feelings of physical tension or discomfort until they really grab my attention.	3.7	4.0	0.3
I forget a person's name almost as soon as I've been told it for the first time.	3.3	3.7	0.5
It seems I am "running on automatic," without much awareness of what I'm doing.	3.5	4.3	0.7
I rush through activities without being really attentive to them.	3.5	4.1	0.5
I get so focused on the goal I want to achieve that I lose touch with what I'm doing right now to get there.	3.5	4.3	0.8
I do jobs or tasks automatically, without being aware of what I'm doing.	4	4.3	0.3
I find myself listening to someone with one ear, doing something else at the same time.	3.1	3.9	0.8

I drive places on 'automatic pilot' and then wonder why I went there.	4.9	5	0.1
I find myself preoccupied with the future or the past.	2.1	3.2	1.1
I find myself doing things without paying attention.	3.3	3.7	0.4
I snack without being aware that I'm eating.	4.0	4.4	0.4
Totals	Average Pretest Score	Average Post-test Score	Average Increase in Mindfulness
	3.5	4.0	0.5

Using the posttest and pretest scores, the average increase in mindfulness was calculated. Pretest scores, posttest scores, and average change in mindfulness for each item are shown in Table 1. The overall average mindfulness improvement was then determined by averaging the net increase in mindfulness of each item. This overall average mindfulness point change for each item was found to be .5, which is a large improvement considering the Likert scale for the Mindfulness Attention Awareness Scale (MAAS) ranges from 1 to 6, and selections are made in 1 point increments. Tables 2 and 3 detail the percent increase in memory and point increase in mindfulness for each participant in both groups. Meditation group participants experienced an average increase in mindfulness of .8, as opposed to .03 for control group participants (see Table 3). This data reveals that each experimental group participant experienced an increase in mindfulness as a result of daily meditation. In addition, the control group's small increase in mindfulness may reflect the participants' increased comfort with taking the MAAS rather than an actual increase in mindfulness. The control group allows the researcher to have higher confidence that mindfulness meditation was the sole cause of the increase in the meditation group's mindfulness scores.

In addition to the mindfulness survey, meditation group participants took a memory test before and after a week of mindfulness meditation. According to Table 2, this average gain in memory from before meditation to after meditation of 40.3% signifies that the meditation group experienced a statistically significant net increase in memory. Thus, it is evident that on average, mindfulness meditation improved the working memory capacity of meditation group participants.

Table 2: *Percent Increase in Memory and Point Increase in Mindfulness For Each Meditation Group Participant and Total Averages for Meditation Group*

Participant #	Percent Increase in Memory	Point Increase in Mindfulness	Calculated Working Memory & Mindfulness Increase
1	32.7%	1.6	Yes
2	11.4%	2.1	Yes

3	9.6%	3.2	Yes
4	11.0%	.1	Yes
5	19.3%	.1	Yes
6	66.7%	.1	Yes
7	17.1%	1.1	Yes
8	41.2%	.9	Yes
9	166.0%	.3	Yes
10	35.0%	.1	Yes
11	63.8%	.5	Yes
12	102.4%	1.1	Yes
13	4.0%	.3	Yes
14	15.3%	.3	Yes
15	8.2%	.7	Yes
16	117.4%	1.9	Yes
17	8.7%	.1	Yes
18	25.6%	.2	Yes
19	11.0%	.3	Yes
Totals	Average Percent Increase in Memory	Average Point Increase in Mindfulness	
	40.3%	0.8	

For each meditation participant, their percent change in memory and the average change in mindfulness both increased. The research question that this study aimed to answer was: To what extent does a week of daily mindfulness meditation improve the working memory and mindfulness of teens in a Connecticut high school? The researcher hypothesized that a week of mindfulness meditation would increase both short term memory and mindfulness compared to the control group. The average increase in memory for each participant was 40.3% and the average point increase in mindfulness was 0.8 (see Table 2). Since both memory and mindfulness scores increased for each meditation participant, it is evident that there is a correlation between working memory capacity and one's mindfulness and thus, the original hypothesis is confirmed.

Table 3: *Percent Change in Memory and Point Change in Mindfulness for Each Running Control Group Participant and Total Averages for Control Group (Non-meditators)*

Participant #	Percent Change in Memory	Point Change in Mindfulness	Calculated Working Memory & Mindfulness Increase
20	-3%	.2	No
21	-7%	.3	No
22	-1%	-.2	No
23	20%	-.1	No
24	23%	-.3	No
25	-23%	-.4	No
26	45%	-.1	No
27	-12%	.7	No
28	-10%	-.2	No
29	-42%	.3	No
30	36%	-.2	No
31	17%	-.1	No
32	8%	-.2	No
33	36%	-.1	No
34	-3%	.8	No
35	24%	-.4	No
36	-17%	.6	No
37	39%	-.1	No
Totals For Control Group	Average Percent Change in Memory	Average Point Change in Mindfulness	
	8.3%	.03	

A study conducted by aforementioned Dianna Quach (2016), Professor of Professional Psychology at Alliant International University, investigated the connection between a short mindfulness intervention and working memory capacity, by comparing the memory score increases of Hatha yoga and mindfulness meditation groups. This study compared the memory score changes and mindfulness score changes of the mindfulness meditation group (see Table 2) with the running control group (see Table 3). While the mindfulness meditation group had an average percent increase of 40.3% in working memory capacity (WMC), the control group only experienced an 8.3% gain in WMC, which is consistent with prior findings (Alloyway 2016). This difference is also seen in the average point change in mindfulness, which was found to be 0.8 in the meditation group and 0.03 in the control group. By utilizing a control group, similar to Quach's design, the researcher was able to determine that the increases in both WMC and mindfulness were due to the mindfulness training and not due to repeating the test a second time with greater familiarity or effort. In addition, Quach examined middle school students in a large public southwestern middle school, while in this study, the researcher focused solely on a small sample of high school students. Quach and her team found that mindfulness meditation increased working memory capacity, which aligns with the results that this study found. This research addresses the gap in the current research of meditation's effects on high school students in particular and thus, builds on Quach's study as well as several others on the impact of mindfulness meditation on cognition and memory of adolescents.

One limitation of this study is the sample size was small, with only 37 participants. The researcher sent an email to the school to gather participants, yet it was difficult to get teenagers to meditate without incentive. It is impossible to know for sure if the participants were meditating, although, they all experienced a net increase in mindfulness from before to after a week, which is consistent with a week of daily mindfulness meditation.

These findings have implications on the future of mindfulness-based interventions in schools as now there is data to support that mindfulness meditation improves memory and mindfulness in high school students. Schools may decide to incorporate daily meditation into the school schedule, given its benefits on not only emotional development but on memory and thus, on academic success.

Implications, Conclusions, and Future Research

Now that the positive impact of mindfulness meditation on the mindfulness and working memory capacity of high school students has been established, there are multiple ways to utilize these findings to help high school students. The clearest way to utilize these findings is to implement mindfulness meditation programs in high schools across the country. There have been several schools that have started meditation programs and seen numerous benefits, such as reduced stress and anxiety and increased self-esteem (Waters, 2015). Now, these results serve to add to the gap in meditation research in teens and reflect that mindfulness meditation does, in fact, increase mindfulness and working memory capacity. Thus, this research simply adds another benefit for students to receive.

In most research studies, there are limitations to the new understanding due to the chosen method or the way the method was implemented. One limitation of this study is the small sample size of only 37 participants. To improve the reliability of the results, this study should be replicated with a larger pool of applicants. Future research should

also include a more socioeconomically diverse population as research shows that those in lower socioeconomic classes, on average, score lower on tests of language and working memory capacity (Noble, 2005). This population of high socioeconomic class may have altered the results by having already high working memory capacity scores.

Another limitation could result from the timing of the study. The study was conducted in late February and early March, the middle of the third quarter of the school year, which is a very stressful time for many students. Many factors, such as cramming for AP Exams and standardized testing, and the start of spring sports, may have contributed to their higher stress levels. This may have impacted the mindfulness survey scores, as the stress levels of teens may have increased during their busy lives and had a mitigating effect on the positive implications of mindfulness meditation. Future studies should examine the differing effectiveness of meditation at different times of the year to determine whether differences in increases in mindfulness and memory scores are found.

Future research could go further in-depth on the impact of different types of meditations on mindfulness and working memory capacity in order to determine which one has the most statistically significant impact on teens, and thus, that could be used in school environments. Additionally, it may be beneficial to more fully examine the effects of meditation on the brain by using more sophisticated neurological tests, such as the Stroop task or the N-back. Finally, researchers could look into how mindfulness meditation affects one's grades, test scores, and other measures of school-related outcomes to help understand whether meditation improves school performance.

Although the aforementioned study conducted by Quach (2016) found that a short mindfulness meditation practice increased working memory capacity in a southwest United States middle school, this study is the first of its kind to provide support for the positive implications of mindfulness meditation on both mindfulness and working memory capacity in high school students.

Acknowledgements

This paper and the research behind it would not have been possible without the exceptional support of my advisor, Professor Michael Posner. His enthusiasm, knowledge and exacting attention to detail have been an inspiration and kept my work on track.

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Mindfulness-based online intervention increases well-being and decreases stress after Covid-19 lockdown

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Mindfulness interventions were shown to be effective in improving well-being and reducing perceived stress in several conditions. These effects were also found in online mindfulness-based training, especially in employees in organizational environments. The aim of this study was to test the effectiveness of an online mindfulness intervention on healthy employees, especially after the first Italian Covid-19 lockdown. Participants in the intervention group underwent an 8-week mindfulness online training program based on the Mindfulness-Based Stress Reduction (MBSR) protocol compared to a control (no-intervention) group. All participants filled in weekly surveys for the whole intervention duration via online questionnaires to measure their habits, mindfulness (FFMQ-15), emotion regulation (ERQ), positive and negative affect (PANAS), depression, anxiety and stress (DASS-21), resilience (RSA) and insomnia (ISI). 69 participants in the intervention group and 63 in the no-treatment control group were considered in the longitudinal analyses. We found significant differences between the intervention and control groups over time in the measures of mindfulness (in particular the nonreactivity subscale), positive affect, depression, and insomnia. Moreover, we found that the frequency of practice and ease perceived in practicing were positively correlated to several indices of well-being (mindfulness, positive affect, cognitive reappraisal) and negatively correlated to several indices of stress (negative affect, depression, anxiety, stress, insomnia, expressive suppression). These results show the importance and effectiveness of online mindfulness training programs to cope with stress among employees, especially after the Covid-19 lockdown.

What is mindfulness. Mindfulness is an intrinsic and modifiable capacity of the human mind, commonly defined as "the awareness that emerges through paying attention on purpose, in the present moment, and non-judgmentally to the unfolding of experience moment by moment"[1]. Mindfulness meditation, in turn, represents a systematic framework and process for cultivating mindfulness in daily life by intentional and sustained practice[2].

The first mindfulness meditation program to be standardized in the 1970s by Jon Kabat-Zinn was the Mindfulness-Based Stress Reduction (MBSR) program[1]. This protocol consists of eight weekly sessions aimed at presenting and teaching different practices[3]. The goal of this program is to reduce perceived stress and to realize benefits for health and well-being. MBSR, first developed and standardized for patients with chronic pain[4–6], demonstrated the benefits of mindfulness-based interventions (MBIs, broadly defined as any mindfulness-focused training protocol[7]) at both mental and body levels in helping people cope with many conditions[8].

In the last decades, interest in research investigating mindfulness-based interventions has increased substantially. Khoury and colleagues[9,10] showed that the MBSR program can provide a significant nonspecific moderate to large effect on reducing stress and increasing well-being in both healthy individuals and patients. In particular, there is an increasing body of evidence showing the clear effectiveness of mindfulness-based interventions in reducing stress, depression, and anxiety[7,11–13].

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When considering the psychological effects of mindfulness-based interventions, it is also crucial to consider the interaction between mindfulness and emotion regulation. Several studies found an overlap between them: awareness and acceptance, two components of mindfulness, are typically exploited in some emotion regulation strategies, both from a conceptual[14] and from a neuroanatomical point of view[15], even though interventions based on the two constructs differ fundamentally in terms of the underlying processes they address[16]. Concerning specific emotion regulation strategies, some studies found mindfulness-based interventions to be linked to increasing use of cognitive reappraisal and decreasing use of expressive suppression[17,18]. On the one hand, cognitive reappraisal is an advanced form of cognitive change that involves representing a potentially emotion-eliciting situation in a way that changes its emotional impact[19] and it is related to experiencing and expressing greater positive emotion and lesser negative emotion (*ibidem*). On the other hand, expressive suppression is a basic form of response modulation that involves inhibiting ongoing emotion-expressive behaviour and it is linked to experiencing and expressing lesser positive emotion and greater negative emotion (*ibidem*). Therefore, previous literature suggests that mindfulness-based interventions foster more advanced and effective emotion regulation strategies. Moreover, several studies showed that mindfulness-based interventions improve the quality of sleep (typical index of well-being) and reduce the incidence of insomnia and sleep disorders[20–22].

Online mindfulness training programs and Covid-19 pandemic. When considering the exponential development of technology and the extensive availability of internet access, the overwhelming increase of online mindfulness interventions and apps over the last years is incontrovertible[23]. Indeed, digital mindfulness interventions offer several advantages, such as increased accessibility, anonymity, standardization, personalization and higher efficacy. Nevertheless, using mindfulness practices via online protocols also has many disadvantages to be kept into account: the possibility of low engagement, shallow learning, unaddressed obstacles and frustration. The presence of a trainer presenting the practices and that may be contacted for doubts or questions may help to solve these disadvantages. As a matter of fact, an extensive meta-analysis[24] demonstrated significantly larger effect sizes for guided online mindfulness-based interventions compared to unguided ones. The same meta-analysis showed a consistent small to moderate beneficial effect of online mindfulness-based interventions on stress, depression, anxiety, well-being, and mindfulness.

Considering the ease of use, the number of smartphone apps focused on mindfulness practices (e.g., HeadSpace, Calm) has notably spread during the last years[25]. Therefore, smartphone apps may be a great instrument to familiarize with and increase the frequency of mindfulness practices. A systematic meta-analysis (*ibidem*) found a significant increase in mindfulness and lower levels of psychological stress in participants using mindfulness apps. Significant effects of these apps on mindfulness, well-being and perceived stress were found in the general population[26,27], in healthy employees[28] and categories prone to burnout, i.e., physicians[29], or with high levels of stress, i.e., college students[30], in particular, medical students[31] and pharmacy students[32].

Mindfulness-based interventions have been spreading among employees in the workplace during the latest years, proving their efficacy on emotional exhaustion and personal accomplishment (two dimensions of burnout), psychological distress, depression, anxiety, and occupational stress, as well as mindfulness, quality of sleep and relaxation[3]. The increase of online mindfulness training programs through video calls or apps has been exploited also in the workplace. Not only it proved effects on well-being comparable with internet-based cognitive-behavioural training[33], but also on organizational parameters such as decision-making, productivity, interpersonal communication, organizational relationships[34], job strain, perceptions of workplace social support[28] and key leadership competencies including those related to decisiveness and creativity[35]. These are the reasons why nowadays mindfulness-based interventions are more and more recommended in the workplace.

The situation in which we observed the greatest increase in the use of online technologies for communication, training and every aspect of our daily life is the Covid-19 (COronaVIrus Disease 19, caused by the Severe Acute Respiratory Syndrome Coronavirus 2—SARS-CoV-2) pandemic. In Italy, some lockdowns limited to cities or regions had already started in February, but the nationwide lockdown started on the 9th of March, 2020, with an estimated 56 million people ordered to remain at home. Apart from the dreadful number of casualties and the enormous economic loss associated with the Covid-19 pandemic, the fear of contagion and the 2-months lockdown had a serious psychological impact on a large part of the Italian population, i.e., 40–50% of adults experiencing psychological distress[36] and 30% of adults and children at risk for developing post-traumatic stress disorders[37]. Moreover, social distancing was previously proven to trigger negative mental health consequences, including intensified anxiety and depression[38,39].

As a matter of fact, several studies assessing the efficacy of online mindfulness-based interventions during lockdown are emerging. An online mindfulness intervention significantly reduced perceived stress in Singaporean participants during lockdown[40]. The same study found comparable effects for online and in-person mindfulness training programs. Furthermore, online mindfulness training proved a reduction of anxiety and depression in Covid-19 patients themselves during isolation[41], an increase of resilience in adolescents[42], as well as employees' sleep duration and work engagement[43]. Besides, several mindfulness-based protocols are currently being tested for their efficacy on Covid-19-related psychological symptoms[44–46].

Aim of the study. The aim of this study is to test the effectiveness of an online mindfulness-based training program on mindfulness, emotion regulation, mood, depression, anxiety, stress, resilience and sleep quality after the period of the first Italian lockdown. In fact, the mindfulness intervention was carried out during the period from the 19th of June to the 13th of August 2020, starting thus about 4 weeks after the end of the first Italian lockdown (which officially ended on the 18th of May 2020). During this period, many measures to prevent contagion were loosened as new cases significantly decreased in May. Nevertheless, the spectre of a second wave was starting to emerge during the end of summer, with a slow increase in new cases.

This time window was chosen because there is still scarce evidence about psychological consequences after the lockdown period, while the psychological effects during the lockdown were well investigated. One study on an Italian students sample found comparable psychopathological indices before and after the lockdown, with the worst depressive symptoms during the lockdown period and changes quickly vanishing after the lifting of lockdown[47]. Nevertheless, another study with a larger sample found that depression, stress, anxiety and fear of Covid-19 remained unchanged during and after the lockdown[48]. Another study from our group even found a worsening of several psychological well-being indices between the phases during and after the lockdown[49]. Therefore, after the lockdown, the psychological sequelae are still unclear and the effects of a mindfulness-based intervention during that period need to be investigated.

In particular, we investigated the effects of the mindfulness training program on a healthy population, specifically employees in a large-scale banking group. Given the increased distress employees have been experiencing during and after the Covid-19 lockdown(s) related to an overwhelming change in working paradigms (i.e., forced working from home) and in habits[50], it is crucial to test the effectiveness of mindfulness interventions on this population since it is effortless and effective to administer it in an online modality on the (virtual) workplace[51].

Based on the previous literature, specific hypotheses are related to (1) the increase in psychological well-being (i.e., mindfulness, use of mature emotion regulation strategies, positive affect, resilience) and decrease in perceived stress (i.e., use of basic emotion regulation strategies, negative affect, depression, anxiety, stress, insomnia) for participants undergoing the intervention, compared to the control group; (2) the protective value of mindfulness (i.e., no changes over time) when the control group experienced a worsening of psychological well-being and higher stress; (3) positive correlation between frequency of practice and indices of well-being, and difficulty perceived in practicing and indices of stress; negative correlation between frequency of practice and indices of stress, and difficulty perceived in practicing and indices of well-being.

Results

Power analysis. In order to identify the most adequate sample size, we performed an a-priori power analysis based on a meta-analysis on the effects of MBSR on healthy individuals[10]. We based the power analysis on the effect size the authors found for studies conducted by a facilitator with mindfulness training/experience (since our procedure respected this criterion): Hedge's $g = 0.60$. This effect size indicated the difference between the intervention and control groups in their changes before and after the intervention, i.e., the time × group interaction effect we investigated in our longitudinal analyses. The significance level was set to 0.05, test's power was set to 0.85, with two-sample test and two-sided alternative hypothesis. This power analysis led to a result of n = 49. This criterion was respected in our final sample size: 69 participants in the intervention group and 63 in the control group (mean n = 66; actually corresponding to a power of 0.936 with the same parameters).

Longitudinal analyses. Results from the longitudinal analyses are focused on the time × group interaction effects based on our a-priori hypothesis. Complete results including fixed main effects of time, group and covariates can be found in the Supplementary Information.

In the habits questionnaire, practicing mindfulness (or different forms of meditation) displayed a statistically significant time × group interaction effect: $F(1, 112) = 44.30$, $p < 0.001$ (Fig. 1A). The simple slope analysis proved that the intervention group showed a significant increase in the habit over time ($b = 0.117$, $t(127) = 8.95$, $p < 0.001$), while the control group did not display any significant change in time ($b = -0.0004$, $t(102) = -0.03$, $p = 0.976$). No other habits showed any significant time × group interaction effects (all Fs < 3.3, all ps > 0.071), except for a significant effect in cooking ($F(1, 112) = 4.35$, $p = 0.039$). The simple slope analysis showed that control participants' cooking habit decreased over time ($b = -0.068$, $t(103) = -4.42$, $p < 0.001$), while this did not happen in the intervention group ($b = -0.021$, $t(126) = -1.28$, $p = 0.202$).

The analysis on the FFMQ total score showed a statistically significant time × group interaction effect: $F(1, 109) = 10.64$, $p = 0.001$ (Fig. 1B). The simple slope analysis highlighted that the intervention group displayed a significant increase in FFMQ total score in time ($b = 0.356$, $t(119) = 4.18$, $p < 0.001$), whereas the control group showed no significant effect of time ($b = -0.024$, $t(103) = -0.30$, $p = 0.764$).

When testing specific FFMQ subscales, only the nonreactivity factor showed a statistically significant time × group interaction effect: $F(1, 109) = 8.83$, $p = 0.004$ (Fig. 1C). The simple slope analysis revealed that the control group exhibited a decrease in nonreactivity over time ($b = -0.117$, $t(102) = -3.39$, $p = 0.001$), while there was no statistically significant effect of time in the intervention group ($b = 0.032$, $t(121) = 0.881$, $p = 0.380$). Moreover, the nonjudging subscale showed a trend towards significance in the same interaction effect: $F(1, 107) = 3.46$, $p = 0.065$. However, the simple slope analysis showed a significant increase in nonjudgment over time in both groups (control: $b = 0.102$, $t(100) = 3.41$, $p < 0.001$; intervention: $b = 0.184$, $t(119) = 5.72$, $p < 0.001$). No other FFMQ subscales showed a significant time × group interaction effect (all Fs < 2.9, all ps > 0.09).

In the ERQ questionnaire, the cognitive reappraisal subscale showed a trend towards statistical significance in the time × group interaction effect: $F(1, 106) = 3.66$, $p = 0.058$ (Fig. 1D). However, the simple slope analysis proved no statistically significant effect of time in either groups (control group: $b = -0.110$, $t(98.8) = -1.90$, $p = 0.060$; intervention group: $b = 0.052$, $t(117) = 0.83$, $p = 0.408$). The expressive suppression subscale did not present any significant time × group interaction effect: $F(1, 93.9) = 1.32$, $p = 0.254$.

When considering the PANAS scale results, the positive affect subscale exhibited a trend towards statistical significance in the time × group interaction effect: $F(1, 106.08) = 3.72$, $p = 0.056$ (Fig. 1E). The simple slope analysis showed a decrease in positive affect over time in the control group ($b = -0.367$, $t(98.7) = -5.06$, $p < 0.001$) and a smaller change in time in the same direction for the intervention group ($b = -0.163$, $t(118) = -2.09$, $p = 0.039$). The negative affect scale did not show a significant time × group interaction effect: $F(1, 111) = 0.38$, $p = 0.845$.

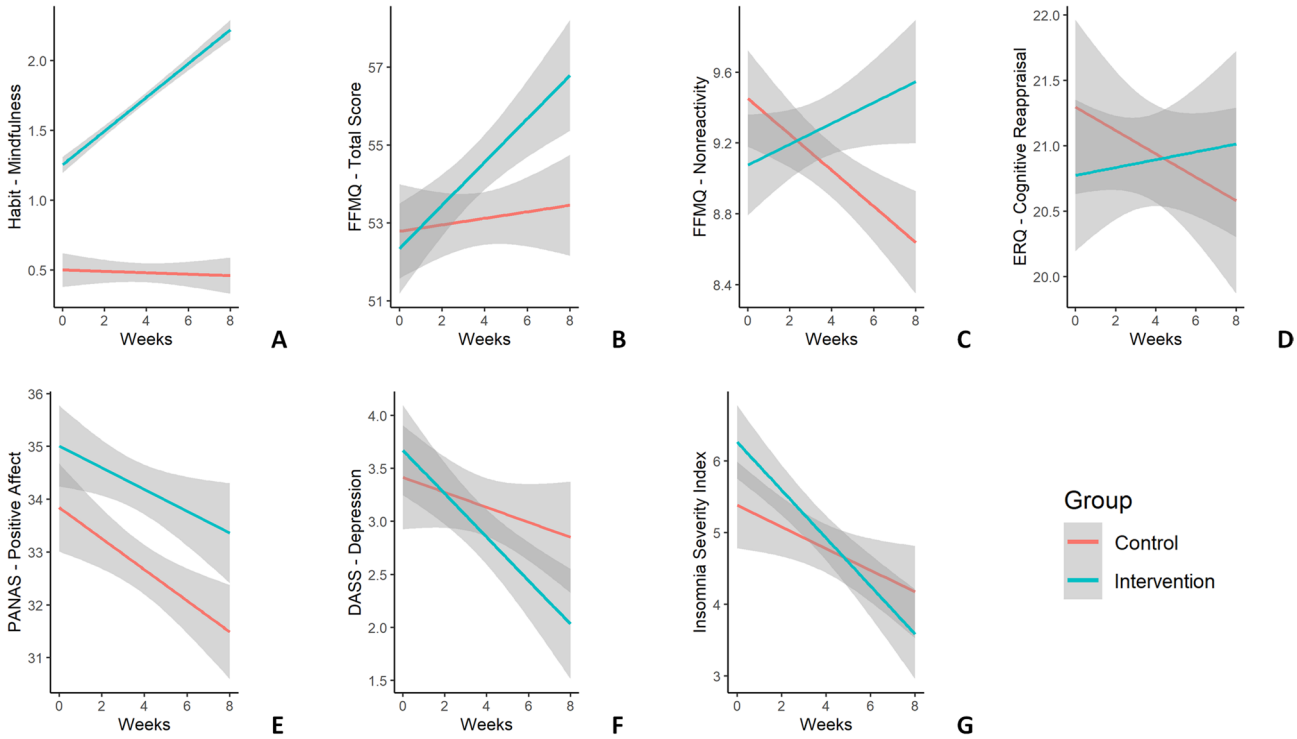

Figure 1. Time course of predicted average scores for different well-being and stress indices in longitudinal analyses. The x-axis in the plots represents the weeks of the intervention (from 0—before intervention—to 8—final week) and the y-axis represents participants' scores. The red line represents the control group (N = 63), while the green line represents the intervention group (N = 69). The grey shaded area represents 95% confidence intervals. The y-axis represents predicted average scores for (**A**) the habit "Please specify how much time you spent doing the following activity: Practicing mindfulness (or other forms of meditation)". See Supplementary Materials for further details on the questionnaire. (**B**) the mindfulness variable (FFMQ-15 questionnaire) total score and (**C**) the FFMQ-15 nonreactivity subscale, (**D**) the cognitive reappraisal variable (ERQ questionnaire), (**E**) the positive affect variable (PANAS questionnaire), (**F**) the depression variable (DASS-21 questionnaire), (**G**) the insomnia score (ISI questionnaire).

In the DASS questionnaire, the total score did not show a significant time × group interaction effect ($F(1, 108) = 1.395$, $p = 0.240$), but the depression subscale displayed a significant effect over the same interaction ($F(1, 108) = 4.026$, $p = 0.047$) (Fig. 1F). The simple slope analysis in this subscale revealed that depression scores decreased significantly over time in the intervention group ($b = -0.169$, $t(120) = -3.59$, $p < 0.001$), while they did not change significantly in the control group ($b = -0.041$, $t(100) = -0.94$, $p = 0.350$). Neither anxiety ($F(1, 106) = 1.50$, $p = 0.224$) nor stress subscales ($F(1, 110) = 0.005$, $p = 0.943$) showed any significant time × group interaction effects.

Neither RSA total score nor any of the subscales showed any significant time × group interaction effects over resilience: all Fs < 1.6, all ps > 0.2.

In the ISI questionnaire, the time × group interaction effect was not statistically significant: $F(1, 103) = 2.53$, $p = 0.115$ (Fig. 1G). An exploratory simple slope analysis proved, however, a significant decrease in insomnia scores for the intervention group ($b = -0.245$, $t(114) = -3.66$, $p < 0.001$), while the control group did not show any significant changes in time ($b = -0.099$, $t(96.4) = -1.56$, $p = 0.122$).

Correlations. All details for correlation results are reported in the Supplementary Information.

In the intervention group, the frequency of practice showed statistically significant positive correlations with several well-being indices (FFMQ total score, FFMQ—Describe, PANAS—positive affect, RSA—structured style) and negative correlations with distress indices (PANAS—negative affect, DASS total score, DASS—depression, DASS—anxiety, DASS—stress, ISI) (Fig. 2).

Conversely, the difficulty perceived in weekly practice was negatively correlated with well-being indices (FFMQ total score, FFMQ—observing, FFMQ—acting with awareness, FFMQ—nonjudging, FFMQ—nonreactivity, ERQ—cognitive reappraisal, PANAS—positive affect) and positively correlated with distress indices (ERQ—expressive suppression, PANAS—negative affect, DASS total score, DASS—depression, DASS—anxiety, DASS—stress, ISI) (Fig. 3).

As a final check, we found a statistically significant strong negative correlation between the frequency of practice and the difficulty perceived in weekly practice: $r = -0.521$, $p < 0.001$.

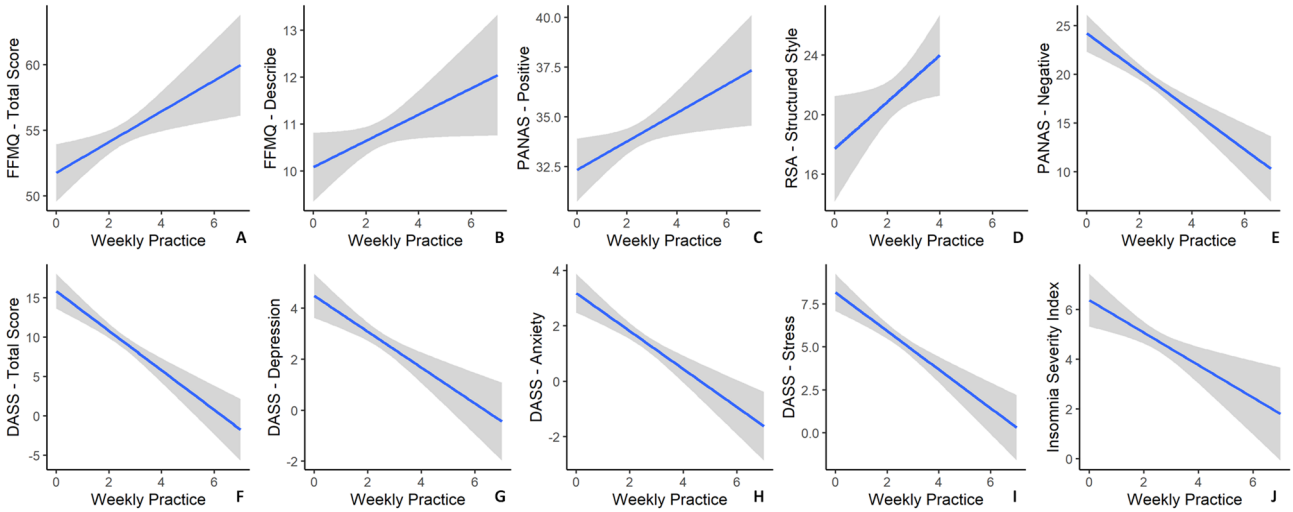

Figure 2. Plots showing significant correlations between the weekly frequency of mindfulness practice and several variables in the intervention group. The x-axis represents the weekly frequency of practice (ranging from 0 to 7 + times a week) and the y-axes represent (**A**) mindfulness total score (FFMQ-15), (**B**) describe subscale (FFMQ-15) (**C**) positive affect (PANAS), (**D**) structured style subscale (RSA) (participants only presented 0 to 4 values on the x-axis in this subsample), (**E**) negative affect (PANAS), (**F**) DASS-21 total score, (**G**) depression subscale (DASS-21), (**H**) anxiety (DASS-21), (**I**) stress subscale (DASS-21), (**J**) insomnia (ISI). The grey shaded area represents 95% confidence intervals.

Discussion

Mindfulness training programs were proven to be effective in improving well-being and reducing perceived stress in several populations (especially those prone to burnout) and conditions[8–10]. These effects were also found in online training, in particular during Covid-19 lockdowns by some preliminary results[40,52]. The aim of this study was to test the effectiveness of an online mindfulness training program after the first Italian Covid-19 lockdown, when the measures to prevent contagion were loosened, but the second wave was starting to emerge. Indeed, the psychological sequelae after the lockdown period are still to be clarified[47,48]. We found significant differences between the intervention group and the control group over time in the measures of mindfulness (in particular the nonreactivity subscale), positive affect, depression and insomnia. Moreover, we found that the frequency of practice and the ease perceived in practicing were positively correlated to several indices of well-being (mindfulness, positive affect, cognitive reappraisal) and negatively correlated to several indices of stress (negative affect, depression, anxiety, stress, insomnia, expressive suppression).

The mindfulness-based intervention showed a positive effect in time on several indices, compared to no changes in time for the control group (practicing mindfulness habit, mindfulness, depression, and marginally insomnia). These results confirm our first hypothesis (i.e., the increase in psychological well-being and decrease in perceived stress for participants undergoing the intervention, compared to the control group). First of all, the difference in practicing mindfulness acted as a double-check and showed the compliance of participants in the intervention group (i.e., participants in the intervention group showed an increase in how often they practiced during the program, while participants in the control group did not; see also section "Participants"). The effects of mindfulness training on mindfulness, depression and insomnia are now quite renowned[8,10,21,53] and the mechanism guiding all these changes seems to be the increase in mindful attitude towards one's own experience, in particular in terms of acceptance, nonreactivity and nonjudgment[54–57]. It is crucial to highlight that these changes were demonstrated also in the period after a lockdown, a time ruled by uncertainties during which people were conflicted between hope and resignation. These results prove that abilities promoted by mindfulness-based interventions can overcome the peculiar psychological conditions reflecting the unprecedented health and social situation. Moreover, these improvements cannot be attributed to the lockdown lifting, given their absence in the control group.

Two indices of well-being (the nonreactivity mindfulness subscale and marginally positive affect) significantly decreased over time in the control group, while they showed no significant differences over time in the intervention group. These results confirm our second hypothesis (i.e., the protective value of mindfulness when the control group experienced a worsening of psychological well-being and higher stress). They are particularly relevant, especially considering the abovementioned importance of nonreactivity in driving the effects of the intervention on well-being[56] and because they reflect how the specific societal context was influencing people in that specific post-lockdown time. The latest intervention weeks corresponded to a small but constant increase in new cases in Italy, prospecting thus the arrival of a second wave in the pandemic. Together with the distress accumulated during the previous months, this could explain the increase in emotional reactivity since hope was giving way to fear and stress related to the perspective of new restrictions and collective danger to people's health. The first lockdown represented a traumatic experience for many people who experienced it[37], and the idea of a second wave meant uncertainty and led to the fear of the impossibility of emerging from the pandemic. This particular and decisive phase was not investigated in detail in the previous literature. The absence of a temporal change

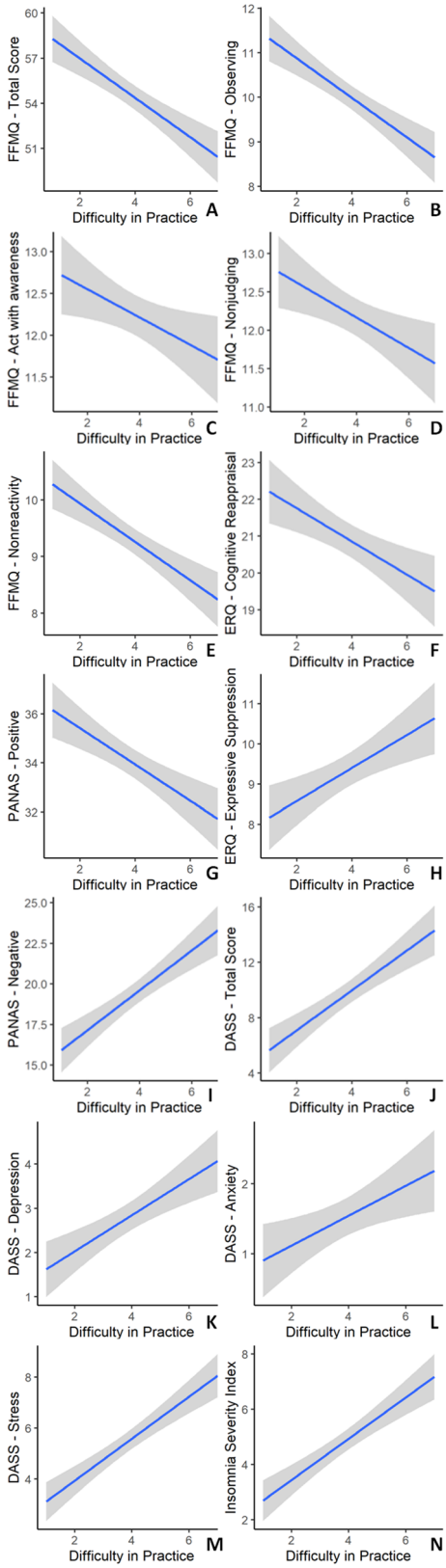

Figure 3. Plots showing significant correlations between the difficulty perceived in weekly mindfulness practice and several variables in the intervention group. The x-axis represents difficulty perceived in weekly practice (ranging from 1—very easy to 7—very difficult) and the y-axes represent (**A**) mindfulness total score (FFMQ-15), (**B**) observing subscale (FFMQ-15), (**C**) acting with awareness subscale (FFMQ-15), (**D**) nonjudging subscale (FFMQ-15), (**E**) nonreactivity subscale (FFMQ-15), (**F**) cognitive reappraisal subscale (ERQ), (**G**) positive affect (PANAS), (**H**) expressive suppression subscale (ERQ), (**I**) negative affect (PANAS), (**J**) DASS-21 total score, (**K**) depression subscale (DASS-21), (**L**) anxiety subscale (DASS-21), (**M**) stress subscale (DASS-21), (**N**) insomnia (ISI). The grey shaded area represents 95% confidence intervals.

in the intervention group showed the protective value of the mindfulness intervention: the program promoted well-being, protected participants from the effects of external stressors and helped them cope with uncertainty and fear. Moreover, we can be confident enough in stating that this difference was due to the intervention, given the absence of differences between groups in the use of habits as coping strategies.

Correlation tests in the intervention group showed that the frequency of practice was positively correlated with well-being indices (mindfulness—total score and describe subscale—positive affect, structured style in resilience) and negatively correlated with several stress indices (negative affect, DASS—total score and all subscales—insomnia), confirming thus our third hypothesis. The positive effect of mindfulness practice on these variables is well known[10], with particular respect to the frequency of practice. Previous literature robustly showed that the time spent in home practice is significantly correlated with the extent of improvement in mindfulness and several indices of well-being also in standard in-person MBSR protocols[58,59]. The result on resilience is too narrow (i.e., significant correlation only on one subscale, no further significant results in group differences) to be interpreted, even though mindfulness-based interventions showed a positive effect on resilience in previous literature[42]. Furthermore, perceived difficulty in practicing was negatively correlated with well-being indices (mindfulness—total score and observing, acting with awareness, nonjudging, nonreactivity subscales—cognitive reappraisal strategy, positive affect) and positively correlated with several stress indices (expressive suppression strategy, negative affect, DASS—total score and all subscales—insomnia). In this case, it is not easy to test a causal effect, also given the bidirectional nature of correlation tests. Indeed, it is arduous to discern whether higher stress made the practice more difficult for participants, or experiencing more difficulties in practicing caused higher stress. Nevertheless, in both cases, these results show the intrinsic relationship between perceived stress and perceived mindfulness in everyday life. A focus on emotion regulation strategies is crucial: we reported that higher difficulty perceived in practice is related to more frequent use of basic strategies to regulate emotions (i.e., expressive suppression) and less frequent use of advanced strategies (i.e., cognitive reappraisal). This result is in line with previous literature showing analogous results[17,18] and supports thus the hypothesis of overlap between "mindfulness" and "emotion regulation" theoretical constructs[14], even though cognitive reappraisal strategies are never explicitly taught in mindfulness practices[16].

Since we focused our online program on a specific healthy population, i.e., employees in a large-scale banking group, it is crucial to take into account the impact of this study on workplace applications. Mindfulness-based interventions have shown a relevant efficacy on workers' well-being[3] and organizational parameters[34], in both in-person and online modalities[33]. Given the increased distress employees have been experiencing during the Covid-19 pandemic[50], caused by a critical change in working paradigms, our study showed that administering online programs aimed at coping with stress on this population is crucial now more than ever. Indeed, this type of intervention is recommended in the workplace, given its critical effects on well-being in this period dominated by uncertainty. Therefore, it is crucial that employers promote and encourage initiatives of this kind in small, medium, and large-scale companies. In this respect, companies should acknowledge that this category of training can now be performed mostly in an online modality and the internet is being overused to work from home, often leading to an increase in techno-stress.

From this perspective, the results that emerged from this study are of particular relevance and novelty when considering the historical period during which they were collected. In the pandemic situation, the internet is abused in every aspect of life (e.g., education, work, personal relationships). At this time, we were living a sort of technological/social paradox: in-person social contact is impossible due to restrictions and the risk of Covid-19 transmission and, yet, we do not wish to use the internet to keep in touch with friends and relatives, given the techno-stress related to the ubiquity of this medium in our life[60,61]. For this reason, online mindfulness-based interventions might have led to an increase in distress related to technology overuse instead of a decrease. On the contrary, our results showed that the protective value of mindfulness was stronger than technology overuse-related stress.

Concerning mindfulness-based interventions, considering and discussing some methodological aspects is of paramount importance, especially given the reproducibility and replicability crisis in psychological science we are experiencing[62]. In the first place, the duration typically suggested in mindfulness programs is at least 8 weeks[1]. De facto, an interesting study proved that an 8-week mindfulness-based intervention can induce neurofunctional changes similar to those observed in traditional long-term meditation practice[63].

A further important aspect is related to home practice: besides the sessions with a trainer, the home practice was proven to be a significant mediator influencing the outcome of training in MBSR[59]. Indeed, a study focused on the MBSR program showed that the time spent engaging in home practice of formal meditation exercises was significantly related to the extent of improvement in most facets of mindfulness and several measures of symptoms and well-being[58]. For this reason, we used minimum practice frequency as an exclusion criterion in the intervention group. The presence of trainers for weekly practice presentations is another crucial aspect of online interventions that was acknowledged in our research since guided online mindfulness-based interventions showed a larger effect size compared to unguided ones[24].

Finally, though several indices of well-being increase thanks to mindfulness practices, a caveat must be made. Mindfulness meditation must not be regarded as a therapeutic panacea for all ailments, and the effects of mindfulness practice on health appear similar in magnitude to the changes demonstrated by other conventional approaches for treating stress, pain, and illness, including the administration of psychoactive medications, psychotherapy, health education, and behaviour modification[2,64]. Unfortunately, with the increase of interest in mindfulness, some studies appeared to present spurious results with poor methodology[65]. Therefore, it is crucial to use clear and rigid experimental methods to draw solid conclusions, starting with adequate an sample size, longitudinal design and collecting data from an adequate control group.

Limitations. The main limitation of this study is the lack of a follow-up measure to test whether the effects of the online program lasted in time through the second Covid-19 wave. This could be a crucial aspect to investigate the long-term effects of mindfulness-based interventions and practice maintenance after the program ended. This element will be investigated in future research. A further limitation to the generalizability of this study is the lack of a direct comparison with an in-person mindfulness program. However, recent literature[40] compared online vs. in-person mindfulness-based interventions during Covid-19 lockdown, finding comparable effects on stress from the two categories of training. A final limitation is represented by the fact that the group sampling was not fully randomised. Indeed, as specified in section "Participants", 28 participants recruited from outside of the banking group were included in the control group to balance sample sizes since the initial response from the (no-treatment) control group was extremely lower than from the intervention group. Although we co-varied participants' origin (i.e., banking group vs. students and acquaintances) in the longitudinal analyses to exclude the effect of this factor, this difference could possibly bias our results, which need to be replicated in future studies.

Conclusions. In this study, we investigated the effects of an online mindfulness-based intervention after the Italian Covid-19 lockdown with adult participants working in the banking industry. We found a positive and protective value of the mindfulness practice over time on mindfulness, positive affect, depression, and insomnia. Moreover, the frequency of practice and the ease perceived in practicing were positively correlated to several indices of well-being and negatively correlated to several stress indices. These results demonstrated the extremely positive effects of mindfulness practice on well-being and stress, especially in a psychologically challenging period such as the Covid-19 lockdown and post-lockdown. For this reason, mindfulness programs should be spread and promoted online during this period, especially in the workplace, as it could be helpful in several aspects of psychophysical well-being.

Methods

Participants. One hundred and thirty-two participants took part in the experiment on a voluntary basis. The only inclusion criterion was the absence of any psychiatric record. These participants were recruited among employees in a large-scale banking group, post-graduate university students, and acquaintances.

The sample size was identified in n = 49 by using an a-priori power analysis based on a previous meta-analysis (see section "Power analysis"). Initially, participants from the banking group were randomly assigned to two groups of seventy participants each. Nevertheless, the response from these two groups was very different; sixty-nine participants from the intervention group completed at least one weekly survey but only thirty-five participants from the (no-treatment) control group did so. Therefore, participants recruited from outside of the banking group (i.e., students and acquaintances, n = 28) were included in the control group to balance sample sizes. This led us to obtain two balanced groups: intervention group (n = 69; 44 F, mean ± sd age 44.7 ± 8.9) and (no-treatment) control group (n = 63; 42 F, mean ± sd age 38.3 ± 10.4).

Volunteers were paid 19.50€ for their participation if they completed the 8-week surveys. In order to control for possible biases related to participants' origin, in all longitudinal analyses participants' origin was co-varied. In addition, these volunteers were blind to the real aim of the study until the final debriefing (in order to avoid possible biased responses).

An Intention-To-Treat analysis approach[66] was used, i.e., data from all participants were included independently of the number of surveys completed. This approach allows having a conservative estimation of the treatment effect and avoiding biases related to drop-outs and participants' adherence.

To verify the intervention's effectiveness, we added two further criteria for potential exclusion. In the intervention group, we checked that each participant's average weekly frequency of practice was at least 1. No participants were excluded according to this criterion (min value = 1.00). In the control group, we checked that participants' habit of practicing mindfulness or other forms of meditation was lower than in the intervention group (by using the habits questionnaire, see section "Materials" and Supplementary Information). Five participants in the control group showed an average value greater than or equal to 2 (i.e., "few times a week"). Focusing on these five participants, we checked that their habit of practicing meditation was not increasing between the starting survey and the following 8 weeks. By using a mixed linear regression with data from these participants, we found no significant effect of time on their frequency of practice ($b = -0.05$, $t = -1.381$, $p = 0.176$). Therefore, we established that these five participants did not change their habits during the 8 weeks of data collection and were not excluded. Moreover, we found a clear increase in the frequency of practice in the intervention group due to the training program exploit, but no significant increase in the control group (see section "Results"). Accordingly, we can conclude that the habits of these five participants reflect the results found on average in the control group.

Ethical statement. All participants were provided with an exhaustive description of all the experimental procedures and were required to sign a written informed consent before taking part in the study. The study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and under a protocol approved by the Area Vasta Nord Ovest Ethics Committee (protocol n. 24579/2018).

Procedure. The starting survey was administered during the week 11th–18th of June 2020, about three weeks after the end of the first Italian lockdown (officially ended on the 18th of May 2020). All surveys were filled in online on the Google Form platform and were accessed by using links sent by the experimenter. In the first part of the starting survey, we asked for sex, age and habits. Habits were investigated by using an ad-hoc questionnaire aimed at studying the use of habits as coping strategies towards stress. In the second part, several validated questionnaires were administered to investigate different constructs related to well-being and stress:

15-item Five Facet Mindfulness Questionnaire (FFMQ-15[67]); Emotion Regulation Questionnaire (ERQ[68]); Positive And Negative Affect Scale (PANAS[69]); Depression Anxiety Stress Scale-21 (DASS-21[70]); Resilience Scale for Adults (RSA[71]); Insomnia Severity Index (ISI[72]). See the following section for more details on each questionnaire. The average completion time was around 15 min.

During the following eight weeks (19th of June–13th of August 2020), participants in the intervention group underwent the mindfulness training program and all participants filled in the intermediate survey on a weekly basis. The intermediate survey included a subsample of the questionnaires in the starting survey, related to state variables: habits, FFMQ-15, ERQ, PANAS, DASS-21, and ISI. Only in the intervention group, participants were also asked to indicate their weekly frequency of mindfulness practice (from 0 to 7 + sessions) and how difficult they perceived their practice (on a Likert scale ranging from 1—very easy to 7—very difficult). The average completion time was around 10 min.

The mindfulness training program lasted for 8 weeks and was administered online only to the intervention group. Eight different practices were chosen based on the MBSR protocol[1], by alternating sitting and moving practices (see Supplementary Information for details). At the start of each week, the weekly practice was presented by two mindfulness trainers on a conference call with the intervention group. The two trainers were trained and instructed in administering the MBSR protocol and in further contemplative practices (i.e., vipassana meditation, yoga, tai-chi chuan). Participants in this group could take part in the weekly call on a voluntary basis. Their privacy was protected by participating anonymously and with no possibility to turn their webcams on. After the practice, participants could ask the trainers any questions about mindfulness practice and their own experience during the online program. The experimenters sent an audio or video guide for the weekly practice (accessible via a link, average duration: 20 min) every week. Participants were asked to practice using the guide in a protected environment at least three times per week.

After the eighth week of intervention, all participants had to fill in the final survey. This survey contained the same questionnaires as the intermediate survey and the RSA. The RSA measures a stable variable (i.e., resilience), therefore we decided to administer it only in the starting and final surveys to assess the difference before and after the program. Thirty-six participants in the intervention group and forty-nine in the control group filled in the final survey. Hence, we could have a measure of the difference in the RSA only for this sub-group of participants. The average completion time was around 15 min.

Participants in the control group were asked to fill in all the weekly surveys (from week 0 to 8) without taking part in the training.

Materials. *Habits.* The habits questionnaire investigated the weekly frequency of 22 different habits used as coping strategies towards stress (e.g., web browsing, cooking, watching movies/series, physical activity). The response to each habit could be: 0: "I do not carry out this activity", 1: "once a week or less", 2: "few times a week", 3: "less than one hour a day", 4: "one to three hours a day", 5: "more than three hours a day". See Supplementary Information for the full questionnaire.

Mindfulness. Mindfulness was investigated by using the 15-item Five Facet Mindfulness Questionnaire (FFMQ-15[67]). Each item is scored on a 5-point Likert scale (from 1 = "Never or very rarely true", to 5 = "Very often or always true"). Items were scored into five subscales: observing (attending to sensory stimuli that mainly derive from external sources and the body as well as related cognitions and emotions), describing (labelling internal experiences with words), acting with awareness (ongoing attention to, and awareness of present activity and experience), nonjudging (having a non-evaluative attitude towards one's thought and emotional processes while focusing on inner experiences, rather than taking on a critical stance), and nonreactivity (assuming a stance that implies being able to perceive thoughts and feelings, especially when they are distressing, but without feeling compelled to react or being overwhelmed). Single items were translated into Italian by using the Italian complete version of the questionnaire[73]. The Italian version of the FFMQ showed good to excellent internal consistency as a whole (alpha = 0.86) with sub-scale consistency ranging from 0.65 to 0.81, test–retest stability for the total score being 0.71, and a good concurrent validity as demonstrated by significant correlations between the FFMQ scores and several self-report measures related to mindfulness[73].

Emotion regulation. Participants' use of different emotion regulation strategies was investigated with the Emotion Regulation Questionnaire (ERQ[68]). This is a 10-item questionnaire, in which each item is scored on a 7-point Likert scale (from 1 = "Strongly disagree" to 7 = "Strongly agree"). Items are scored into two separate subscales investigating expressive suppression (basic emotion regulation strategy, i.e., suppressing the behavioural expression of the emotion) and cognitive reappraisal (more advanced cognitive emotion regulation strategy, aimed at modifying the internal representation of an event to change one's own emotional experience)[19]. Previous literature (*ibidem*) showed that people who use cognitive reappraisal more often tend to experience and express greater positive emotion and lesser negative emotion, whereas people who use expressive suppression experience and express lesser positive emotion, yet experience greater negative emotion. Both subscales showed high internal consistency reliability (Alpha values ranging from 0.68 to 0.80 across four different samples) and test–retest reliability across 3 months was 0.69 for both scales[19].

Positive and negative affect. Participants' affect was recorded by using the Positive And Negative Affect Scale (PANAS[69,74]). Given the weekly administration, we used the PANAS with the "week" time instruction, i.e., each participant was asked to rate to what extent s/he felt as specified by each item during the last week. Each of the 20 items is scored on a 5-point Likert scale (from 1 = "very slightly or not at all" to 5 = "extremely"). Half of the items constituted the positive affect subscale, whereas the remaining half constituted the negative affect subscale.

The alpha internal consistency reliability indices were shown to be acceptably high, ranging from 0.86 to 0.90 for positive affect and from 0.84 to 0.87 for negative affect. Test–retest reliability showed no significant differences across an 8-week interval[74].

Depression, anxiety and stress. Perceived depression, anxiety and stress were measured using the Depression Anxiety Stress Scale-21 (DASS-21[70]). It is a 21-item self-report questionnaire assessing core symptoms of anxiety, depression and stress. Each item is scored on a 4-point Likert scale (ranging from 0 = "Did not apply to me at all over the last week" to 3 = "Applied to me very much or most of the time over the past week"). The DASS-21 has been shown to have good psychometric properties, i.e., internal consistency: Cronbach's alphas were 0.94 for Depression, 0.87 for Anxiety, and 0.91 for Stress; concurrent validity indices above 0.60 with several other inventories) both in clinical and non-clinical samples[75], and contains three subscales: Depression, Anxiety, and Stress.

Resilience. The Resilience Scale for Adults (RSA[71,76]) measures six resilience protective factors, of which four are intrapersonal factors (personal strength, planned future, social competence, and structured style) and two are interpersonal factors (family cohesion and social resources). This scale comprises 33 items, scored along a 7-point semantic differential scale. This questionnaire was administered only in the starting and final surveys, given its construct stability in time (*ibidem*). From a psychometric perspective, the internal consistency of the subscales of the RSA was satisfactory, ranging from 0.67 to 0.90. The test–retest correlations were all satisfactory for the subscales of RSA, ranging from 0.69 to 0.84 ($p < 0.01$)[76].

Insomnia. The Insomnia Severity Index (ISI[72,77]) is a 7-item self-report brief questionnaire designed to assess the severity of insomnia symptoms and sleep disorders. Given the weekly frequency, questions were referred to the last week and participants were asked to report the severity of symptoms on a 5-point Likert scale (ranging from 0 = "no problem" to 4 = "very severe problem"). Sleep was proven to be affected by anxiety/stress levels and to be modulated by mindfulness practice[21,22]. ISI internal consistency was excellent for both clinical and non-clinical samples (alpha of 0.90 and 0.91). Convergent validity was supported by significant correlations between total ISI score and measures of fatigue, quality of life, anxiety, and depression[72].

Statistical analyses. In longitudinal analyses, the time course of each variable of interest (i.e., specific habits and the subscales from each questionnaire) was analysed by using mixed-effects linear models. In each model, the variable of interest was used as the dependent variable, while time and group (2-level factor: intervention vs. control) were used in interaction as fixed effects. Time was coded as a continuous variable, representing the weeks of training (therefore ranging from 0 to 8). Participants' origin (2-level factor: banking group vs. students and acquaintances) was co-varied in all longitudinal analyses to control for possible biases related to this variable. Since a significant difference between the intervention group and the control group was found in the FFMQ—Acting with awareness variable in t0 (see Supplementary Information), we also co-varied this variable in all longitudinal analyses to investigate whether group differences had an influence on the results. Random intercept and time effect were computed on each participant. As a matter of fact, the multilevel nature of mixed-effects models allowed us to fit a regression line for each participant in each variable, and then compare the time course (i.e., the slope of the regression line) between groups[78]. Degrees of freedom in mixed-effects models were computed using Satterthwaite's approximation.

The main effect of interest was the two-way interaction time × group, as this effect represents a different trend over time for the intervention group compared to the control group. When this interaction effect was found as statistically significant, a simple slope analysis was performed in order to test whether the time slope was significantly different from zero in the two groups. The simple slope analysis was performed also when the inferential tests suggested a trend towards a difference between the two groups ($p < 0.06$) since we a priori hypothesized differences over time between the two groups and these trends could suggest their presence. Moreover, when testing planned comparisons, the interaction effects probed by using simple slope analyses do not necessarily need to be statistically significant if comparisons are based on a priori hypotheses[79]. To control for Type I error, all inferential tests in simple slope comparisons were corrected by using Tukey's HSD method.

Moreover, we made a specific focus on participants in the intervention group to investigate what indices of well-being are most affected by the frequency of practice and difficulty perceived in practice. When considering data from the intervention group in intermediate and final surveys (i.e., weeks from 1 to 8), we computed a Pearson's correlation matrix between the frequency of practice (and difficulty perceived in practicing) and all the state variables we recorded in the questionnaires (i.e., FFMQ-15, ERQ, PANAS, DASS-21, RSA, ISI). All correlation tests are corrected for multiple comparisons by using Tukey's HSD method.

All statistical analyses were performed in RStudio software[80]. Power analysis was performed by using the *pwr* package[81]; mixed-effects models were estimated by using the *lme4* and *lmerTest* packages[78,82]; simple slope analyses were performed with the *gamlj* package[83], based on *emmeans*[84]; plots were created using the *ggplot2* package[85].

Data availability

Data and materials will be made available by the authors upon request, without undue reservation.

Received: 18 November 2021; Accepted: 1 April 2022
Published online: 20 April 2022

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Acknowledgements
The research was conducted under a cooperative agreement between the IMT School for Advanced Studies Lucca and Intesa Sanpaolo Innovation Center S.p.A. and Intesa Sanpaolo banking group. The authors would like to thank Francesca Maggi from Intesa Sanpaolo Innovation Center—Neuroscience Lab for her precious contribution during data collection, Andrea Minogini (Group Senior Director—People & Process Care—Intesa Sanpaolo) and Andrea Prampolini (Head of Financial Markets Analytics & Digital Solutions Intesa Sanpaolo) for their contribution, Marco Poggi and Mida S.p.A. society for the audio materials used during the mindfulness program, Luigi Ruggerone (Head of Trend Analysis and Applied Research—Intesa Sanpaolo Innovation Center) for his insightful comments, and Alessandra Virgillito for her precious revision and clever comments on the manuscript.

Author contributions
F.B., A.P.M., and E.R. contributed to the design and the conception of the research. F.B. contributed to the implementation and the analysis of the results. F.B. and F.Z. contributed to administering the mindfulness intervention. F.B. contributed to writing the manuscript. F.B., A.P.M., and E.R. contributed to the manuscript revision. S.D'A., as a member of Intesa Sanpaolo Innovation Center S.p.A., assisted with the project management between IMT School for Advanced Studies Lucca and Intesa Sanpaolo Group. All authors contributed to the article, read and approved the submitted version.

Funding
The authors acknowledge financial support from Intesa Sanpaolo Innovation Center S.p.A.

Competing interests
The authors declare no competing interests.

Additional information
Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-022-10361-2.

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Mindfulness
https://doi.org/10.1007/s12671-022-01885-9

REVIEW

Mindfulness-Based School Interventions: a Systematic Review of Outcome Evidence Quality by Study Design

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Accepted: 28 March 2022

Abstract

Objectives The purpose of this systematic review was to assess the current literature on mindfulness-based school interventions (MBSIs) by evaluating evidence across specific outcomes for youth.

Methods We evaluated 77 studies with a total sample of 12,358 students across five continents, assessing the quality of each study through a robust coding system for evidence-based guidelines. Coders rated each study numerically per study design as 1 + + (RCT with a very low risk of bias) to 4 (expert opinion) and across studies for the corresponding evidence letter grade, from highest quality ("A Grade") to lowest quality ("D Grade") evidence.

Results The highest quality evidence ("A Grade") across outcomes indicated that MBSIs increased prosocial behavior, resilience, executive function, attention, and mindfulness, and decreased anxiety, attention problems/ADHD behaviors, and conduct behaviors. The highest quality evidence for well-being was split, with some studies showing increased well-being and some showing no improvements. The highest quality evidence suggests MBSIs have a null effect on depression symptoms.

Conclusions This review demonstrates the promise of incorporating mindfulness interventions in school settings for improving certain youth outcomes. We urge researchers interested in MBSIs to study their effectiveness using more rigorous designs (e.g., RCTs with active control groups, multi-method outcome assessment, and follow-up evaluation), to minimize bias and promote higher quality—not just increased quantity—evidence that can be relied upon to guide school-based practice.

Keyword Mindfulness · School-based interventions · Youth · Systematic review · Evidence-based practice · School mental health

Many preschool, elementary, and high school students experience problems related to anger, anxiety, depression, and low self-esteem (Barnes et al., 2003; Fisher, 2006; Langer et al., 2015; Mendelson et al., 2010; Rempel, 2012) that negatively influence their academic and social development (Leigh & Clark, 2018; Maughan et al., 2013; Murphy et al., 2015) and have lasting effects on their well-being (Steger & Kashdan, 2009). Schools can play a pivotal role in promoting students' mental health and their social, emotional, and behavioral development (Barnes et al., 2003; Fisher, 2006; Mendelson et al., 2010). To address these challenges, many schools have adopted mindfulness-based interventions (MBIs). Studies conducted over the past 15 years have examined the impact of MBIs on mental health, educational performance, and related outcomes in children and adolescents (Kallapiran et al., 2015; Meiklejohn et al., 2012).

Mindfulness is the process by which we "pay attention in a particular way: on purpose, in the present moment and nonjudgmentally" (Baer, 2003; Roeser, 2014). Originally adapted for adults, practicing mindfulness typically includes meditation exercises and bringing mindful awareness to daily activities, such as eating and walking. These practices are intended to foster purposeful focused attention,

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Published online: 23 May 2022

coupled with a nonjudgmental attitude toward moment-to-moment experience (Kabat-Zinn, 2003). Mindfulness-based interventions target many aspects of well-being, resiliency, and mental health by cultivating a present-centered awareness and acceptance (Fjorback et al., 2011; Gawrysiak et al., 2018; Greeson, 2009; Khoury et al., 2013; Roeser, 2014). In particular, emotion regulation has been the focus of much MBI research (Guendelman et al., 2017; Wisner, 2014). Individuals who have difficulty with emotion regulation have problems processing, experiencing, expressing, and managing emotions effectively (Chambers et al., 2009). Furthermore, the nonjudgmental awareness in mindfulness may facilitate a healthy engagement with emotions, allowing individuals to experience and express their emotions without *under-engagement* (e.g., experiential avoidance and thought suppression) or *over-engagement* (e.g., worry and rumination; Hayes & Feldman, 2004; Ivanovski & Malhi, 2007). Specifically, research indicates that MBI with adults can increase awareness of moment-to-moment experience and promote reflection, empathy, and caring for others (Hölzel et al., 2011). Mindfulness training with adults can also improve stress regulation, resilience, anxiety, and depression (Forkmann et al., 2014; Hofmann et al., 2010; Irving et al., 2009; Klatt et al., 2015; Li & Bressington, 2019; Marcus et al., 2003; Morton et al., 2020; Tang et al., 2007).

Despite extensive empirical support for mindfulness practice with adults, the question of whether MBI also benefits youth remain less clear, as far fewer studies examine mindfulness practice with school-aged children and adolescents (Caldwell et al., 2019; Greenberg & Harris, 2012; Zoogman et al., 2015). Mindfulness practices have gained recent worldwide popularity as a school-based intervention (Burke, 2010; Greenberg & Harris, 2012; Zenner et al., 2014). These mindfulness-based school interventions (MBSIs) target a host of outcomes, including increasing awareness, empathy, compassion, gratitude, perspective-taking, psychological flexibility, present centeredness, and self-regulation such as regulating behaviors, cognitions, and emotions (Bernay et al., 2016; Eva & Thayer, 2017; Hill & Updegraff, 2012; Moses & Barlow, 2006; Sapthiang et al., 2019; Schonert-Reichl et al., 2015). MBIs with youth have shown reductions in behavioral problems, affective disturbances, stress, and suicidal ideation as well as improvements in ability to manage anger, well-being, and sense of belonging (Carsley et al., 2018; Coholic et al., 2019; Felver et al., 2016; Murray et al., 2018). Empirical studies have also demonstrated improvements in attention skills, social skills, sleep quality, and reductions in somatic and externalizing symptoms (Beauchemin et al., 2008; Biegel et al., 2009; Bootzin et al., 2005; Britton et al., 2010; Napoli et al., 2005; Zylowska et al., 2008).

The practices incorporated in MBSIs include psychoeducation about emotions and mindfulness, as well as specific mindfulness exercises, including awareness of breath, mindful body scans, and awareness of thoughts, feelings, and sensations. MBSIs are often delivered in the context of whole class instruction (general population of students) or targeted intervention (at-risk or clinical populations; Kuyken et al., 2013; Napoli et al., 2005; Raes et al., 2014). In addition, MBSIs are offered in a variety of formats (i.e., delivered by the research team or teacher, as multi-session programs or brief single-session workshops, with a variety of activities and exercises included), which previous reviews have shown to impact the effectiveness of MBSIs (Bender et al., 2018; Carsley et al., 2018; Schonert-Reichl & Roeser, 2016; Semple et al., 2017).

Mindfulness practices targeting school-aged populations include developmentally appropriate adaptations for children and adolescents (Bostic et al., 2015; Carsley et al., 2018). For example, time for practices is shorter; they incorporate multiple sensory modalities into activities, and rely on simplified metaphors to communicate difficult concepts; and there is more time for explaining key concepts (Burke, 2010; Felver et al., 2013). Most MBSIs tested in schools are designed to increase resilience to stress and decrease depression and anxiety symptoms (Wisner, 2014). Early studies showed promising results in decreasing anxiety, fatigue, depressive symptoms, stress-related issues, and disorders for various conditions (Bei et al., 2013; Fjorback et al., 2011; Grossman et al., 2004; Piet & Hougaard, 2011; Piet et al., 2012). Furthermore, mindfulness training for youth has been shown to be efficacious for some neurocognitive, psychosocial, and psychobiological outcomes while also showing that MBIs are feasible and acceptable for youth in schools (Black, 2015). Although there have been studies examining outcomes of MBIs, there are limited reviews focused solely on school-based interventions. Additionally, it is important to examine which outcomes show promising results together with outcomes that are not improved through MBSIs. Previous reviews and meta-analyses examined the quantity and strength of the evidence but did not weigh this by the quality of the evidence according to research design. Thus, the present study addresses this gap in the literature by providing a systematic review that examines MBSIs on youth outcomes by quality of study design using evidence-based guidelines, which is key to advancing the field of MBSIs. Prior to turning to the present study, we first consider what is known from previous reviews of MBI with youth and in schools.

Several meta-analytic and systematic reviews include MBIs delivered across multiple settings, including schools. Previous reviews found that youth who practiced mindfulness have positive outcomes for cognitive performance, resilience to stress, mindfulness, executive functioning, attention, depression, anxiety, and negative behaviors (Chi et al., 2018; Dunning et al., 2019; Zenner et al., 2014). Following is a summary of ten published meta-analytic and

systematic reviews that examined the use of MBIs for youth (Bender et al., 2018; Black, 2015; Carsley et al., 2018; Kallapiran et al., 2015; Klingbeil, Fischer, et al., 2017; Klingbeil, Renshaw, et al., 2017; Maynard et al., 2017; Semple et al., 2017; Zenner et al., 2014; Zoogman et al., 2015). First, it is important to note the types of primary studies that were included. One meta-analysis included single-case designs (Klingbeil, Fischer, et al., 2017), three included any group designs (Carsley et al., 2018; Klingbeil, Renshaw, et al., 2017; Zoogman et al., 2015), and one included only randomized controlled trials (RCTs; Kallapiran et al., 2015). Five systematic reviews included randomized control trials, nonrandomized control trials, case studies, cohort studies, and quasi-experimental designs (Bender et al., 2018; Black, 2015; Maynard et al., 2017; Semple et al., 2017; Zenner et al., 2014). The findings from these several reviews across study design types found that MBIs with youth improve cognitive and socio-emotional competencies, executive functions, depressive symptoms, anxiety symptoms, rumination, internalizing problems, externalizing problems, prosocial skills, stress, physical health, well-being, perceptions of peer relations, mood, quality of life, academic achievement, disruptive behavior, and negative and positive emotions (Bender et al., 2018; Black, 2015; Carsley et al., 2018; Kallapiran et al., 2015; Klingbeil, Fischer, et al., 2017; Klingbeil, Renshaw, et al., 2017; Maynard et al., 2017; Semple et al., 2017; Zenner et al., 2014; Zoogman et al., 2015). Compared to MBIs in other settings, MBSIs have effects that are in the cognitive domain as well as in psychological measures of stress, coping, and resilience (Zenner et al., 2014). Furthermore, MBSIs appear to be more effective for decreases in negative mental traits (e.g., affective disturbances, anxiety) as opposed to increases in positive mental traits (e.g., positive affect, prosocial functioning; McKeering & Hwang, 2019). However, further research comparing the relative strength of MBSIs for improving different mental traits is needed, particularly research weighting evidence of these outcomes by study design.

These reviews indicate the need for future studies to examine the effects of MBI with youth and in schools on symptoms of psychopathology, to include more active controls as the comparison group to allow future meta-analyses to compare the effects of the intervention, and to examine potential moderators that potentially influence program effectiveness (e.g., length of program), as well as to investigate the additional benefit of incorporating mindfulness practices with other evidence-based practices.

Considering the findings from the previous meta-analyses and systematic reviews, there seems to be a clear pattern of evidence suggesting that MBIs are, on the whole, safe and effective for use with youth (generally) as well as in schools (specifically) for improving a host of valued outcomes. Although most of the outcomes in most reviews showed small to moderate positive effects, it is noteworthy that some reviews yielded null effects for some outcomes. For example, Maynard et al. (2017) found no effect for behavioral and academic outcomes; similarly, Zenner et al. (2014) found no effect for emotional problems. Therefore, further examination is needed on the consistency of positive outcomes from MBSIs. That said, it is also important to note that none of the previous reviews indicated harmful or iatrogenic effects.

Finally, previous reviews have not focused on grading the quality of evidence but instead produced the average effect sizes. Given that several reviews collapsed all the studies together, the evidential quality is mixed, which makes it challenging to know how strong the quality of evidence is that supports the outcomes (Bender et al., 2018; Black, 2015; Carsley et al., 2018; Klingbeil, Fischer, et al., 2017; Klingbeil, Renshaw, et al., 2017; Maynard et al., 2017; Semple et al., 2017; Zenner et al., 2014; Zoogman et al., 2015). Likewise, one review that only examined RCTs produced much higher quality evidence (Kallapiran et al., 2015). Since these reviews either collapsed all studies together or looked at RCT only, none of the reviews systematically considered the quality of evidence both across study designs and within RCTs.

To address the growing interest in MBSIs and to inform those choosing programs, we systematically reviewed published studies of MBSIs for youth in schools (cf. Felver et al., 2016; Zenner et al., 2014). Unlike prior systematic reviews and meta-analyses, our review sought to examine the *quality* of outcome evidence by research design, as well as the quantity of evidence across studies. Specifically, the first objective was to determine the quality of the evidence across diverse outcomes including well-being, self-compassion, social functioning, mental health, self-regulation and emotionality, mindful awareness, attentional focus, psychological and physiological stress, problem behaviors, academic performance, and acceptability. The second objective was to investigate the quantity of the evidence across studies. Finally, the quality and quantity combined was examined across studies to determine which outcomes are most robustly associated with MBSIs. We anticipate that findings from our systematic review would contribute to the literature by providing evidence-based recommendations to clinicians, educators, and school-based researchers on which specific outcomes can be reliably targeted with MBSIs.

Methods

We identified studies through a systematic search of published articles of MBSIs with youth from the first available date until July 2021. The electronic databases searched were PsycINFO, EBSCOHost, MEDLINE, and CINAHL using terms related to MBSIs: (school-based mindfulness

interventions subt.exact ((“mindfulness” OR “mindfulness-based interventions” AND “students” OR “preschool students” OR “elementary school students” OR “high school students” OR “adolescent” OR “schools” OR “adolescent development” OR “curriculum” OR “teachers” OR “educational programs” OR “middle school students” OR “elementary school teachers” OR “public school education”) NOT (“middle aged” OR “yoga” OR “college students” OR “young adult” OR “occupational stress” OR “parents” OR “chronic pain” OR “drug abuse” OR “neoplasms” OR “parenting” OR “substance-related disorders” OR “relapse prevention” OR “no terms assigned” OR “psychotherapy” OR “test construction” OR “health care services” OR “medical students” OR “mobile phones” OR “adult” OR “pregnancy”)) NOT su.exact (“Thirties (30–39 yrs)” OR “Middle Age (40–64 yrs)” OR “Aged (65 yrs & older)” OR “Very Old (85 yrs & older)”) NOT po.exact (“Outpatient” OR “Inpatient” OR “Animal”) AND PEER(yes) AND la.exact (“English”) NOT rtype.exact (“Comment/Reply” OR “Editorial” OR “Erratum/Correction” OR “Review-Book” OR “Letter”)). We found 352 articles through this initial search prior to eligibility coding (see Fig. 1 for the study selection process). In defining MBSIs, we selected only intervention studies that applied mindfulness meditation including dialectical behavior therapy (Linehan, 1993) and acceptance and commitment therapy (Strosahl & Wilson, 1999) as intervention frameworks since they both focus on acceptance and mindfulness.

Eligibility Ratings

Two coders assessed the eligibility of each journal article for inclusion based on the following criteria: (1) peer-reviewed journal article; (2) mindfulness-based school intervention, program, or strategies; (3) mindfulness outcome on teachers or children and/or implementation outcomes; (4) review paper on school-based mindfulness interventions; and (5) grade levels from kindergarten to 12th grade. Exclusion criteria included the following: (1) studies focusing only on yoga, creativity, or other approaches not specific to mindfulness; (2) parent-based training on mindfulness; (3) clinic-based mindfulness interventions; (4) student age group ≥ 22 years (as students with disabilities in the USA can stay at school until they are 21 years old). Raters reached high inter-rater reliability ($k = 0.98$) in determining article eligibility. When raters disagreed, they discussed eligibility to reach a consensus.

Extracted Data from Studies

The following information was extracted from each study: (1) country, (2) sample characteristics (sample size, mean age [or age range if mean was not provided], percentage of males and females, ethnicity, socioeconomic status, whether children were of a special needs population), (3) information on the school level (preschool, elementary, middle, or high school), classroom setting (general education, special education, or alternative school; private or public), (4) type of intervention, (5) research design (quantitative, qualitative, or mixed), (6) evaluation design (e.g., RCT, pre-post), (7) the mediator (i.e., person who conducted the intervention), (8) the findings on outcomes (outcome measures), (9) outcome measure type (self-report, teacher-report, etc.), (10) control group, and (11) whether teacher training was provided. We believe it is important to consider the research and evaluation design of studies given the impact of methodological variations on the results. Furthermore, it is also essential to examine whether teacher training was provided since research shows that there are significant effects at follow-up

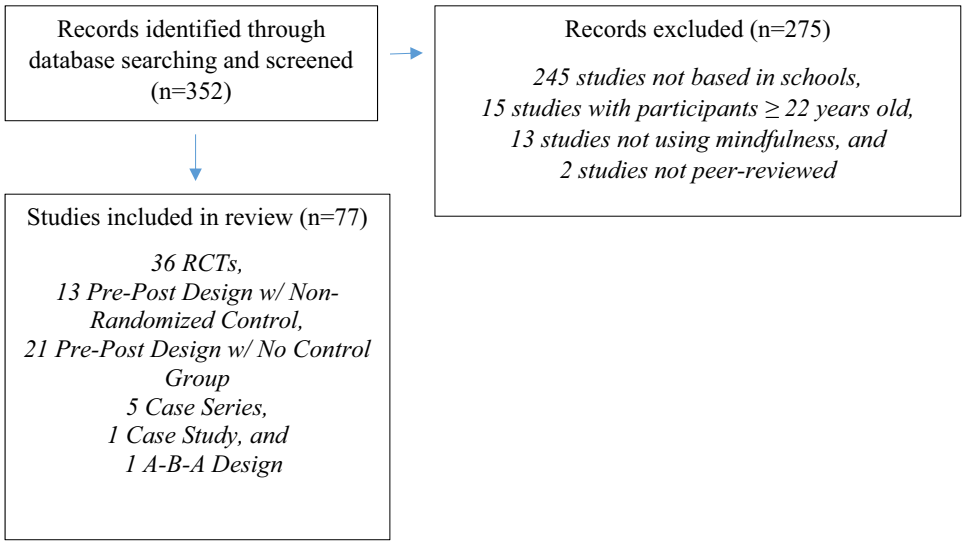

Fig. 1 Article screening, inclusion, and design

when teachers are trained to deliver the program (Carsley et al., 2018).

Evidence Ratings

We used a robust system for grading recommendations in evidence-based guidelines (Harbour & Miller, 2001) to weigh evidence per study design in a two-step process. Using PRISMA 2020 as a guideline for our systematic review, we used the Harbour and Miller (2001) ratings to examine the level of evidence since PRISMA 2020 recommends assessing certainty in the body of evidence of an outcome (item #15 in the PRISMA checklist) and to present assessments of certainty in the body of evidence for each outcome assessed (item #22 in the PRISMA checklist). We are not using the Harbour and Miller guidelines in replacement of the PRISMA 2020 guidelines, but rather to grade evidence per study design in order to adhere to items #15 and #22 in the checklist. As such, we graded evidence based on the methodological rigor of studies to draw conclusions about the state of the science of MBSIs, and to make informed recommendations to advance the field. First, for all eligible articles, two authors independently assigned a numerical rating regarding the level of evidence for each article on a scale outlined by Harbour and Miller (2001), ranging from 1 + + (RCTs with a very low risk of bias), 1 + (RCTs with a low risk of bias), 1 − (RCTs with a high risk of bias), 2 + + (high-quality case–control or cohort studies with a very low risk of confounds, bias, or chance, and a high probability that the relationship is causal), 2 + (well-conducted case–control or cohort studies with a low risk of confounds, bias, or chance and a moderate probability that the relationship is causal), 2 − (case–control or cohort studies with a high risk of confounds, bias, or chance and a significant risk that the relationship is not causal), 3 (non-analytic studies, e.g., case reports, case series) to 4 (expert opinion). We further specified criteria relating to risk of bias; for example, studies rated as 1 + + were RCTs that include at least three of the following criteria: competence/fidelity measurement, daily program implementer meetings, high participant attendance rate of 90% or higher, experienced program implementer, large sample size, 8 week or longer sessions, conducted follow-ups post-intervention. See Table 1 for the full grading system of recommendations in evidence-based guidelines. Using the breakdown mentioned above, ratings of studies included in this review ranged from 1 + +, 1 +, 1 −, 2 + +, 2 +, 2 −, 3 to 4, with

Table 1 Grading system for recommendations in evidence-based guidelines based on Harbour and Miller (2001)

Levels of evidence

- **1 + +** RCTs with a very low risk of bias, competence/fidelity measured, program implementers meet regularly to prevent drift, facilitator/teacher blind to study condition, participant attendance rate 90% or higher, program implementer has 3 + years of mindfulness training, large sample size (> 100), 8-week or longer, 10 session course, follow-ups on studies that are 12 months or longer
- **1 +** RCTs with a low risk of bias, facilitator/teacher blind to study condition, participant attendance rate 80% or higher, medium sample size (40–100), 6–7 week or 8–9 session course
- **1 −** RCTs with a high risk of bias, small sample size (< 40), self-reported data, facilitator/teacher not blind to study condition, competence/fidelity not formally measured, single study site (less generalizable), high percentage of female vs. male (or vice versa), < 6 week or < 8 session, implementation of program was shorter than intended
- **2 + +** High-quality case–control or cohort studies with a very low risk of confounds, bias, or chance and a high probability that the relationship is causal, competence/fidelity measured, program implementers meet regularly to prevent drift, facilitator/teacher blind to study condition, participant attendance rate 90% or higher, program implementer has 3 + years of mindfulness training, large sample size (> 100), 8-week or longer, 10 session course, follow-ups on studies that are 12 months or longer, has a control group
- **2 +** Well-conducted case–control or cohort studies with a low risk of confounds, bias, or chance and a moderate probability that the relationship is causal, facilitator/teacher blind to study condition, participant attendance rate 80% or higher, medium sample size (40–100), 6–7 week or 8–9 session course
- **2 −** Case–control or cohort studies with a high risk of confounds, bias, or chance and a significant risk that the relationship is not causal, small sample size (< 40), self-reported data, facilitator/teacher not blind to study condition, competence/fidelity not formally measured, single study sight (less generalizable), missing data, high percentage of female vs. male (vice versa), < 6 week or < 8 session, lack of control group, implementation of program was shorter than intended
- **3** Non-analytic studies, e.g., case reports, case series
- **4** Expert opinion

Grades of recommendations

- **A** At least one RCT rated as 1 + + and directly applicable to the target population, or a body of evidence consisting principally of studies rated as 1 + directly applicable to the target population and demonstrating overall consistency of results
- **B** A body of evidence including studies rated as 2 + + directly applicable to the target population and demonstrating overall consistency of results, or extrapolated evidence from studies rated as 1 + + or 1 +
- **C** A body of evidence including studies rated as 2 + directly applicable to the target population and demonstrating overall consistency of results, or extrapolated evidence from studies rated as 2 + +
- **D** Evidence level 3 or 4 or extrapolated evidence from studies rated as 2 +

high inter-rater reliability ($k = 0.91$). Raters discussed the six discrepant articles that they initially rated differently until they reached a consensus on the ratings.

Second, after determining the level of evidence for each article, a lettered grading system was applied based on a summary of the numbered ratings across studies: A (at least one RCT rated as 1 + + and directly applicable to the target population, or a body of evidence consisting principally of studies rated as 1 + directly applicable to the target population and demonstrating overall consistency of results), B (a body of evidence including studies rated as 2 + + directly applicable to the target population and demonstrating overall consistency of results), C (a body of evidence including studies rated as 2 + directly applicable to the target population and demonstrating overall consistency of results), and D (a body of evidence including studies rated as 3 or 4). See Table 1 for the full grading system of recommendations in evidence-based guidelines with further specificity per evidence rating level. There was often variability in the numbered study ratings across outcome measures. The ultimate letter grade was determined by the inclusion of the number and number rating for high-quality studies (1 + + or 1 +), as described above. For example, for an outcome documented in two studies rated 1 + and 3, the letter grade would be Grade B as there was only one 1 + rated study (if there was a 1 + + rated study or a body of 1 + rated studies, the letter grade would be Grade A).

Results

Study Characteristics

We identified 77 eligible articles, which incorporated data from 12,358 students across 5 continents (North America, South America, Europe, Asia, and Australasia). The breakdown of articles by methods was as follows: 9 qualitative, 49 quantitative, and 19 mixed methods. For the control group type, there were 28 active control groups, 21 passive control groups, and 28 without a control group. There were 35 elementary schools, 8 middle schools, 25 high schools, 1 preschool, 5 mixes of elementary and middle schools, and 3 mixes of middle and high schools. Given that all studies took place in a school setting, the data from this review are community-based instead of clinically based.

Forty-three percent of schools did not report on setting (e.g., public, private), but across those that did, 22% were private, 55% public, 5% alternative schools, 2% specialized school, and 16% a combination of schools. Fifty-two percent of children were female. Forty percent of studies did not include race/ethnicity, but those that did showed a diverse sample of 44% while 16% had homogenous samples within the study. Likewise, most studies did not include socioeconomic status (62%).

Regarding the person that mediated the treatment delivery, 3% did not report on the mediator, and of the studies that did report on the mediator, 40% were researchers, 28% teachers, 19% trained instructors, 7% mix of researcher and teacher/mindfulness instructor, 4% mindfulness instructors, and 3% counselors. In terms of teacher training on mindfulness interventions, only 31% reported teacher training. Furthermore, 50% reported using self-report as their outcome measure, 17% used both teacher report and self-report, 11% used a cognitive test with teacher or self-report, 8% used only teacher report, 8% used two or more measures, and 7% used other forms of outcome measure (i.e., computer tasks, cognitive tests, observation). See Online Resource 1 and Online Resource 2 for participant demographics, design, and methods for each of the 77 included studies.

Outcomes

Outcomes from studies of MBSIs fit into the following 11 categories determined by the main findings: (1) well-being, (2) self-compassion, (3) social functioning, (4) mental health, (5) self-regulation and emotionality, (6) mindful awareness, (7) attentional focus, (8) psychological and physiological stress, (9) problem behaviors, (10) academic performance, and (11) acceptability. For the purposes of this study, we conceptualized well-being as subjective well-being (i.e., feelings of contentment, life satisfaction) and mental health as per clinical descriptors (i.e., depression, anxiety, suicidality, trauma, eating disorders).

Summary of the Highest Quality Evidence Across Outcomes

In this systematic review of the quality of existing scientific literature base of MBSIs (see the "Methods" section, "Evidence Ratings"), the strongest level of evidence ("A Grade") across outcomes indicated that MBSIs increased prosocial behavior, resilience, executive function, attention, and mindfulness, and decreased anxiety, attention problems/ADHD behaviors, and conduct behaviors, with evidence for well-being being split, with some studies showing increased well-being and some showing no improvements. As described in the "Methods" section, "A Grade" evidence comes from at least one RCT rated as 1 + + and directly applicable to the target population, or a body of evidence consisting principally of studies rated as 1 + directly applicable to the target population and demonstrating overall consistency of results. See Table 1 for a description of each level of evidence, Table 2 for the outcomes per study, Fig. 2 for the breakdown of studies for each outcome by quality, and Online Resource 3 for the numbered list of included studies from Table 2.

Table 2 Results and evidence grades from MBSI studies

Category	Results	References	Grade of evidence
1) Well-being	***General well-being***		
	↑ Well-being	35, 45, 64, 67, 68	A
	= Well-being	10, 16, 22, 32, 33	A
	↑ Feelings of contentment	13	D
	↓ Life satisfaction	65	C
2) Self-compassion	***Self-compassion/intrapersonal***		
	↑ Self-compassion	13	D
	↑ Intrapersonal strengths	73	C
	↑ Embracing life	45	D
	↑ Self-acceptance	15	C
	↑ School self-concept	58	B
	↓ Inferiority complex	45	D
3) Social functioning	***Social relationships***		
	↑ Interpersonal problems	28	D
	↑ Interpersonal strengths	73	C
	↑ Psychosocial functioning	73	C
	↑ Relationships with others	71	D
	↑ Prosocial behavior	60, 71	A
	= Psychosocial adjustment	47	D
	↑ Empathy	45, 58	B
	= Empathy	53	C
	↑ Connection with others	45	D
	= Compassion	53	C
	↑ Caring/respect for others	11	D
	↑ Social competence	25	B
	↑ Social skills	6	D
	↓ Social problems	52	C
	Social participation		
	↑ Collaboration	19	D
	↑ Communication	19	D
	↑ Participation in activities	11	D
	Social bias		
	↓ Stereotype/prejudice towards Israeli-Palestinian outgroup	9	B
4) Mental health	***Depression***		
	↓ Depressive symptoms	8, 12, 20, 46, 48, 54	B
	= Depressive symptoms	16, 18, 32, 33	A
	↓ Rumination	62	C
	Anxiety		
	↓ Anxiety symptoms	7, 8, 41, 48, 62, 63	B
	↓ Generalized Anxiety Disorder	42	A
	↓ State and trait anxiety	6	D
	= Anxiety	16, 32, 33	C
	↓ Worry	42	A
	↓ Panic disorder	42	A
	↓ Obsessive-compulsive Disorder	42	A
	↓ Psychosomatic complaints	49	C
	↓ Internalizing problems	14, 18, 27, 42	A
	Suicidality		

Table 2 (continued)

Category	Results	References	Grade of evidence
	↓ Suicidal thoughts	44	C
	Trauma		
	↓ Posttraumatic symptoms	63	B
	Eating disorder		
	↓ Dietary restraint	1	C
	↓ Thin ideal internalization	1	C
	↓ Eating disorder symptoms	1	C
	↓ Psychosocial impairment	1	C
	= Weight/shape concern	32, 33	C
	↓ Weight/shape concern	1	C
5) Self-regulation and emotionality	***Self-regulation***		
	↑ Self-regulation	23, 28, 44, 53, 66	B
	↑ Emotion regulation	4, 15, 49, 58, 71	B
	↑ Resilience	70	A
	↑ Coping skills	63	B
	↑ Distress tolerance	59	D
	↑ Emotional awareness	49	C
	↑ Emotional clarity	49	C
	↑ Feelings of relaxation	15	C
	↑ Relaxed in school	66	B
	↑ Calmness	15	C
	↑ Self-control	11, 75	D
	↑ Effortful control	64	D
	↑ Anger management skills	68	D
	↑ Executive function	31, 34, 43, 52, 77	A
	↑ Cognitive control	50, 58	B
	↑ Cognitive inhibition	74	C
	Emotionality		
	↑ Positive mood	45, 55	B
	↓ Negative feelings	9, 21, 37	B
	↓ Negative affect	15, 45, 69	C
	= Negative affect	16	C
6) Mindful awareness	***Mindfulness***		
	↑ Mindfulness	10, 21, 23, 37, 59	A
	= Mindfulness	22, 33, 38	C
	↑ Awareness of thoughts	76	B
	↑ Awareness of feelings	76	B
	↑ Awareness of emotions	76	B
	↑ Awareness of bodily sensations	76	B
	↑ Being present in life	76	B
	↑ Sense of efficacy	59	D
	↓ Mind-wandering	58	B
	Positive outlook		
	↑ Optimism	23, 57	C
	↑ Positive thinking	23	D
	Perspective-taking	58	B
	↑ Perspective-taking		
7) Attentional focus	***Attention***		
	↑ Attention	11, 22, 31, 37, 53, 66, 72	A

Table 2 (continued)

Category	Results	References	Grade of evidence
	↑ Selective attention	51	C
	↑ Attention awareness	23	D
	↑ Concentration	55	B
	↑ Controlled thoughts	75	D
	↑ On-task behavior	36, 56	D
	= Task-shifted facilitation	1	C
	↓ Attention problems	14, 18, 48	A
	↓ Distractibility	66	B
	↓ Off-task behaviors	24, 56	D
	↓ ADHD behaviors	51, 60	A
	Impulsivity		
	↓ Impulsivity	26	B
8) Psychological and physiological stress	***Psychological stress***		
	↓ Stress	5, 17, 29, 46, 49, 67, 68, 75	B
	↑ Stress	28, 61	D
	= Stress	16	C
	Physiological stress		
	↑ Stress physiology—skin temperature/conductivity	40	B
	↓ Stress physiology—cortisol	58	B
	↓ Right amygdala activation to fearful stimulus	5	B
	↓ Tiredness	15	C
	↓ Aches/pains	15	C
	↑ Sleep	7	D
	↑ Functional connectivity	5	B
	↑ Brain plasticity	5	B
9) Problem behaviors	↓ Aggression	26, 48, 52	B
	↓ Disruptive behaviors	39	D
	↓ Conduct behavior	2, 48, 60, 71	A
	↓ Externalizing problems	14, 27	C
10) Academic performance	***General academic performance***		
	↑ School specific efficacy	28	D
	↑ Academic performance	6, 8, 25	B
	↑ Creativity	19	D
	↑ Critical thinking	19	D
	↑ Meta-cognition	69	D
	↑ Auditory-verbal memory	55	B
	↑ Grade Point Average	3	B
	↑ Data-driven information processing	74	C
	↑ Academically engaged behavior	24	D
	↑ Positive attitude towards academic subjects	37	B
	↓ Test anxiety	51	B
	↓ Cognitive errors	50	C
	Math		
	↑ Math performance	58	B
	↑ Math score	3	B
	Reading		
	↑ Grades in reading	2	C
	= Reading fluency	30	D
	Science		

Table 2 (continued)

Category	Results	References	Grade of evidence
	↑ Grades in science	2	C
	Social studies		
	↑ Social studies score	3	B
11) Acceptability	↑ Satisfaction with program	61	D
	↑ Understanding and willingness to use strategies	61	D
	↑ Acceptance of mindfulness	7, 32, 68	C

Note: ↑ increase, ↓ decrease, = no change. See Online Resource 3 for numbered list of included studies

Below we summarize the results per outcome type, highlighting "A Grade" and "B Grade" evidence, and noting any differences that were apparent between the overall summary of results from pre- to post-treatment incorporating all studies and when examining studies per research design (quantitative, qualitative, and mixed), evaluation design (RCT, pre-post, single case/series, etc.), or per control group type (active, passive, none). For a full breakdown of outcomes by these study characteristics and individual study evidence ratings, see Online Resource 4.

Well-being

Ten of the 77 eligible articles (13%) targeted well-being domain outcomes. Results were mixed regarding well-being outcomes, with 50% of studies showing improved well-being, and the rest showing no difference (42%) or lower well-being (8%). The mixed results from studies specifically studying well-being were both from "A Grade" evidence. No differences were apparent when examining results per research design, evaluation design, or control group type, except no pre-post design studies reported null improvements in well-being.

Self-compassion

Five of the 77 eligible articles (6%) targeted self-compassion domain outcomes. 100% of studies across research designs, evaluation designs, and control group types that examined self-compassion showed greater improvement. There was no "A Grade" evidence and the strongest evidence ("B Grade") documented higher school self-concept.

Social Functioning

Fifteen of 77 eligible articles (19%) targeted social functioning domain outcomes. Most studies (86%) that examined social functioning found that MBSIs improved social relationships and social participation as well as reduced social bias, and those that found no improvements were of low evidence quality ("C and D Grades"). The highest quality of evidence documented ("A Grade") was for improvements in prosocial behavior, followed by "B Grade" evidence showing improvements in empathy and social competence, and reduced prejudice towards outgroups. No differences were apparent when examining results per research design, evaluation design, or control group type, except no pre-post or passive design studies reported null improvements in social functioning.

Mental Health

Nineteen of 77 eligible articles (25%) targeted mental health domain outcomes. Most studies reported reduced depression and anxiety symptoms (71% and 80%, respectively). However, higher quality evidence ("A Grade") shows no decrease in depression symptoms (compared to "B Grade" evidence that does show a decrease in depression symptoms). By contrast, studies showing no decrease in anxiety were of lower quality evidence ("C Grade") compared to evidence showing a decrease in generalized anxiety disorder, worry, and panic disorder ("A Grade"), or anxiety symptoms ("B Grade"). The one study examining suicidality and the one study examining trauma each found reduced symptoms. Only one of the three studies examining eating disorder symptoms reported a reduction in symptoms. No differences were apparent when examining results per research design, evaluation design, or control group type, except no pre-post design studies reported null improvements in mental health.

Self-regulation and Emotionality

Thirty-one of 77 eligible articles (40%) targeted self-regulation and emotionality domain outcomes. Most studies (97%) in this category reported improved self-regulation and emotionality across research designs, evaluation designs, and control group types, except for one study of "C Grade" evidence that found no change in negative affect. No differences were apparent when examining positive vs. null improvement studies in terms of research design, evaluation

design, or control group type. For the self-regulation category, the highest quality evidence ("A Grade") documented improvements in resilience and executive function, followed by "B Grade" evidence showing improvements in self- and emotion regulation, coping skills, and cognitive control, as well as more frequent relaxed states at school.

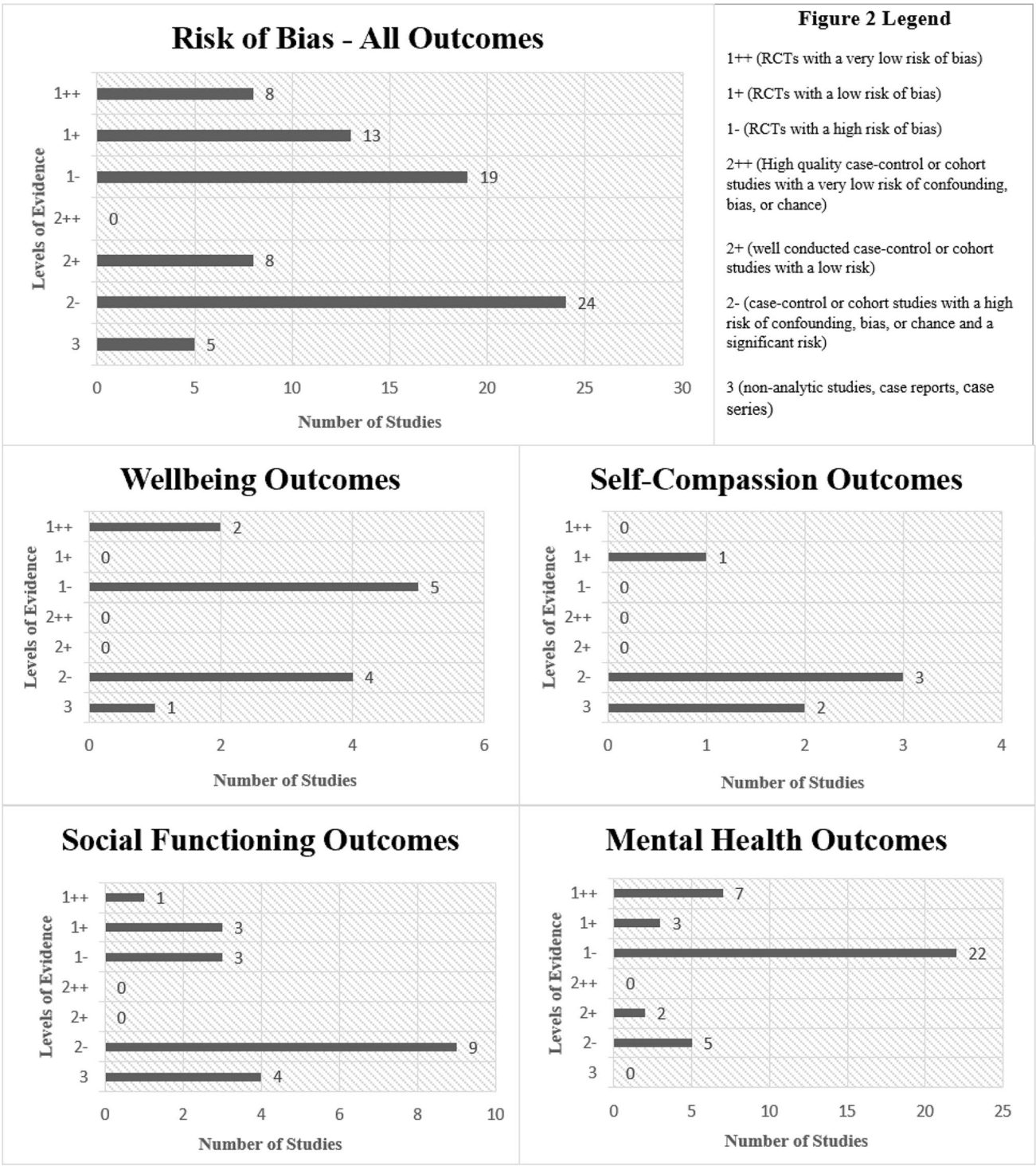

Fig. 2 Breakdown of studies for each outcome by quality. *Note*: Acceptability outcomes were not included in the breakdown as few studies examined this outcome

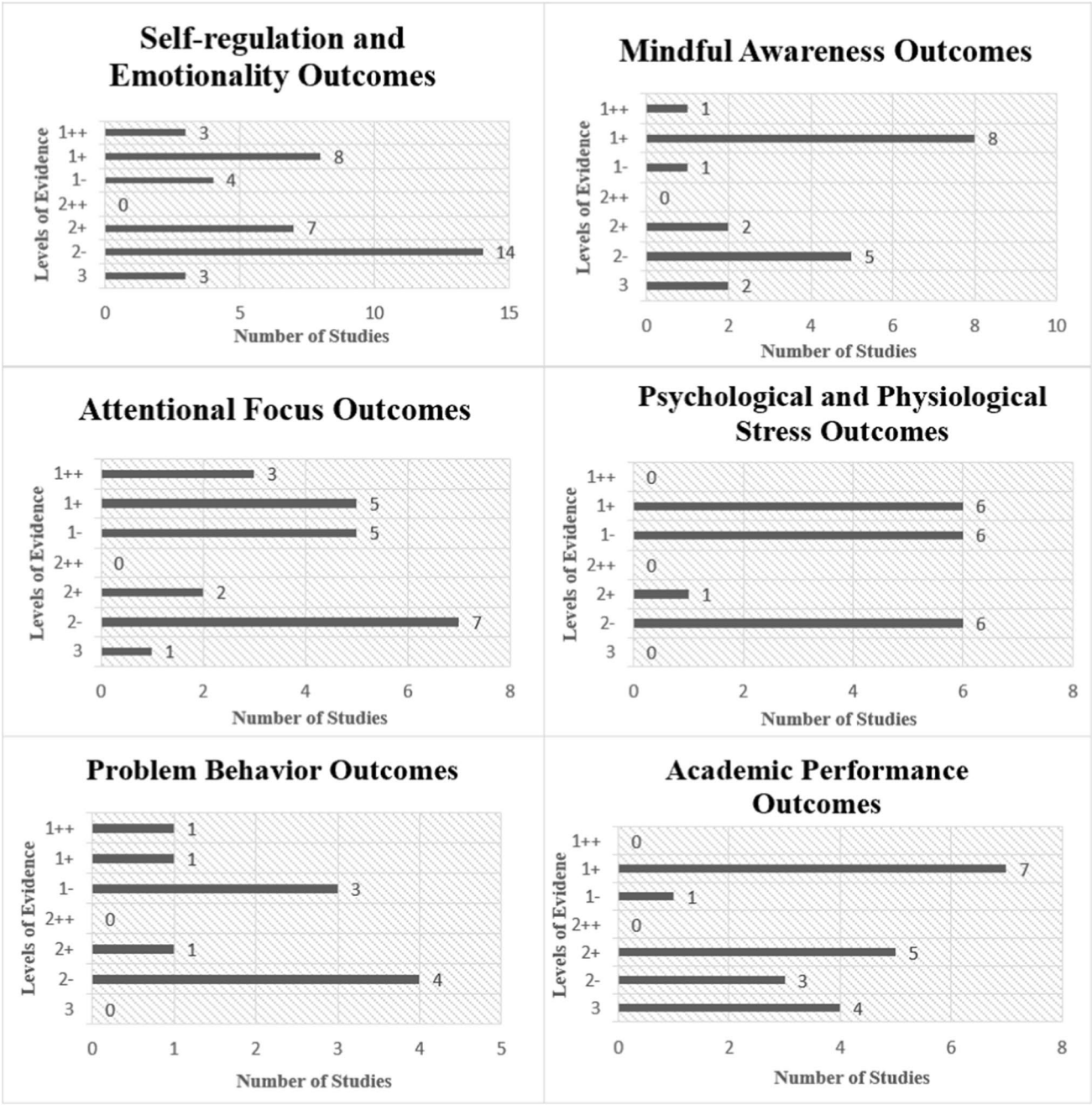

Fig. 2 (continued)

For the emotionality category, the highest quality studies ("B Grade") documented higher positive moods and lower negative feelings.

Mindful Awareness

Eleven of 77 eligible articles (14%) targeted mindful awareness domain outcomes. All studies documented improved perspective-taking and having a positive outlook, and most (73%) documented improvements in mindfulness; however, evidence showing no improvements in mindfulness was of a lower quality ("C Grade"). No differences were apparent between positive and null improvement studies when examining results per research design, evaluation design, or control group type. The strongest evidence ("A Grade") showed improvements in mindfulness, followed by "B Grade" evidence showing increased awareness of thoughts, feelings,

emotions, and bodily sensations, being more present in life as well as decreased mind-wandering.

Attentional Focus

Twenty of 77 eligible articles (26%) targeted attentional focus domain outcomes. Most studies (95%) showed improvements in attention and reduced impulsivity across research designs, evaluation designs, and control group types, except one study finding no effects in task-shifted facilitation; however, evidence showing no improvements was of a lower quality ("C Grade"). The highest quality evidence ("A Grade") found increased attention, and decreased attention problems and ADHD behaviors, followed by "B Grade" evidence showing increased concentration, and decreased distractibility and impulsivity.

Psychological and Physiological Stress

Fifteen of 77 eligible articles (19%) targeted psychological and physiological stress domain outcomes. Overall, most studies (73%) showed that MBSIs decreased psychological and physiological stress. Specifically for psychological stress, eight studies showed a reduction in stress ("B Grade" evidence), one study (7%) showed a null effect on stress ("C Grade" evidence), and two studies (13%) showed an increase in psychological stress ("D Grade" evidence). Specifically for physiological stress, four studies showed a reduction in stress ("B–D Grades" evidence) and one study showed an increase in stress ("B Grade" evidence). There was no "A Grade" evidence for this domain, and regarding research designs, evaluation designs, and control group types, no studies with active control groups found null/negative effects on psychological stress.

Problem Behaviors

Nine of 77 eligible articles (12%) targeted problem behavior domain outcomes. All studies reported a reduction in problem behaviors across research designs, evaluation designs, and control group types, including reduced aggression, disruptive behaviors, conduct behavior, and externalizing problems. The highest quality evidence ("A Grade") showed a decrease in conduct behavior, followed by "B Grade" evidence showing a decrease in aggression.

Academic Performance

Sixteen of 77 eligible articles (21%) targeted academic performance domain outcomes. In most studies (94%) across research designs, evaluation designs, and control group types, MBSIs improved academic performance. One study found null improvements in reading fluency, so this was characterized as "D Grade" evidence. There was no "A Grade" evidence for this domain. The strongest evidence ("B Grade") documented specific improvements in academic performance, auditory-verbal memory, GPA, math performance, math score, and social studies score, as well as an increase in positive attitudes towards academic subjects and lower test anxiety.

Acceptability

Only four of 77 eligible articles (5%) examined the acceptability of MBSIs, with all finding that they were highly acceptable; however; this evidence was of "C and D Grades." There was no "A or B Grade" evidence reported for this domain.

Discussion

Our findings on the highest quality of evidence on MBSIs ("A Grade") are consistent with previous studies on adults which have documented increased prosocial behavior, resilience, executive function, attention, and mindfulness, and decreased anxiety, attention problems/ADHD behaviors, and conduct behaviors (e.g., Goldberg et al., 2021; Guendelman et al., 2017; Hofmann et al., 2010; Hoge et al., 2013; Kemeny et al., 2012; Ramasubramanian, 2017; Rogers, 2013). In addition, these results are in line with recent studies where MBIs have demonstrated therapeutic effects targeting these mental health outcomes with youth in both clinical and school settings (Borquist-Conlon et al., 2019; Dunning et al., 2019; Renshaw et al., 2017).

Unlike in previous reviews, by examining the evidence grade per outcome measure, it is evident that there is a true split in evidence on well-being outcomes, with some high-quality evidence showing increased well-being and some other high-quality evidence showing no improvements (both "A Grade" evidence). When considering the studies rated as 1 + + (the highest evidence level), the positive effect study included middle school students from private schools and the null effect study included elementary school students from public schools; therefore, the difference in outcomes may relate to resources or student age groups. Further research is needed to elucidate this issue. Moreover, our re-examination of the evidence per evidence grades has highlighted that MBSIs have a null effect on depression symptoms (as per "A Grade" evidence).

Findings on well-being and depression are in contrast with prior reviews examining adults, where there are many well-designed RCTs examining the efficacy of mindfulness relative to control groups. These RCTs have shown that the

intervention is effective in reducing depression and demonstrating improvements in well-being (Goldberg et al., 2021; Hofmann & Gómez, 2017; Strauss et al., 2014). Previous reviews have also shown that MBSIs positively affect well-being and depression among youth (Chi et al., 2018; Erbe & Lohrmann, 2015). Our findings also are inconsistent with previous meta-analyses with adults (Khoury et al., 2015) and youth (Dunning et al., 2019; McKeering and Hwang, 2019), which suggested that mindfulness practice improves well-being.

The next tier of evidence (B grade) supported the role of MBSIs in improving self-concept, social competence, self- and emotion regulation, coping, executive function, cognitive control, and mood, as well as reducing social bias and attentional problems. Our review accords with previous studies (Joss et al., 2019; Nejati et al., 2015; Quaglia et al., 2019) and a recent narrative review (Renshaw & Cook, 2017) of MBSIs, which strengthens the evidence that MBSIs improve these outcomes for youth (Barnes et al., 2003; Flook et al., 2010; Mendelson et al., 2010). With improved self-concept and social competence, students can pay attention without judgment to what is happening with themselves and with others (Schonert-Reichl et al., 2015). This can allow them to become resilient and to confront the challenges they will face in classroom settings, such as exam stress, problems concentrating, and dealing with difficult peers (Keye & Pidgeon, 2013). As a result of mindful practice, students may be better able to increase overall self-care by making constructive changes in their personal and professional lives, allowing for a healthier relationship with themselves and with others (Napoli & Bonifas, 2011).

Strong (B grade) evidence also showed that MBSIs improved mindfulness, awareness of thoughts, feelings, emotions, and bodily sensations, being more present in life, concentration, and attention, as well as reduced mind-wandering, distractibility and impulsivity. Our findings on these outcomes are in line with increasing evidence on the benefits of mindfulness for adults (Norris et al., 2018; Rahl et al., 2017; Shapero et al., 2018) and youth (Dunning et al., 2019; Renshaw, 2020). Although there is strong (B grade) evidence showing improved attention and reduced mind-wandering, there is still insufficient evidence as to how much mindfulness practice is needed to benefit students' attention regulation (Wimmer et al., 2020). Therefore, future studies should focus on the dosage—whether the length of intervention time, number of sessions, or total mindfulness practice time—needed for students to achieve improved attention regulation.

Strong (B grade) evidence also showed that MBSIs improved academic performance, specifically, report card grades, auditory-verbal memory, GPA, math, and social studies performance. Several studies examining MBSIs have been shown to improve academic performance with children (Lu et al., 2017; Thierry et al., 2016) although one review found that MBSIs did not improve academic achievement (Maynard et al., 2017). Given the mixed results, the methodological differences in the quality of reviews compared to studies should be considered before determining whether MBSIs improve academic performance with children. It is noteworthy that gender differences in response to mindfulness may also play an important role in youth academic performance. For example, a preliminary analysis indicated a greater increase in both mindfulness and self-compassion for females compared to males (Bluth et al., 2017). Likewise, in terms of academics, girls tend to achieve higher grades than boys (Duckworth & Seligman, 2006; Duckworth et al., 2015). Therefore, examining potential gender effects is especially important given the prevalence of gender differences in affective disturbances and treatment outcomes among youth (Kang et al., 2018). Future studies are needed to further explore these factors when looking at gender and academic performance to refine and enhance existing programs and to inform future development of MBSIs.

Nonetheless, a smaller group of studies suggested positive changes (B grade) in physiology, neurophysiology, and brain plasticity. MBSIs have been shown to influence physiological changes in adults, although relatively fewer studies examine this connection compared to other behavioral and mental health outcomes (Creswell et al., 2019). Given our knowledge of brain plasticity in early development, future research in this area with children is especially important (Black, 2015; Burke, 2010; Zoogman et al., 2015). Considering the potential neurophysiological processes of mindfulness, future studies should also explore the relationships among length and quality of mindfulness practice, developmental stages of students, and their mental health outcomes (Wielgosz et al., 2019). These factors may benefit MBIs in schools by improving memory and language skills (i.e., reading), which can increase academic success (Mundkur, 2005).

Overall, there were no systematic differences between positive vs. null/negative effect studies in terms of research design (quantitative, qualitative, and mixed), evaluation design (RCT, pre-post, single case/series, etc.), and per control group type (active, passive, none), suggesting overall consistency in terms of these factors in the body of literature to date on MBSIs. However, there were outcomes in need of higher quality evidence, including self-compassion, psychological and physiological stress, academic performance, and acceptability.

Limitations and Future Research

There are several areas of notable strengths when considering the literature on MBSIs used in schools. All studies reported on group-based interventions conducted in typical

classrooms during normal school hours, suggesting the generalizability of the results to school-based practice. Another strength is that many studies in this review used components of MBSR, the mindfulness-based intervention with the most empirical support for its effectiveness (Kabat-Zinn, 2003; Klingbeil, Fischer, et al., 2017; Klingbeil, Renshaw, et al., 2017; Kriakous et al., 2020). Finally, several studies included data on student educational, attentional, and behavioral outcomes, such as student achievement, ability to focus, and grades. However, additional studies and meta-analyses are needed to explore the evidence of the effectiveness of MBSIs on these educational outcomes, which may be relevant to educators and other school-based stakeholders.

Nevertheless, the literature exploring the effects of MBSIs with youth has several limitations. Many studies included in this review relied on small samples, with studies averaging around 35 participants. Future studies may benefit from larger sample sizes to power statistical analyses adequately and to aid in the generalizability of the findings. There also are significant limitations in how outcomes were measured. Most studies relied on questionnaire measures to assess for effects (particularly student self-report), which are limited by possible response bias and retrospective memory biases. Although some studies included used multiple methods (e.g., subjective self-reports, behavioral observations, and objective neurocognitive, and physiological testing), the majority relied on a single method. To address these limitations, we recommend future MBSI studies to collect data regarding the training quality of the instructors and the amount of meditation conducted during training, as well as to use substantially larger and more diverse samples of students to examine both the immediate and long-term impact of mindfulness training post-treatment.

A third limitation of studies included in this review was the lack of reporting of participant characteristics. For example, 40% of studies in this review did not provide details about participant race and ethnicity, which is important given the underrepresentation of racial and ethnic populations in rigorous trials of MBIs (Waldron et al., 2018). Very few studies included students receiving education supports, and only five studies specifically examined the impact of MBSIs on children with disabilities (see Online Resource 1 for more details). Given that most of these studies were conducted through whole class instruction, it is possible that existing mindfulness interventions are not well suited to the specific needs and reality of a classroom for children with disabilities. Attention to specific developmental child characteristics (e.g., cognitive ability, attention span) is therefore required when adapting MBSIs.

Few studies, all of lower quality, investigated the impact of MBSIs on problem behaviors such as aggression, disruptive behaviors, conduct behavior, and externalizing problems. More studies of higher quality are needed to better address these problem behaviors in schools since it has been positively associated with teacher burnout and self-efficacy (Brouwers & Tomic, 2000; Burke et al., 1996). This leads to poor student–teacher relationships, which could affect students' learning and achievement (Herman et al., 2018). Although many studies examined the acceptability and feasibility of child adaptations to adult MBIs (Bluth et al., 2016; Broderick & Metz, 2009; Hiltz & Swords, 2021; Luiselli et al., 2017; Metz et al., 2013; Quach et al., 2017), future work on MBSIs should consider scalability and other factors known to impact the implementation of other school-based or youth-focused programs. This includes principal and district buy-in, individual attitudes towards the intervention, and organizational climate and culture, as well as implementation climate and leadership (Locke et al., 2016). To facilitate effective implementation and sustainment of MBSIs, studies should use a mixed-methods approach to assess both outcomes and acceptability, adopting methods such as teacher reports on student outcomes, review sessions, observations of training sessions, and student questionnaires and interviews (Zenner et al., 2014).

Finally, despite compelling theory and emerging evidence from adult samples (Gu et al., 2015), no studies examined the mechanisms or active ingredients of mindfulness to understand the key components of MBSIs for producing positive outcomes. These studies are essential to explore the various active ingredients in mindfulness-based interventions such as social support, relaxation, and cognitive-behavioral elements. Examining the central construct of mindfulness itself is also important to determine if the development of mindfulness is what leads to the positive changes that have been observed (Shapiro et al., 2006). This is important to advance knowledge on how to best develop, adapt, and implement MBSIs to optimize outcomes. Also, no studies examined the long-term impact of MBSIs after 1 year, which would be beneficial in learning about the lasting impact that MBSIs have on youth. Future studies should therefore examine both mediating mechanisms and the long-term impact of school-based mindfulness training post-treatment.

We should note several limitations of our review methodology as well. First, we did not include gray/unpublished literature, which may have resulted in missing some relevant studies. Indeed, there may have been a publication bias in the literature included, in that published studies are systematically different from results of unpublished studies due to either non-submission for publication or rejection at the review stage. Second, we did not evaluate specific mindfulness practices (e.g., sitting meditation, body scan, movement meditations) and program delivery aspects (e.g., level of teacher training). Given that mindfulness training is highly variable across studies, it is important for future research to examine these factors to determine which intervention

best fits the needs of youth. We also did not examine program fidelity, which is important to moderate the relationship between the intervention and its outcomes as well as to prevent potentially false conclusions from being drawn about the intervention's effectiveness. Third, our review did not analyze the age appropriateness and pedagogy used for MBSIs so future studies may benefit from examining these factors. We would also like to acknowledge that comparing public school versus private school as well as integrating socioeconomic status into the analysis would have added to higher quality studies. Given that our study did not incorporate this into our analysis, we recommend that future studies consider these factors when examining the quality of MBSIs. Furthermore, our "Results" section focused mainly on the outcomes of the MBSIs without reporting the differences in the effectiveness of MBSIs based on the other data that was extracted from individual studies (e.g., research or evaluation design, teacher training, educational level). Since our review examined the quality of outcome evidence by research design, as well as quantity and strength of evidence across studies, examining the differences in the effectiveness of MBSIs based on the mentioned constructs is beyond the scope of our study. The descriptive information we coded about the studies was intended to describe the characteristics of the population studies we reviewed rather than examining moderator and mediator analyses. As such, we suggest future studies to include moderator and mediator analyses when looking at the overall effectiveness of MBSIs and suggest considerations of these factors in further considerations of outcome quality. Finally, there are limitations to using a systematic review methodology, which could have resulted in the variability of our findings. Various design factors such as the educational level of students, type of intervention, and type of delivery may have impacted the lack of effectiveness observed in this present review. We recommend future studies to conduct a meta-analysis using high-quality evidence, especially for the outcomes with mixed results.

This study reviews the studies of MBSIs for youth using a robust system for grading recommendations that considers the methodological rigor of studies to determine effectiveness recommendations of MBSIs for producing certain outcomes. Strong evidence (B grade) indicates that MBSIs improve self-compassion, social relationships, mental health, self-regulation and emotionality, mindful awareness, attentional focus, physiological stress, and academic performance. The strongest evidence (A grade) indicated that MBSIs produce improvements in resilience and anxiety across youth. In addition, the strongest evidence suggests no changes in decreasing depression symptoms and increasing well-being across youth receiving MBSIs. Given the difficulties that children and adolescents face in an increasingly demanding world, this review demonstrates the promise of incorporating mindfulness interventions to youth in a school setting. Despite the benefits that MBSIs may have with youth, this area of research is still maturing, with many studies incorporating pre-post design or otherwise less rigorous evaluation methods. Therefore, we urge researchers interested in MBSIs to study their effectiveness using more rigorous designs (e.g., RCTs with active control groups, multi-method outcome assessment, and follow-up evaluation), to minimize bias and promote higher quality—not just increased quantity—evidence that can be relied upon to guide school-based practice.

Acknowledgements This paper would not have been possible without the exceptional support of the lead author's friends and family.

Author Contribution MP: conceptualized the research, reviewed the literature, wrote the paper, submitted the manuscript. TR: collaborated in the writing and editing of the final manuscript. JC: reviewed the literature. JG: collaborated in the writing and editing of the final manuscript. EM: conceptualized the research, reviewed the literature, designed measurement approach. ZAD: reviewed the literature. ND: reviewed the literature. HT: reviewed the literature. DM: designed measurement approach, designed analytic approach, and collaborated in the writing and editing of the final manuscript. HN: developed general research design, conceptualized the research, designed measurement approach, designed analytic approach, conducted data analysis, wrote the "Results" section, and collaborated in the writing and editing of the final manuscript. All authors approved the final version of the manuscript for submission.

Declarations

Conflict of Interest The authors declare no competing interests.

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Cerebral Cortex February 2015;25:396–405
doi:10.1093/cercor/bht234
Advance Access publication August 28, 2013

Neural Mechanisms of Brain Plasticity with Complex Cognitive Training in Healthy Seniors

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Complex mental activity induces improvements in cognition, brain function, and structure in animals and young adults. It is not clear to what extent the aging brain is capable of such plasticity. This study expands previous evidence of generalized cognitive gains after mental training in healthy seniors. Using 3 MRI-based measurements, that is, arterial spin labeling MRI, functional connectivity, and diffusion tensor imaging, we examined brain changes across 3 time points pre, mid, and post training (12 weeks) in a randomized sample (n = 37) who received cognitive training versus a control group. We found significant training-related brain state changes at rest; specifically, 1) increases in global and regional cerebral blood flow (CBF), particularly in the default mode network and the central executive network, 2) greater connectivity in these same networks, and 3) increased white matter integrity in the left uncinate demonstrated by an increase in fractional anisotropy. Improvements in cognition were identified along with significant CBF correlates of the cognitive gains. We propose that cognitive training enhances resting-state neural activity and connectivity, increasing the blood supply to these regions via neurovascular coupling. These convergent results provide preliminary evidence that neural plasticity can be harnessed to mitigate brain losses with cognitive training in seniors.

Keywords: aging, brain plasticity, CBF, cognitive training, MRI

Introduction

The world's aging population is growing disproportionately; the lifespan is being extended dramatically. Research is needed to determine whether progress can be made in lengthening human cognitive span to more closely match extended life expectancy. Efforts focused on discovering ways to strengthen cognitive capacity to reason, to make informed decisions, and support living independently may be particularly beneficial (Hertzog et al. 2009). Extensive evidence has documented continuous age-related cognitive declines, even in the absence of a diagnosed dementia (Cepeda et al. 2001; Mahncke et al. 2006; Mattay et al. 2006; Kennedy et al. 2009; Cappell et al. 2010). Concomitantly, age-related brain losses are represented in structural shrinkage, loss of white matter integrity, and reduced functional connectivity, preferentially affecting frontal and temporal networks (Kennedy et al. 2009; Cappell et al. 2010; Hafkemeijer et al. 2012). Until recently, age-related cognitive declines were viewed as a consequence of living longer rather than a brain condition to be mitigated or solved.

One key issue that warrants serious consideration is the extent to which brain plasticity can be induced following strategy-based cognitive training. The mechanisms of brain plasticity (i.e., functional and structural changes) that support cognitive gains with training remain poorly understood. Advances in magnetic resonance imaging (MRI) are elucidating a broad spectrum of neural mechanisms that underpin brain changes—whether in decline or gain (Draganski and May 2008). Studies to date have largely characterized brain changes that represent aging brain in decline or precede onset of dementia (Kennedy et al. 2009; Lu et al. 2011). For instance, a reduction in global cerebral blood flow (CBF) has been reported with increased age as measured by pseudocontinuous arterial spin labeling (pCASL) MRI (Lu et al. 2011). Also, age-related reductions in functional and structural connectivity have been reported, as measured by functional connectivity MRI (fcMRI) and diffusion tensor imaging (DTI) MRI respectively (Kennedy et al. 2009; Hafkemeijer et al. 2012). The aforementioned findings have been linked to cognitive declines manifested as early as 3 years prior to cognitive decline (Hafkemeijer et al. 2012; Schlee et al. 2012). Whereas evidence is still equivocal, cognitive training has been shown to induce benefits which have been measured predominantly by cognitive performance (Ball et al. 2002; Mahncke et al. 2006; Draganski and May 2008; Willis and Schaie 2009; Landau et al. 2012). A growing trend suggests that strategy-based cognitive training, in particularly, may have a beneficial impact on preventing and potentially reversing age-related brain decline (Valenzuela et al. 2007; Boyke et al. 2008; Anand et al. 2011). In a prior study, Anand et al. (2011) identified improved ability on synthesized thinking and generalized gains to frontally mediated processes of switching and verbal fluency in cognitively healthy adults, mean age 75 years, using the same strategy-based cognitive training as incorporated in the present study. However, few studies have incorporated direct measures of change in brain function and structure. The studies that exist show training-related brain changes in only one aspect of measurement (e.g., structural/functional connectivity or activation patterns) (Nyberg et al. 2003; Mozolic et al. 2010; Brehmer et al. 2011).

This investigation addressed whether neuroimaging methodologies of resting-state brain mechanisms could be utilized to characterize coherent patterns of brain change following cognitive training (Nyberg et al. 2003; Mozolic et al. 2010). Review of fcMRI studies suggests that resting-state functional connectivity may be informative in clinical research not only at a group level but also at an individual level as an index of change (Biswal et al. 2010). Assessment of training-induced brain alterations at rest is informative given that the brain's resting energy needs (20% of the body's energy) are much greater than task-evoked neural activity (representing only 5%

of the total energy use) (Raichle and Mintun 2006; Fox and Greicius 2010). Resting-state studies reportedly have 3 times the signal to noise ratio compared with conventional task-based activation studies (Fox and Greicius 2010). Additionally, cognitive training has been shown to induce significant increases in resting-state functional connectivity in young adults when compared with nonintervention controls (Takeuchi et al. 2012). Evidence, while equivocal, seems to suggest that a higher level of resting connectivity across different brain networks and CBF may be associated with higher cognitive performance (Hampson et al. 2006; Xu et al. 2007; Takeuchi et al. 2012); whereas lower connectivity has been linked to lower cognitive function (Li et al. 2002; Sorg et al. 2007). In addition to the potential to achieve increases in functional connectivity and CBF in brain resting-state, cognitive training may serve to enhance other energy-consuming neural components such as increased concentration of neurotransmitter receptors, greater rate of turnover of cellular proteins, enzymes, member lipids, and greater axoplasmic transport, according to the "energy budget" of the brain (Attwell and Laughlin 2001).

The key purposes of this study were to elucidate the neurobiology of resting-state brain changes associated with complex mental training in cognitively healthy seniors when compared with a wait-list control group. This research advances prior evidence of cognitive gains from complex mental training by careful study of changes in brain function and structure (Anand et al. 2011; Vas et al. 2011). The study examined training-induced brain changes and timing across a broad array of sensitive brain measurements at rest; specifically, using CBF measured by pCASL MRI, functional connectivity of gray matter using fcMRI and measures of structural connectivity by employing DTI MRI to measure changes in the integrity of white matter tracts. We proposed that complex cognitive training would result in higher CBF and functional connectivity, in 2 separate but coordinated brain networks, central executive network (CEN) and default mode network (DMN), as well as related structural changes in cognitively healthy older adults. Finally, we were interested in the correspondence between significant brain blood flow and cognitive changes.

Materials and Methods

Participants

A total of 37 cognitively normal adults (mean age = 62.9 ± 3.6; 56–71 years of age) were randomized to 2 different groups: wait-list control and cognitive training. All participants underwent Telephone Interview of Cognitive Status-Modified (TICS-M) to screen for dementia, Montreal Cognitive Assessment (MoCA) to detect early cognitive impairment, Beck Depression Inventory-II (BDI) to screen for depressive symptoms, and complete medical, physical, and laboratory assessments by a physician to ensure good general health. The criteria for inclusions were no history of neurological or psychiatric conditions, normal IQ range, native English speakers, and minimum of high school diploma. Exclusionary criteria included: MR scanning contraindications, cognitive status (TICS-M < 28 and MoCA < 26), depression indication (BDI > 14), left-handedness, increased body mass (BMI > 40,BMI = mass (kg)/height $(m)^2$). Written informed consent was obtained from all subjects in accordance with the Institutional Review Board (IRB) of our academic institutions: The University of Texas at Dallas, the University of Texas Southwestern Medical Center, and the Cooper Institute.

Complex Cognitive Training Program

The training group underwent an evidenced-based, manualized cognitive training program referred to as gist reasoning (Anand et al. 2011; Vas et al. 2011). Gist reasoning training is strategy-based rather than content specific and entails a systematic use of 3 cognitive processes including strategic attention, integrated reasoning, and innovation to process all types of data. The gist reasoning training involved top-down cognitive control of complex information that is maintained, manipulated and synthesized into abstracted meanings (Anand et al. 2011). Cognitive control processes entailed in gist reasoning have been associated with frontal lobe networks and nodes within both the CEN and DMN (Nichelli et al. 1995; Chapman et al. 2005; Chen et al. 2006). Specifically, the program trained individuals to continually synthesize meanings and goals (i.e., gist reasoning) integral to information encountered in everyday life across a multitude of contents (e.g., medical information, investment information, movies, lectures, newspaper articles, travel highlights). Training also involved practice of innovative thinking by generating diverse interpretations as well as a wide variety of ways to approach or solve a task at hand, whether work or leisure related. Participants were taught to consolidate and incorporate the 3 cognitive processes as often as possible within the context of their own life activities and goals, whether during training, in real life, or in one's own internal thought processes, to train a habit of thinking about information and tasks at hand. The training was delivered by a trained expert in small groups ($n \leq 5$) of one 1-h session per week (hours = 12). Additionally, each participant worked individually at home without supervision for 2 additional 1-h sessions per week for 12 weeks (hours logged = 24). Record logs of time and assignment completion were kept for the individual work with feedback from trainers on performance.

MRI Acquisition

MRI investigations were performed on a 3 Tesla MR system (Philips Medical System, Best, The Netherlands). A body coil was used for radio-frequency (RF) transmission and an 8-channel head coil with parallel imaging capability was used for signal reception. We used different MRI techniques to investigate changes at rest: a pCASL sequence was used to measure CBF (Aslan et al. 2010), fcMRI was used to assess functional connectivity of the brain (Raichle et al. 2001), and DTI MRI to provide an assessment of structural connectivity between brain regions via white matter tracts (Mori and Barker 1999). Additionally, a high-resolution T_1-weighted image was acquired as an anatomical reference. The details of imaging parameters and their processing techniques are provided below:

Imaging parameters for pCASL experiments were: single-shot gradient-echo EPI, field-of-view (FOV) = 240 × 240, matrix = 80 × 80, voxel size = 3 × 3 mm^2, 27 slices acquired in ascending order, slice thickness = 5 mm, no gap between slices, labeling duration = 1650 ms, time interval between consecutive slice acquisitions = 35.5 ms, TR/TE = 4020/14 ms, SENSE factor 2.5, number of controls/labels = 30 pairs, RF duration = 0.5 ms, pause between RF pulses = 0.5 ms, labeling pulse flip angle = 18°, bandwidth = 2.7 kHz, echo train length = 35, and scan duration 4.5 min. The post labeling delay was 1525–2448 ms for slice #1 through 27, respectively. Using the current protocol and labeling location, our previous technical study had measured an arterial transit time of 938 ms in young individuals (Liu et al. 2011). Therefore, even considering that the arterial transit time in elderly individuals can be 20% longer and be more variable, the post labeling delay used is expected to be sufficient for the labeled bolus to reach the imaging slices. The sequence parameters for fcMRI were FOV = 220 × 220, matrix = 64 × 64, slice thickness = 4 mm, no gap between slices, voxel size = 3.44 × 3.44 × 4 mm^3, 36 axial slices, TR/TE = 2000/30 ms, flip angle = 70°, 120 image volumes, and scan duration = 4 min. The DTI sequence parameters were single-shot spin-echo EPI, FOV = 224 × 224 mm^2, matrix = 128 × 128, slice thickness = 3 mm (includes 1 mm slice gap), voxel size = 1.75 × 1.75 × 3 mm^3, 50 slices, TR/TE = 4410/51 ms, SENSE factor 2.5, 30 gradient-encoding directions with a b value of 1000 s/mm^2, and scan duration = 3.7 min. The high-resolution T_1-weighted image parameters were magnetization prepared rapid acquisition of gradient-echo (MPRAGE) sequence, TR/TE = 8.3/3.8 ms, shot interval = 2100 ms, inversion time = 1100 ms, flip angle = 12°, 160 sagittal slices, voxel size = 1 × 1 × 1 mm^3, FOV = 256 × 256 × 160 mm^3, and duration 4 min.

MR Data Processing

PCASL image series were realigned to the first volume for motion correction (SPM5's realign function, University College London, UK). An

in-house MATLAB (Mathworks, Natick, MA, USA) program was used to calculate the difference between averaged control and label images. Then, the difference image was corrected for imaging slice delay time to yield CBF-weight image, which was normalized to the Brain template from Montreal Neurological Institute (MNI). This procedure was carried out using a nonlinear elastic registration algorithm, Hierarchial Attribute Matching Mechanism for Elastic Registration (HAMMER, University of Pennsylvania, PA, USA). The HAMMER algorithm detects and corrects for region-specific brain atrophy which is commonly seen in elderly subjects. Last, the absolute CBF was estimated by using Alsop and Detre's equation in the units of mL blood/min/100 g of brain tissue (Alsop and Detre 1996). This method is represented by the following equation:

$$f_{p\mathrm{CASL}}(x,y,z) = \frac{\lambda \cdot e^{(\delta/T_{1a})}}{-2\alpha \cdot M_b^0 \cdot T_1 \cdot \left[e^{(\min(\delta - w_z),0/T_1)} - e^{(-w_z/T_1)(1-T_{1\mathrm{RF}}/T_1)}\right]} \times \Delta M(x,y,z)$$

where $f_{p\mathrm{CASL}}$ is the blood flow value at voxel (x,y,z) obtained from pCASL in ml blood/min/100 g brain; α is the labeling efficiency (0.86); λ is the blood-brain partition coefficient (0.98 mL/g); δ is the arterial transit time of blood from the tagging plane to the imaging slice (2 s); w is the delay between the end of labeling and the start of acquisition (1.525 s); T_1 is the brain tissue T_1 (1.165 s); T_{1a} is the T_1 of arterial blood (1.624 s); $T_{1\mathrm{RF}}$ is the T_1 in the presence of off-resonance irradiation (0.75 s); M_b^0 is the value of equilibrium magnetization of brain tissue, which was obtained from manual ROI drawing of midaxial slice of the control image and accounting for the saturation recovery of the magnetization (T_1 = 1.165 s, recovery time = labeling time + post labeling delay of this slice).

The whole-brain blood flow values were calculated by averaging all the voxels in the brain. In voxel-based analyses (VBA), the individual CBF maps were spatially smoothed (with full-width half-maximum [FWHM] of 4 mm) to account for small differences in sulci/gyri location across subjects. For cluster extent inference, we used a program based on AlphaSim, called *3dClustsim* in AFNI (NIMH Scientific and Statistical Computing Core, Bethesda, MD, USA), which controls false-positive activation clusters over the set of all activation clusters throughout the whole-brain volume. We refer to this procedure in Results as familywise error correction (FWE corrected). For cluster inference, we tested the volume of clusters which is conditional on 2 criteria: smoothness of the voxel map and cluster-defining threshold. We estimated the smoothness to be 10 mm FWHM (inherent smoothness plus additional smoothness applied—described above) and set the cluster-defining threshold to the 99.5th percentile of t-statistic distribution. Then, the minimum cluster size of 238 voxels (1904 mm^3) yielded a FWE-corrected significance level of 0.05.

Functional connectivity images were analyzed by using AFNI (NIMH Scientific and Statistical Computing Core, Bethesda, MD, USA) and in-house MATLAB scripts. The dataset was preprocessed with slice timing correction, motion correction (realignment), removal of the linear trend, transformation to standard Talairach space (matrix = 61 × 73 × 61, resolution = 3 × 3 × 3 mm^3), and smoothing by a Gaussian filter with a FWHM of 6 mm. Next, the whole-brain functional connectivity was analyzed by parcellating the images into 70 anatomical regions per Automated Talairach Atlas Labels in AFNI software (Lancaster et al. 2000). Each region's signal time course was band-pass filtered (0.01–0.1 Hz) to keep only the appropriate frequency fluctuations. Both white matter and cerebrospinal fluid signals were regressed out using averaged signals from the white matter and the ventricles for each ROI. The cross-correlation coefficients (cc) between any possible pair of ROI time series were calculated (70 × 70 Matrix) for each subject at each time period. Next, the correlation matrix was transformed to a z-score matrix and then the upper triangular part of the matrix was average to calculate the whole-brain functional connectivity (Wang et al. 2009).

In the network analysis of functional connectivity, the preprocessed images were band-pass filtered (0.01–0.1 Hz) on a voxel-by-voxel basis to keep only the appropriate frequency fluctuations. Next, the signals in white matter and cerebrospinal fluid were regressed out using averaged signals from the white matter and the ventricles from each voxel time series. The fcMRI data were analyzed using a seed-based approach by choosing bilateral posterior cingulate [±10 −56 −12] and dorsolateral prefrontal [±45 +16 +45] cortices based on MNI coordinates (size = 0.73 cm^3) (Sridharan et al. 2008; Xu et al. 2011). The cross-correlation coefficient between these seed voxels and all other voxels was calculated to generate a correlation map. Then, the correlation maps were transformed to a z-score map using Fisher's inverse hyperbolic tangent transformation. An ROI analysis was performed based on 2 known DMN regions: posterior cingulate cortex (PCC) and middle frontal cortex (MFC) and 2 CEN regions: dorsolateral prefrontal cortex (composed of BA 9 and 46) and inferior parietal cortex. The functional ROIs were defined as follows: first, each region's anatomical region was defined based on Talairach Daemon database in AFNI. Then, a functional ROI was defined by choosing the top 200 voxels at each time point (i.e., T1, T2, and T3) and the intersection (i.e., common voxels) of the masks was calculated. Last, to assess the overlap between fcMRI and CBF regions, the fcMRI functional ROIs were then applied to each participant's CBF map.

DTI images were realigned and corrected for eddy current distortions using DTIstudio's AIR program (The Johns Hopkins University, Baltimore, MD). Next, tensor fitting and fractional anisotropy (FA) calculations were performed. The whole-brain FA average was calculated by thresholding the FA images at 0.25 and then averaging all the remaining voxels in the brain. In the tractography analysis, white matter tracts were constructed with minimum FA of 0.25 and maximum turning angle of 70°. The uncinate fasciculus (UF) tract was delineated via 2 techniques: manual and automatic tractography. In manual tractography, the left and right UF were delineated by drawing manual region-of-interests (ROI) per Wakana et al. (2007) method. In the automatic tractography, the CBF clusters were coregistered to each subject's native DTI space and used as an ROI to delineate fiber tract. Specifically, these regions were dilated twice in 26 directions to ensure the clusters were expanded into the white matter tissue. Last, an "AND" operation between the 2 clusters was performed and the resultant fiber was the left UF from the left middle temporal and left superior medial frontal gyri.

Neurocognitive Measures

A battery of neurocognitive measures was administered at 3 time periods, that is, baseline/pretraining (T1), midtraining week 6 (T2), and at end of training, week 12 (T3) for both control and training groups. Assessment of changes in trained functions included 3 randomized versions of the Test of Strategic Learning (TOSL) to measure the ability to synthesize global meanings. This measure was developed and tested to systematically quantify participants' capacity to abstract gist meanings from complex input (Anand et al. 2011; Vas et al. 2011). Measurements of untrained cognitive functions included tests of executive function, memory, and complex attention. Measures of executive function included: Daneman and Carpenter (working memory), "Trails B–Trails A" (switching), and WAIS-III Similarities (concept abstraction). Immediate memory was assessed with trial one of the California Verbal Learning Test-II (CVLT II) - 2 versions used alternatively over time intervals. Finally, complex attention was evaluated with the Delis Kaplan Executive Function System (DKEFS) Color Word Interference (selective attention) and Backward Digit Span. The results were Bonferroni corrected within neuropsychological domain and 1-tailed because of anticipated improvements in the neurocognitive measures of the training group.

Statistical Analysis

A general statistical linear model was applied to assess the contribution of cognitive training on neurocognitive, CBF, functional connectivity, and structural connectivity measures. The model included sessions (T1, T2, and T3), group status (cognitive training and control) and the interaction between these factors. Two variance components—one due to variability across subjects, and one due to variability in the same subject over time—were included to account for the different levels of variability and estimated by residual maximum likelihood (REML). We were primarily interested in how the groups differed across the training

sessions, and we hypothesized that the cognitive training group would show an increase in mean measures (except Trails B–Trails A; since it is a timed measure and lower score represent faster performance), either by T2 or T3, relative to the control group. This hypothesis led to 2 orthogonal polynomial interaction contrasts: linear and quadratic. The linear interaction contrast tested whether the mean change between the groups increased monotonically from T1 to T3, and the quadratic interaction contrast tested whether the mean change between groups increased maximally at T2 before decreasing (either back to baseline or only partially) at T3.

Neural Correlate Analysis

Pearson correlations were tested to examine the relationship between the group mean change in voxel-wise CBF and the group mean change in neurocognitive measures. The results were reported as 1-tailed based on the anticipated changes in the positive direction in both domains.

Results

Participant Characteristics

All 19 control participants (CN) completed the neuropsychological assessments and all 18 cognitive training participants (CT) completed the training and neuropsychological assessments at each time point. However, several participants either did not complete all 3 time points of each MR protocol or had gross movement of >3 mm and >3°. As a result, the final MRI data analyses were conducted on the majority of the participants, shown in Table 1. No significant differences in age, gender, Intelligence Quotient (IQ), Montreal Cognitive Assessment (MoCA), Telephone Interview of Cognitive Status-Modified (TICS-M) were noted between groups ($P > 0.05$).

MRI Measurements

CBF was measured by pCASL MRI in both control and cognitive groups. The global CBF at T1 for both control and cognitive training groups were similar; 47.2 mL/100 g/min and 47.0 mL/100 g/min, respectively ($P = 0.98$). The cognitive training group's global CBF increased by 7.9% from T1 to T2 and remained elevated (7.9%) at T3. To evaluate which brain regions may have contributed to the CBF increase, we conducted a voxel-wise analysis. Figure 1 shows the VBA results between control and cognitive training groups, testing whether the CBF differences increase monotonically from T1 to T3 due to cognitive training or whether the CBF differences peak at T2. The cognitive training group showed a significant increase in blood flow at T3 in left middle temporal, left superior medial, left inferior frontal gyri compared with the control group. Additionally, the cognitive training group showed a peak increase at T2 in the inferior temporal gyrus, precuneus, and posterior cingulate gyrus compared with the control group. The control group did not show any significant changes at T2 or T3 in CBF compared with the cognitive training group. Table 2 summarizes these findings with a FWE rate maintained at 0.05 ($P < 0.05$, cluster volume ≥ 1904 mm^3).

Based on the increased regional CBF findings in Table 2, we characterized 2 distinct brain networks: default mode network (DMN) and central executive network (CEN) (Fox et al. 2005; Sridharan et al. 2008). Both DMN and CEN networks have been identified as integrated functional hubs that mediate higher order cognitive control processes such as embodied in gist reasoning. The components of these networks, respectively, were combined to summarize the relationship between regional blood flow and functional connectivity. Figure 2*A* shows the average functional connectivity maps (i.e., *z*-score maps) in the DMN and CEN for the cognitive training group, in which is seen

Table 1

Subject characteristics and total number of subjects per group, assessments, and MRI technique (mean ± SD)

	Control	Cognitive training
Age (years)	64.0 ± 3.6	61.8 ± 3.3
Gender (M/F)	5/14	8/10
IQ	120.9 ± 10.5	121.6 ± 8.0
MoCA	28.2 ± 1.4	27.9 ± 1.4
TICS-M	29.6 ± 2.0	29.4 ± 2.2
Participants (*n*)		
Cognitive exams	19	18
pCASL MRI	18	13
fcMRI	16	15
DTI	17	14

Notes: IQ, Intelligence Quotient; MoCA, Montreal Cognitive Assessment; TICS-M, Telephone Interview of Cognitive Status-Modified.

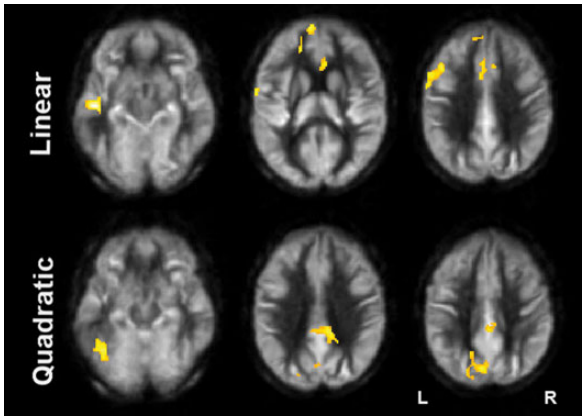

Figure 1. Results of CBF voxel-based comparison superimposed on an average CBF map of all participants for linear and quadratic interaction contrasts at $P < 0.05$ (FWE corrected) and $k \geq 1904$ mm^3. Note: The regions experiencing a linear increase are located in the frontal lobe while the regions experiencing a quadratic pattern of CBF increase are located in the posterior.

Table 2

CBF regions that showed significant blood flow increase at rest in Cognitive Training compared with Control group

Brain regions	BA	Cluster size (mm^3)	MNI			*T*-value
			X	*Y*	*Z*	
Linear						
L. MTG	20/21/22	2696	−50	−14	−14	4.96
L. SMFG	9/10/32	2824	−2	54	22	4.06
L/R ACG	9/32/24	4400	6	22	18	4.03
L. tIFG	6/9/44/45/46	3016	−58	6	26	3.90
Quadratic						
L. ITG	20/37	2560	−42	−56	−18	3.95
L. Precuneus	7/19/31	3440	−6	−78	40	3.86
L/R PCG	23/31	1952	12	−36	26	3.78

Notes: MTG, middle temporal gyrus; SMFG, superior medial frontal gyrus; ACG, anterior cingulate gyrus; tIFG, triangular part of inferior frontal gyrus; ITG, inferior temporal gyrus; PCG, posterior cingulate gyrus; L/R, left/right.
The colored Brodmann Areas (BA) represent DMN (red) and CEN (green) regions based on prior research.

qualitatively that functional connectivity increases over the training sessions—monotonically (T1-to-T3) in the DMN and with a maximum increase at T2 in the CEN. Moreover, the functional connectivity changes in DMN and CEN mirrored the blood flow changes in the same regions (Fig. 2*B*). Specifically, DMN's functional connectivity and CBF both increased monotonically (T1-to-T3) in the cognitive training group relative to controls ($P = 0.04$ and $P = 0.01$, respectively, Table 3). Also, CEN's functional connectivity and CBF showed similar peak increases at T2 in the cognitive training group relative to controls ($P = 0.03$ and $P = 0.0005$, respectively, Table 3). The whole-brain functional connectivity of the cognitive training group did not show significant temporal changes compared with the control group (Table 3).

Based on the monotonic blood flow increase in left middle temporal and left superior medial frontal gyri, we identified the white matter structure connecting the 2 regions called left UF. The UF tract was delineated both manually (Wakana et al. 2007) and automatically (shown in Fig. 3). In the manual tractography method, the FA of left UF showed a monotonic increase from T1 to T3 compared with the control group ($P = 0.003$). The FA of right UF of cognitive training group, however, did not show any significant temporal changes relative to the control group. In the automatic tractography method, the FA of the left UF similarly showed a monotonic increase in the cognitive training group compared with the control group, which signals better white matter integrity ($P = 0.02$). Whole-brain FA did not show significant differences as a result of training, as shown in Table 3.

Neurocognitive Measures

Table 4 shows the neuropsychological exam results per domain for control and cognitive training groups. No significant differences were noted in the baseline scores (i.e., T1) between the cognitive training and control groups. We found, however, that the cognitive training group significantly improved over time in 2 cognitive domains relative to the control group. The most complex cognitive domain, Strategic Reasoning, that is, ability to synthesize generalized meanings from lengthy textual input, and a measure of Executive Function, Similarities, that is, ability to abstract concepts showed a significant monotonic increase from T1 to T3 ($P = 0.002$ and $P = 0.05$, respectively).

CBF Correlates of Cognitive Changes

Mean changes between groups in TOSL (measure of ability to synthesize complex information) and WAIS-III Similarities (concept abstraction) were found to correspond to mean changes between groups in brain blood flow in particular brain regions. Table 5 summarizes the Pearson correlation tests of temporal changes between groups on TOSL and WAIS-III Similarities scores with corresponding contrasts of CBF regions reported in Table 2. The significantly improved cognitive changes corresponded with increased regional brain plasticity as measured by blood flow increases at rest in specific brain–behavior patterns.

Discussion

Our principal finding was that strategy-based cognitive training has the potential to reverse some of the negative consequences of age-related functional and structural brain losses. The goal of this study was to evaluate functional and structural mechanisms of brain change in response to a manualized cognitive training program in healthy older adults. The data serve to inform whether a specific training program could induce positive brain plasticity, to complement previously identified cognitive gains in aging adults across abstract thinking, concept formation, and other executive function measures (Anand et al. 2011; Vas et al. 2011). Specifically, we found that the training positively altered the intrinsic activity of the brain at rest as well as its structural connectivity. To our knowledge, this work provides the first convergent evidence of significant positive neurophysiological and neuroanatomical changes across 3 brain measures at rest, namely: CBF, functional, and structural connectivity.

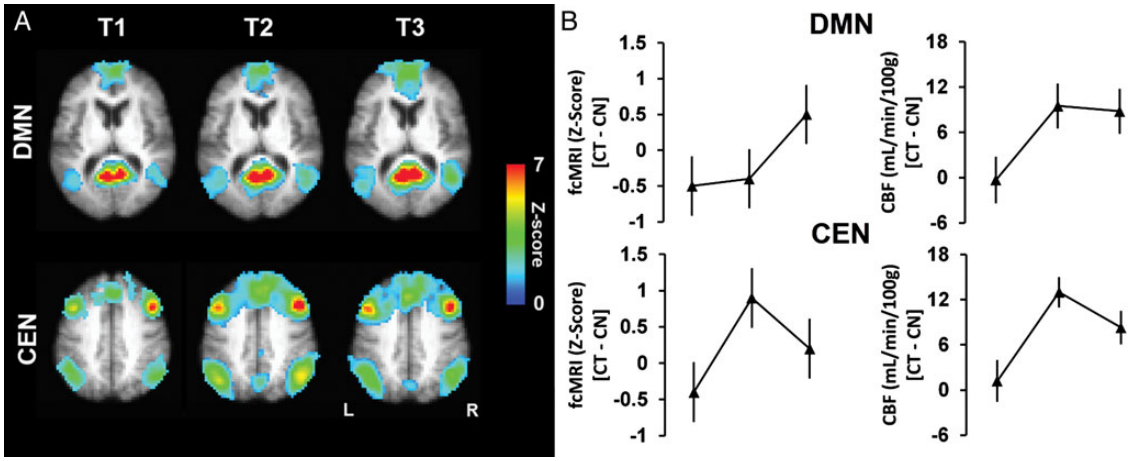

Figure 2. (*A*) The average functional connectivity maps (i.e., DMN and CEN) of the cognitive training group are overlaid on their average T_1-weighted image. For illustration purposes, the *z*-score maps were arbitrarily thresholded (*z*-score ≥ 1, $k \geq 50$) to qualitatively visualize the change in the intensity and cluster size. (*B*) Mean change in fcMRI *z*-scores (left column) and mean change in absolute CBF (right column) are shown for DMN and CEN across time periods. The DMN shows an increase in both mean fcMRI and mean aCBF from T1 to T3 for the cognitive training (CT) group relative to controls (CN). The CEN shows a maximal increase in both mean fcMRI and mean aCBF at T2 for the cognitive training group relative to controls.

Training-Induced Brain Plasticity

The findings of regained global/regional CBF, increased functional interdependence within brain networks, and improved white matter integrity are important given the evidence that significant negative plasticity occurs with aging even in the absence of disease pathology (Rypma and D'Esposito 2000; Raz et al. 2005; Lu et al. 2011). Negative plasticity is a term used to refer to the age-related cognitive decline and degradation in brain function that results from decreased brain use and weakened function of top-down neuromodulatory systems that underlie efficient learning and memory (Moller et al. 2006). The training-induced gains in the present study were identified in relevant brain measures/regions that heretofore have shown decline in older adults. These significant increases support reversals in age-related declines as reflected by good agreement between increases in both CBF and greater functional connectivity in both the default mode and the central executive networks, and improvement in white matter integrity (Rypma and D'Esposito 2000; Lu et al. 2011).

The present convergent findings provide insight into modifiable brain plasticity mechanisms in healthy older adults given strategy-based cognitive training. We propose that the cognitive training increased the overall cellular activity and metabolic rate in certain brain regions included in 2 networks, the DMN and CEN. These changes are manifested by the indirect markers of fcMRI and CBF presumably via the dogma of neurovascular coupling (i.e., higher metabolic demand, higher blood supply) since cellular activity and metabolic rate are difficult to measure in humans.

Increases in Global CBF

This study provides preliminary evidence that complex cognitive training may serve to increase whole-brain blood flow in healthy older adults. As a tightly regulated system, resting CBF is remarkably consistent (Raichle and Gusnard 2002). In contrast, regional CBF may increase or decrease during mental activation tasks due to redistribution of blood. The regional activation effect is transient and the local CBF elevation typically is restored to baseline level when the brain returns to resting state (Raichle and Gusnard 2002). The present results, showing a maintained increase in global CBF from T2 to T3, support the possibility of increasing resting whole-brain blood flow and achieving a new homeostasis level in the aging brain. Furthermore, the capacity to increase resting whole-brain blood flow as an outcome of complex mental training may have clinical implications in light of evidence that resting blood flow shows an age-related decline beginning in early adulthood (Lu et al. 2011). With further validation, CBF measures could potentially become useful markers of treatment effects at an individual level, indexing key physiologic brain changes to detect reversal of losses, preserved brain function, or continuing brain decline. We propose that greater connectivity and neural activity result in higher CBF as well as the

Table 3

Pre (T1), Mid (T2), and Post (T3) neuroimaging results at rest per MR technique (mean ± SEM)

	Control (CN)			Cognitive training (CT)			*P*-value	
	T1	T2	T3	T1	T2	T3	Linear	Quadratic
WB aCBF	47.2 ± 1.1	44.3 ± 2.0	46.8 ± 2.0	47.0 ± 2.4	50.7 ± 2.3	50.7 ± 2.4	0.04	0.002
WB fcMRI	0.12 ± 0.02	0.10 ± 0.02	0.11 ± 0.02	0.11 ± 0.02	0.10 ± 0.02	0.11 ± 0.02	0.73	0.76
WB FA	0.425 ± 0.002	0.424 ± 0.002	0.424 ± 0.002	0.425 ± 0.002	0.424 ± 0.002	0.426 ± 0.002	0.37	0.75
fcMRI (DMN)	6.8 ± 0.4	7.1 ± 0.4	6.6 ± 0.4	6.3 ± 0.4	6.7 ± 0.4	7.1 ± 0.4	0.04	0.26
aCBF (DMN)	55.6 ± 2.8	49.9 ± 2.7	53.2 ± 2.7	55.3 ± 3.1	59.4 ± 3.0	62.0 ± 3.0	0.01	0.06
fcMRI (CEN)	4.0 ± 0.4	3.8 ± 0.4	4.1 ± 0.4	3.6 ± 0.4	4.7 ± 0.4	4.3 ± 0.4	0.23	0.03
aCBF (CEN)	47.0 ± 2.5	41.2 ± 1.8	44.2 ± 2.0	48.2 ± 2.8	54.2 ± 2.0	52.5 ± 2.2	0.01	0.001
DTI MT (L. UF)	0.502 ± 0.006	0.498 ± 0.006	0.495 ± 0.006	0.488 ± 0.007	0.495 ± 0.007	0.503 ± 0.006	0.003	0.45
DTI MT (R. UF)	0.470 ± 0.005	0.468 ± 0.005	0.476 ± 0.005	0.481 ± 0.006	0.481 ± 0.006	0.482 ± 0.006	0.53	0.42
DTI AT (L. UF)	0.498 ± 0.007	0.493 ± 0.007	0.493 ± 0.007	0.493 ± 0.008	0.494 ± 0.007	0.504 ± 0.007	0.02	0.41

Notes: WB, whole brain; aCBF, absolute cerebral blood flow in mL/min/100 g; fcMRI, functional connectivity MRI in *z*-score; DMN, default mode network; CEN, central executive network; DTI, diffusion tensor imaging; UF, uncinate fasciculus; MT, manual tractography of UF; AT, automatic tractography of UF; and L/R, left/right.
Linear and quadratic refer to orthogonal polynomial contrasts of mean group differences over the 3 training sessions.

Table 4

Neuropsychological exam results (mean ± SEM)

	Control (CN)			Cognitive training (CT)			*P*-value	
	T1	T2	T3	T1	T2	T3	Linear	Quad
Strategic reasoning								
TOSL (rs)	5.8 ± 0.5	4.4 ± 0.5	4.7 ± 0.3	4.7 ± 0.5	5.6 ± 0.5	5.6 ± 0.3	0.002	0.07
Executive function								
WAIS-III similarities (ss)	13.1 ± 0.6	13.2 ± 0.5	13.8 ± 0.4	12.9 ± 0.6	13.9 ± 0.5	14.9 ± 0.4	0.05	0.71
Daneman Carpenter (rs)	2.8 ± 0.2	3.1 ± 0.2	3.2 ± 0.2	2.8 ± 0.2	3.3 ± 0.2	3.1 ± 0.2	0.81	0.32
Trails B–Trails A (rs)	28.5 ± 3.6	27.3 ± 4.0	31.2 ± 3.3	29.9 ± 3.7	29.8 ± 4.2	27.4 ± 3.4	0.42	0.66
Memory								
CVLT trial 1 (rs)	7.5 ± 0.4	6.9 ± 0.4	7.7 ± 0.6	6.6 ± 0.4	6.2 ± 0.4	8.3 ± 0.6	0.12	0.39
Complex attention								
DKEFS Color cond3 (ss)	17.4 ± 0.7	14.6 ± 0.6	15.3 ± 0.8	16.1 ± 0.7	15.7 ± 0.6	14.7 ± 0.8	0.34	0.50
Backward digit span (ss)	8.0 ± 0.5	8.5 ± 0.5	8.7 ± 0.6	8.0 ± 0.5	8.9 ± 0.5	8.0 ± 0.6	0.43	0.27

Notes: TOSL, Test of Strategic Learning; WAIS, Wechsler Adult Intelligence Scale; CVLT, California Verbal Learning Test; DKEFS, Delis Kaplan Executive Function System; ss, standard score; rs, raw score.

Table 5
Correspondence between mean change in cerebral blood flow and mean change in cognitive gains between the cognitive training and control groups

Cognitive exam	CBF region	*r*	*P*-value
TOSL (Linear)	L. MTG (Linear)	0.50	0.002
TOSL (Linear)	L. ITG (Quad)	0.47	0.004
TOSL (Linear)	L. Precuneus (Quad)	0.35	0.03
TOSL (Linear)	L/R PCG (Quad)	0.33	0.04
TOSL (Quad)	L. MTG (Linear)	0.39	0.02
TOSL (Quad)	L/R ACG (Linear)	0.32	0.04
TOSL (Quad)	L. tIFG (Linear)	0.30	0.05
TOSL (Quad)	L. Precuneus (Quad)	0.33	0.04
WAIS-III (Linear)	L/R PCG (Quad)	0.39	0.02
WAIS-III (Linear)	L. MTG (Linear)	0.33	0.04
WAIS-III (Linear)	L. SMFG (Linear)	0.31	0.05

Notes: MTG, middle temporal gyrus; ITG, inferior temporal gyrus; PCG, posterior cingulate gyrus; ACG, anterior cingulate gyrus; tIFG, triangular part of inferior frontal gyrus; SMFG, superior medial frontal gyrus; L/R, left/right.

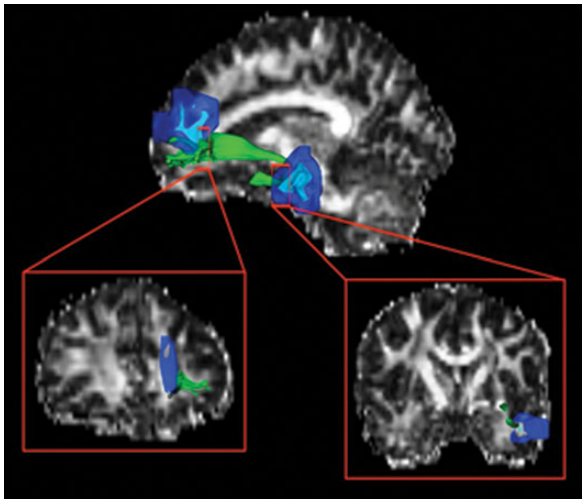

Figure 3. A representative participant's uncinate fasciculus (green) is overlaid on his fractional anisotropy map. The frontal and temporal ROIs (light blue) were expanded twice (dark blue) to ensure expansion into white matter.

reverse pattern where lower connectivity would be indicative of lower CBF demands.

Convergence in Functional Connectivity and Resting CBF

The current investigation identified increases in 2 relevant networks: default mode and central executive networks. Despite diminishing DMN's connectivity with age (Hafkemeijer et al. 2012), we have shown that cognitive training has the potential to reverse this age-related loss which is in agreement with prior investigations in younger adults (Takeuchi et al. 2012). We found monotonic increases from T1 to T3 in functional connectivity that was mirrored in resting CBF of DMN's regions, posterior cingulate, and medial prefrontal cortices. This increasing pattern in the DMN suggests that the potential benefit of training did not plateau within the time period of our study training. These results are consistent with recent work showing training-induced changes in both resting functional connectivity and resting CBF in the DMN following working memory training in young adults (Takeuchi et al. 2012).

The improvement of CEN's functional connectivity in the training group compared with the control group is a novel finding. Similar to DMN, the CEN's connectivity change was mirrored in its regional CBF, dorsolateral prefrontal (BA 9 and 46) and inferior parietal cortices. However, rather than a monotonic increase as identified in DMN, we found a peak increase at T2. It is important to note that the increases in connectivity and CBF at T2 do not return to baseline by T3. We interpret this quadratic pattern in CEN to mean that the training had a large onset effect, which then reached plateau or may even have slightly settled down, which happens when the neuronal changes are consolidated (e.g., forming new synapses rather than firing at higher frequency using existing synapses).This pattern of increased connectivity in the CEN was not found in young adults following working memory training by Takeuchi et al. (2012). The divergent patterns between studies in the CEN's intrinsic activity may be due to differences in the nature of the cognitive training, delineation of network nodes since these are currently undergoing refinement (Bressler and Menon 2010), or differences related to age effects. In sum, cognitive training induced changes in the DMN and CEN connectivity, accompanied by a similar temporal pattern of change in CBF.

Convergence of Regional CBF and Structural Connectivity

Another noteworthy pattern was reflected in the concomitant improvements in the left middle temporal and left superior medial frontal resting CBF and FA of left UF, which connects these 2 regions. Higher FA has been associated with higher white matter integrity (i.e., myelination) as water molecules diffuse more anisotropically along the axonal fibers (Teipel et al. 2010). It has been shown that healthy older adults have reduced FA in the intracortical projecting fiber tracts such as UF (Teipel et al. 2010), and it is associated with age-related cognitive decline (Charlton et al. 2006). The present evidence offers promise that some of the losses at the level of white matter tracts may be reversible with strategy-based cognitive training.

Whereas the functional changes in CBF and functional connectivity were apparent earlier in the time course at T2, the structural changes on DTI emerged later at T3. This time course is concordant with accumulating evidence that neurophysiologic plasticity is followed by structural plasticity occurring concomitantly with acquisition of new skills within a few weeks of cognitive training (Kennedy et al. 2009). The present findings confirm prior evidence that functional brain changes are more frequent and rapid than structural plasticity (Bruel-Jungerman et al. 2007). A similar sequence in brain markers of decline was characterized in individuals showing memory loss manifested first by decline in functional neuroimaging (PET-CBF) followed by structural brain changes (MRI) then cognitive decline (Clark et al. 2012).

Cognitive Plasticity and CBF Correlates

The present results support positive cognitive plasticity from the complex cognitive training—that is, synthesizing global meanings and concept abstraction. Previous literature revealed that synthesized thinking is related to cognitive control measures purported to activate the prefrontal networks included within the CEN and DMN; further complex strategy-based training generalizes to untrained cognitive control (Mahncke et al. 2006; Anand et al. 2011; Vas et al. 2011). There

is growing motivation to investigate congruent evidence in both brain and cognitive mechanisms to more objectively assess training-induced gains (Takeuchi et al. 2012). The present study provides promising evidence that complex mental training may facilitate parallel gains in regional blood flow and cognition in older adults. The significant relationships between gains in complex synthesizing and increased CBF in both the left inferior frontal and left middle temporal gyri represent brain-cognition relationships that have been previously implicated (Seghier et al. 2010). Synthesizing abstracted and original meanings and conceptual integration have been previously linked to nodes of the CEN, but heretofore training-induced changes have not been examined according to parallel changes in both CBF and cognition. We propose that cognitively challenging application of strategies to improve information processing is supported by intrinsic brain mechanisms, but perhaps more importantly, mental exercise can bring about significant positive changes that modify brain systems (Bressler and Menon 2010).

Plausible Mechanisms of Brain Plasticity

To date, little is known about the temporal pattern of training-induced changes to intrinsic brain activity in 2 or more brain networks as measured by resting CBF as well as functional connectivity in aging. This pilot study represents a first step to investigate cognitive training changes in older adults over 3 time periods in 2 distinct brain networks, central executive network (CEN) and the default mode network (DMN) in 2 imaging methods measuring resting metabolic brain activity. We demonstrated that functional connectivity/CBF changes in CEN occurred more rapidly emerging at T2 and DMN increased continuously over time with greatest increases observed at T3 in the cognitive training group compared with controls, respectively. Comparing across imaging modalities, the present data suggest that CBF may be a more sensitive marker as the changes are detected globally whereas diffusion and functional connectivity measures only showed regional effects.

The cognitive training targeted the CEN, but may also have impacted the DMN. The gist reasoning training involved top-down cognitive control of complex information that is maintained, manipulated, and synthesized into abstracted meanings (Anand et al. 2011). Cognitive control processes have been associated with both CEN and DMN networks/nodes. The increases in connectivity and CBF in CEN did not return to baseline level instead remaining elevated above baseline at T3 suggesting that the gains were relatively stable. The nature of the cognitive gist training and its prior link to frontal brain networks within the CEN perhaps account for why increases in both connectivity and CBF appeared more rapidly in CEN at T2 (i.e., Week 6). The DMN did not plateau in the short training period and continued to increase from T1 to T3, raising the possibility that the DMN is also integrally involved and facilitates consolidation and maintenance of complex cognitive performance. The significant relation between improved brain metabolism and higher cognitive performance suggest that the increases in both CEN and DMN were positive as suggested by Hampson et al. (2006).

We propose a coherent mechanism by which complex mental exercise promotes brain plasticity and improves cognitive brain health. Specifically, we speculate that the cognitive training regime would leave a "footprint" on the resting brain such that greater resting-state spontaneous neural activity occurs in DMN and CEN regions. This increased activity is manifested as greater functional connectivity. The reason that the footprint is still present even though the training has ended could be because of aggregations of neurotransmitter receptors as a consequence of previous activations, which essentially prepare the brain to react "better" for future stimulus of similar type, even at resting state. Protein and lipid synthesis in the neuron may also be enhanced, which may serve to form/strengthen new synapses if the trained habits are maintained for a substantial period of time. All of these will cost energy, manifested as greater blood supply to these brain regions. The increased activities in dendrites/synapses/somas are likely to be accompanied by white matter changes such as increased myelin thickness, which may be the reason for a greater FA in DTI scans.

In sum, we propose that the multidimensional increases in brain function and structure are driven by task-dependent brain activation during training that increases resting brain network synchrony. Evidence reveals tight coupling of brain activity during active thinking that is mirrored to a large degree in intrinsic resting brain activity during internally driven cognitive thought processes (Smallwood et al. 2012). A precedent for a link between active cognitive training and increases in intrinsic resting activity in brain networks has been previously established (Takeuchi et al. 2012).

Limitations to Current Findings

The present findings need to be interpreted cautiously in light of a few key limitations. The first is small sample size. We propose that the convergent findings in 2 major networks—CEN and DMN identified in 2 brain mechanisms—both CBF and functional connectivity of intrinsic brain activity at rest, combined with enhanced white matter connectivity support the potential for a strategy-based cognitive training program to significantly enhance brain integrity in cognitive healthy seniors even given this small sample size. Moreover, the current cognitive gains replicate previous findings of generalized improvement in cognitive skills in healthy older adults (Anand et al. 2011).

Another limitation in our study was the potential for nonresponse bias due to missing data from those participants whose MRI data had to be excluded due to missing MRI scans or excessive movement. We investigated this possibility by comparing all of our neuropsychological contrasts of interest between the subjects with and without MRI scans in the cognitive training group. We found that the contrast estimates themselves exhibited evidence of a "missing-at-random" mechanism of data loss, wherein the actual signs of the estimates were evenly distributed, a finding that would not be expected from nonresponse bias. Interestingly, a significant linear interaction contrast was identified from the TOSL, exhibiting a mean increase in those without MRI scans relative to those with MRI scans in the cognitive training group ($P = 0.048$.) If a nonresponse bias exists, therefore, the bias may be reducing the magnitude of our reported findings, rather than inflating them.

Lack of an active control group may be a third limitation. However, we do not believe that the significant increases in intrinsic brain activity across large-scale brain networks could be accounted for simply by active stimulation alone. This assumption is based on a randomized trial study whereby a

strategy-trained group was compared with an active-stimulation control group, with the latter not manifesting significant cognitive gains (Vas et al. 2011).

We were not able to address whether the increases in functional and structural brain connectivity or the cognitive gains were maintained at a distant time point (beyond 12 weeks) from the immediate training period. We expect that the training gains may persist at least for individuals who are continual strategy-adopters, because the training was embedded in real-life activities and prior work has shown maintained and even improved performance after training ceased (Anand et al. 2011; Vas et al. 2011).

Finally, our post labeling delay time may not be sufficient for individuals with hemodynamic delays related to cerebrovascular diseases (Macintosh et al. 2012). A longer post labeling delay time may be useful in alleviating this possible limitation, although at a potential cost of sensitivity.

Conclusions and Future Directions

The potential for individuals to improve their own cognitive brain health by habitually exercising high-order mental strategies is intriguing and is just beginning to be more fully exploited. Our work is in accord with prior claims that engaging in complex mental activity may offer promising ways to enhance brain integrity to promote successful cognitive aging. Valenzuela and colleagues claim that complex mental activity induces broad-based changes in brain function and structure (Valenzuela et al. 2007). In the present study, the training-dependent brain changes were likely achieved by top-down (i.e., high-level) strategy-based stimulation that are believed to activate large-scale brain circuitry that work interdependently within widely distributed brain regions (Bressler and Menon 2010). Specifically, the cognitive training involved considerable usage of lengthy language-based materials as well as rich visual stimuli where participants were required to construct novel and abstract interpretations. This processing required complex top-down information processing, implicating multiple brain regions within the DMN and CEN. Not only were functional connectivity and CBF increased to these regions but the specific white matter tract connecting certain regions was enhanced. Animal models of complex cognitive stimulation have shown to be protective against cognitive decline, diminishing brain amyloid burden, and increasing hippocampal synaptic immunoreactivity (Cracchiolo et al. 2007). The present findings offer a promising complement to large-scale randomized trials where smaller trials may be informative and cost effective, particularly as a first run trial, when they incorporate multiple levels of the neurobiological mechanisms of brain and cognitive plasticity in well-defined populations. Clarifying both the brain and cognitive plasticity changes in response to strategy-based mental training will elucidate the neurogenerative potential in the cognitively healthy aging brain.

Funding

This work was supported by a grant from the National Institute of Health (RC1-AG035954, R01-NS067015, R01-AG033106) and by grants from the T. Boone Pickens Foundation, the Lyda Hill Foundation, and Dee Wyly Distinguished University Endowment. Funding to pay the Open Access publication charges for this article was provided by funds from the Dee Wyly Distinguished University Endowed Chair held by Sandra Bond Chapman.

Notes

Conflict of Interest: None declared.

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Neuroscience Research 175 (2022) 53–61

Contents lists available at ScienceDirect

Neuroscience Research

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Review article

Neurophysiological dynamics for psychological resilience: A view from the temporal axis

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ARTICLE INFO

Keywords:
Stress
Resilience
Multi-temporal scale
Rodents
Humans
Simultaneous fMRI-EEG

ABSTRACT

When an individual is faced with adversity, the brain and body work cooperatively to adapt to it. This adaptive process is termed psychological resilience, and recent studies have identified several neurophysiological factors ("neurophysiological resilience"), such as monoamines, oscillatory brain activity, hemodynamics, autonomic activity, stress hormones, and immune systems. Each factor is activated in an interactive manner during specific time windows after exposure to stress. Thus, the differences in psychological resilience levels among individuals can be characterized by differences in the temporal dynamics of neurophysiological resilience. In this review, after briefly introducing the frequently used approaches in this research field and the well-known factors of neurophysiological resilience, we summarize the temporal dynamics of neurophysiological resilience. This viewpoint clarifies an important time window, the more-than-one-hour scale, but the neurophysiological dynamics during this window remain elusive. To address this issue, we propose exploring brain-wide oscillatory activities using concurrent functional magnetic resonance imaging (fMRI) and electroencephalogram (EEG) techniques.

1. Introduction

1.1. Definition of psychological resilience

From daily rush-hour trains to a large earthquake, psychological and physical stressors require us to adapt to the environment. Failure to handle stressful situations can lead to psychiatric illnesses, such as major depressive disorder (MDD) and post-traumatic stress disorder (PTSD). The ability to handle these stressors varies among individuals, and this is referred to as "psychological resilience," which is usually assessed by the diagnosis of medical doctors/counselors or self-reported questionnaires. Although the definition of psychological resilience is partially different across researchers (Fletcher and Sarkar, 2013), in this paper, we follow the simple definition of psychological resilience by Feder et al. (Feder et al., 2009), which defined it as "a person's ability to adapt successfully to acute stress, trauma, or more chronic forms of adversity." This definition includes two essential components, 'adversity' and 'positive adaptation' (Fletcher and Sarkar, 2013).

To uncover the underlying neurophysiological factors of psychological resilience, we hereafter define them as "neurophysiological resilience." It is important to capture the temporal adaptation dynamics of various biological signals driven by stressful events in resilient (RES) and susceptible (SUS) individuals. The dynamics can be observed as (1) neurophysiological representations prior to exposure to stress as a risk factor for future depression (stress vulnerability), (2) individual reaction variability to the faced stress, and (3) behavioral changes after the development of depressive symptoms (stress susceptibility). To the best of our knowledge, this is the first study to review recent findings of psychological resilience related to the temporal dynamics of biological signals.

1.2. Experimental approaches to investigate psychological resilience

The neurophysiological basis of psychological resilience has been intensively studied over the past two decades. Researchers have constructed several systematic approaches to investigate differences in individual sensitivity to stressors in both rodents (Table 1) and humans (Table 2). Rodent studies mainly aim to create animal models of MDD (Table 1). Recently, an increasing number of studies have focused on social stress via a frequently used protocol, the chronic social defeat

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https://doi.org/10.1016/j.neures.2021.11.004
Received 7 October 2021; Received in revised form 15 November 2021; Accepted 15 November 2021
Available online 18 November 2021

Table 1
Stress intervention protocols preferentially used for rodent resilience studies.

Protocol	Features	Selected references
Chronic restraint stress (cRS) *(MDD model)*	A rodent is put in a small hemicylindrical plastic tube for several minutes per day, for several weeks. This stress induction strategy has ultimately no social and motor components.	Bauer et al., 2001; Kim et al., 2013
Chronic variable stress (cVS) *(MDD model)*	A rodent experiences multiple unpredictable mild stress for several weeks. Stressors often include foot-shocks, tail-suspension, forced-swim, restraints, and sometimes social defeats. This method has an advantage as the rodent cannot predict and habituate to the stressors.	Hodes et al., 2014; Tye et al., 2013
Chronic social defeat stress (cSDS) *(MDD model)*	This method is developed to induce depression driven by social contexts. A rodent (C57BL/6 J mouse) is placed in the home cage of an aggressive larger animal (CD1 mouse) for 5−10 minutes. Subsequently, the rodent is placed on one side of the cage physically separated with a perforated divider for 24 h. The subject rodent is placed into novel CD1's home cage every day and experiences defeats. This procedure usually continues for 10 days.	Berton et al., 2006; Golden et al., 2011; Hodes et al., 2014; Krishnan et al., 2007; Warren et al., 2013
Predator scent stress (PSS) *(PTSD model)*	Freezing responses are induced by the exposure of cat or fox litter odor to rats. This stressor may be related to PTSD because a single exposure causes long-term depressive symptoms in rats.	Cohen et al., 2006,2008; Dopfel et al., 2019

stress (cSDS: Golden et al., 2011). Notably, rodents that have experienced cSDS protocols have high constructive, face, and predictive validities as a model of MDD in humans (Golden et al., 2011). Regarding constructive validity, the cSDS protocol corresponds to social defeats, such as accepting a low social rank in humans (Huhman, 2006). Regarding face validity, this protocol develops strong depressive physiological responses and behavior (e.g., weight loss, anhedonia, and circadian rhythm changes) analogous to MDD symptoms (Huhman, 2006; Krishnan et al., 2007; Wells et al., 2017). Regarding predictive validity, human patients with MDD gradually but not acutely recover pro-social behaviors by antidepressant drugs. Such gradual recovery is observed in cSDS-experienced animals (Berton et al., 2006). While MDD models have been well-established, researchers are still developing a PTSD model in rodents to investigate the individual neurophysiological differences in psychological resilience against traumatic experiences (Verbitsky et al., 2020; Yehuda and LeDoux, 2007).

In contrast to the rodent models, the experimental scheme in most human studies is any one of (1) a comparison between clinical patients (MDD or PTSD) and non-patients, (2) a cohort survey of individuals in highly stressful environments, such as the army, and (3) personality traits related to stress resilience in healthy populations (Table 2). Using these schemes, researchers are trying to establish better behavioral and neurophysiological markers to evaluate individual differences in psychological resilience (Grueschow et al., 2021; Kaldewaij et al., 2021; Walker et al., 2017).

2. Neurophysiology of psychological resilience

In this chapter, we briefly introduce the neurophysiological factors of psychological resilience. We focused on the resilience-related physiological factors in MDD and PTSD across species (see Cathomas et al., 2019; Furuyashiki and Kitaoka, 2019 for detailed reviews on MDD models in rodents). This comparison revealed that the neurophysiological mechanisms of the resilience between PTSD and MDD are different, with some overlap in humans. However, this neurophysiological

Table 2
Experimental approaches for human resilience studies.

Approach	Features	Selected references
Evaluation of PTSD or MDD patients	One of the most fundamental approaches is to compare individuals who showed PTSD or MDD symptoms and those who did not show these symptoms in spite of facing similar traumatic experiences or being under stressful environments. The advantage of this approach is that researchers can discriminate resilient (RES) and susceptible (SUS) individuals using robust and stable criteria, whereas the disadvantage is that it is impossible to compare between pre-trauma and post-trauma data within an individual.	Drysdale et al., 2017; Harnett et al., 2021; Mary et al., 2020
Longitudinal study under highly stressful environments	This approach targets newcomers in stressful workplaces, such as the army, police, or intensive care unit. The advantages of this method are that it is possible to compare pre-stressed data with post-stressed data within an individual and that it allows predictive analyses; however, it takes time and effort for data collection.	Admon et al., 2009; Grueschow et al., 2021; Kaldewaij et al., 2021
Questionnaire survey	This approach enables researchers to understand individual differences in psychological resilience among healthy populations, as well as psychiatric patients. This approach possibly has the highest reliability and reproducibility as long as people honestly answer the questions. The advantages of this approach is its simplicity and ease of collecting big samples; however, this approach itself cannot evaluate the temporal dynamics of neurophysiological resilience.	Connor and Davidson, 2003; Friborg et al., 2005; Kong et al., 2015; Smith et al., 2008
Behavioral indicators	Despite various attempts, researchers have not successfully invented behavioral paradigms that predict individual resilience. Recent approaches are related to emotional conflict regulations, such as emotional Stroop task or emotional approach-avoidance task.	Grueschow et al., 2021; Kaldewaij et al., 2021; Keynan et al., 2019; Mary et al., 2020

difference has not been sufficiently verified in rodents because of the lack of established protocols that mimic individual differences in the responses to traumatic experiences (Verbitsky et al., 2020; Yehuda and LeDoux, 2007).

2.1. Role of monoamines in the central nervous system

Accumulated findings indicate that monoamines such as dopamine (DA), serotonin (5HT), and noradrenaline (NA) are major neurophysiological factors that play a role in psychological resilience (Fig. 1, *red circles*). The following human research suggests that decreases and increases of DA and NA differ between MDD and PTSD patients.

2.1.1. Dopamine

Several studies in rodents have reported that the firing of DA neurons in the ventral tegmental area (VTA) increases in SUS but not RES mice after cSDS exposure (Cao et al., 2010; Chaudhury et al., 2013; Krishnan et al., 2007). Human studies with patients with PTSD or MDD partially support these findings but provide more complex insights. DA transporter (DAT) density, an index of DA abundance, increases in the

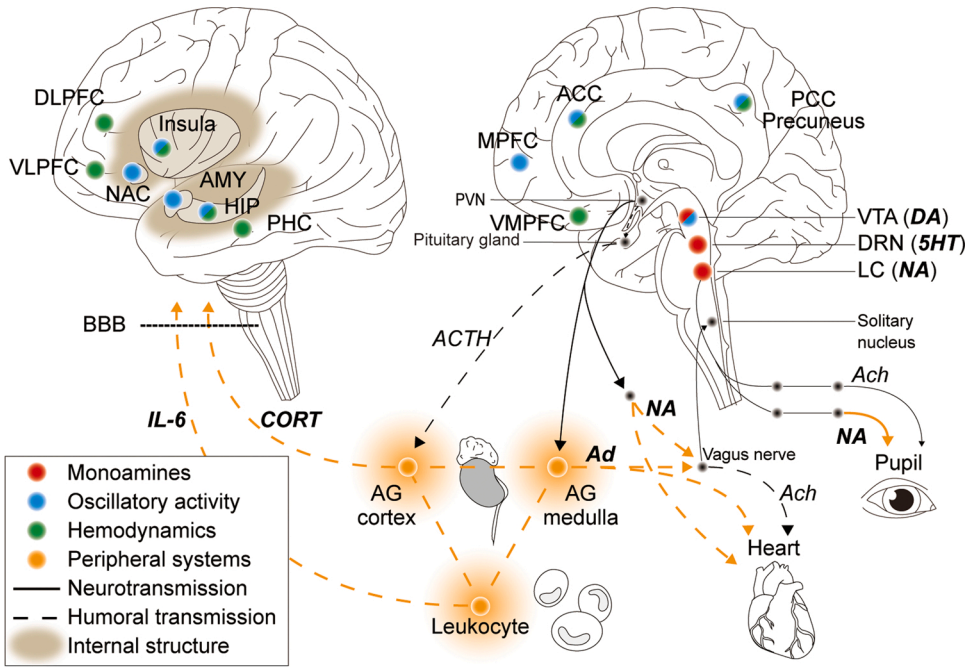

Fig. 1. Neurophysiological factors involved in psychological resilience. Several specific regions in the brain and organs in the body interactively work to adapt to stress positively. The molecules written in boldface represent neurophysiological factors introduced in the main texts. The laterality (left or right hemisphere) of the brain is ignored in this figure. Abbreviations: ACC, anterior cingulate cortex; Ach, acetylcholine; ACTH; adrenocorticotropic hormone; Ad, adrenaline; AG, adrenal ground; AMY, amygdala; BBB, blood-brain-barrier; CORT, corticosterone and cortisol; DLPFC, dorsomedial prefrontal cortex; DRN, dorsal raphe nucleus; HIP, hippocampus; IL-6, interleukin 6; LC, locus coeruleus; MPFC, medial prefrontal cortex (or prelimbic and infralimbic cortex in rodents); NA, noradrenaline; NAC, nucleus accumbens; PCC, posterior cingulate cortex; PHC, parahippocampal cortex; PVN, paraventricular hypothalamic nucleus in hypothalamus; VLPFC, ventrolateral prefrontal cortex; VMPFC, ventromedial prefrontal cortex; and VTA, ventral tegmental area.

striatum of patients with PTSD (Hoexter et al., 2012). In contrast, DAT density decreases in patients with MDD in the striatum and VTA (Meyer et al., 2001; Pizzagalli et al., 2019). The effectiveness of monoamines is also influenced by the projected regions and their receptor types. DA receptor type 1 (D1R) decreases in SUS mice with cSDS in the nucleus accumbens (NAC) (Francis et al., 2015) and medial prefrontal cortex (MPFC) (Shinohara et al., 2018), but DA receptor type 2 (D2R) increases in RES mice in the MPFC (Shinohara et al., 2018).

2.1.2. Serotonin

As shown by the fact that serotonin reuptake inhibitors are a major treatment option for MDD, the dysfunction of 5HT transmission is strongly associated with stress susceptibility. A reduction in 5HT levels in the dorsal raphe nucleus (DRN) has been observed in both rodents (Challis et al., 2013; Zou et al., 2020) and humans (Stockmeier, 2003; Sullivan et al., 2013) studies. For example, in humans, 5HT receptor type 1A (5HT1A), an auto-receptor that suppresses 5HT release, was highly expressed in DRN in patients with MDD (Stockmeier, 2003 for more details). A similar 5HT1A increase in the DRN was also reported in patients with PTSD (Sullivan et al., 2013 for more details).

2.1.3. Noradrenaline

Both rodent and human studies have shown that NA derived from the locus coeruleus (LC) is also related to psychological resilience. Isingrini et al. found that the NA levels around the VTA increased only in RES mice after cSDS and that these increases resulted in the suppression of DA neuron firing (Isingrini et al., 2016). Consistently, in patients with MDD, postmortem analyses revealed decreased expression levels of NA transporters in the LC (Klimek et al., 1997). Patients with MDD showed that the expression of NA α2 adrenergic receptor (α2AR), which suppresses NA release, increases in the LC (Ordway et al., 2003). However, in patients with PTSD, chronic NA density increases in the cerebrospinal fluid (Geracioti et al., 2001), and medical treatments with NA inhibitors are effective in reducing hyperactivity symptoms (Strawn and Geracioti, 2008). These studies suggest that, compared with healthy individuals, patients with MDD have lower levels of NA in the LC, whereas the opposite is true for those with PTSD.

2.2. Brain rhythms

The relationship between oscillatory neural activity (Buzsáki et al., 2012) and stressors has been investigated in rodent and human studies. In summary, the current state of knowledge does not provide an integrated understanding of the brain rhythms underlying psychological resilience, but oscillatory activity around beta frequency bands would play a key role (Fig. 1, *sky blue circles*).

Hultman et al. reported that stress vulnerability (future depression risk) in mice is represented in beta synchronization across the MPFC/NAC–amygdala (AMY)/VTA–ventral hippocampus (HIP) pathway, while stress susceptibility (depression phenotype) is represented in both delta/beta synchronization across the NAC–ventral HIP/VTA pathway and in delta synchronization across the MPFC/NAC–AMY pathway (Hultman et al., 2018). A human magnetoencephalography (MEG) study also reported patients with MDD have increased beta synchronization between the insula and AMY (Nugent et al., 2015). Another MEG study, including patients with PTSD, showed that the individual psychological resilience measured by CD-RISC (Connor-Davidson resilience scale: Connor and Davidson, 2003) was negatively correlated with beta synchronization of the MPFC with the dorsal anterior cingulate (ACC), insula, and precuneus (Brunetti et al., 2017). However, the roles of oscillations in other frequency bands are still under debate (e.g., Dunkley et al., 2014; Jiang et al., 2019).

2.3. Hemodynamics

Functional magnetic resonance imaging (fMRI) is frequently used to identify psychological resilience-related brain regions in humans. Interestingly, some identified regions, such as the insula, ventromedial PFC (VMPFC), and lateral PFC (LPFC), have not been well studied in rodents (Fig. 1, *dark green circles*).

2.3.1. Insula

An early study reported that the hemodynamics in the anterior insula increase in low-resilient participants when presented with visually stressful stimuli (unpleasant pictures) (Waugh et al., 2008). Resting-state fMRI (rsfMRI) studies also reported that resilience questionnaire scores are negatively correlated with spontaneous activity in

the insula and dorsal ACC (Kong et al., 2015).

2.3.2. VMPFC

Sinha et al. reported that VMPFC activity gradually increased during the six-minute stress exposure (Sinha et al., 2016). This increase was positively correlated with the individual active coping level, which is one of the traits of psychological resilience.

2.3.3. LPFC

This region contributes to the suppression of memory and emotion regulation. Mary et al. identified that the suppression signal from the right anterior dorsolateral PFC (DLPFC) to HIP and precuneus decreases in patients with PTSD during the intentional memory suppression task (Mary et al., 2020). Kaldewaij et al. reported that left ventrolateral PFC (VLPFC) activity during the emotional conflict regulation task buffers developments of PTSD against traumatic experiences among police rookies (Kaldewaij et al., 2021).

Interestingly, abnormal resting-state functional connectivity across the insula, VMPFC, VLPFC, and multiple subcortex areas was also detected as a biomarker of MDD (Drysdale et al., 2017). Whereas in patients with PTSD, abnormalities in subgenual ACC, parahippocampal cortex (PHC), and AMY were detected (Koch et al., 2016).

2.4. Peripheral nervous system

The central and peripheral nervous systems influence each other, resulting in autonomic, hormonal, and immune reactions to adapt to environmental stress. The dysregulation of this brain-body loop may cause stress vulnerability and susceptibility. We herein list several markers of the peripheral nervous system for resilience (*orange circles and arrows* in Fig. 1).

2.4.1. Heart

The cardiac rhythm is controlled by the sympathetic-adrenal-medullary (SAM) axis (Schommer et al., 2003). Several human studies have reported greater heart rate changes to acute stressors and higher heart rate variability (HRV) at rest in high-resilient individuals (Lü et al., 2016; Souza et al., 2007, 2013). Similarly, one rat study reported lower resting heart rates and higher resting HRV in RES rats after cSDS (Morais-Silva et al., 2019).

2.4.2. Pupil

The SAM axis also affects the iris muscles, which control the size of the pupil. Pupil size is highly correlated with firing rates in the LC (Joshi et al., 2016). Grueschow et al. attempted to predict the future anxiety and depression levels of new workers in the ICU and found that pupil size or LC activity alone did not predict future anxiety levels, but their combination did (Grueschow et al., 2021).

2.4.3. Glucocorticoid (CORT)

Cortisol in humans or corticosterone in rodents is a stress hormone that regulates the activity of the hypothalamic-pituitary-adrenal (HPA) axis (Sapolsky et al., 2000). Some studies have reported that the CORT response to stress was more robust in RES individuals than in SUS individuals in both rodents and humans (Galatzer-Levy et al., 2014; Kim et al., 2013). Our unpublished data in humans also showed that individual CORT levels in response to acute stress were positively correlated with CD-RISC scores (but see also García-León et al., 2019).

2.4.4. Immune response

Chronic increases in cytokine concentrations have been observed in patients with MDD (Dowlati et al., 2010; Ménard et al., 2017) and those with PTSD (Baker et al., 2012; Gill et al., 2009). Hodes et al. revealed that higher peripheral circulating leukocyte and interleukin (IL)-6 levels prior to cSDS exposure predict future depression symptoms in mice, indicating stress vulnerability (Hodes et al., 2014). Their group also reported that peripheral IL-6 could promote depression by infiltrating the blood-brain-barrier (BBB) around the NAC (Menard et al., 2017; Dudek et al., 2020). Microglia also influence resilience. Nie et al. reported increased IL-1α and tumor necrosis factor (TNF)-α release from the microglia in the MPFC in SUS mice's brain after cSDS (Nie et al., 2018).

3. Temporal dynamics of neurophysiological resilience

As introduced in Chapter 1, psychological resilience is a process of adaptation to a given environmental stress. This feature in psychological resilience raises several possibilities of how neurophysiological resilience is underpinned in temporal dynamics. The first possibility is that each resilience-related neurophysiological factor differes in amplitude between RES and SUS individuals. The second possibility is that each factor differs over time. Although the actual temporal dynamics of each factor can be represented as a combination of these two possibilities, to the best of our knowledge, there is no systematic understanding of the temporal dynamics of physiological resilience introduced in Chapter 2. A major reason for this was the limited number of sampling points in each study. In this chapter, we systematically review the findings of the temporal dynamics of physiological resilience by comparing them across studies (Fig. 2).

3.1. Stress vulnerability as a risk factor for future depression

Growing evidence shows that future risks of depression (stress vulnerability) are related to several neural and physiological factors (*Naive column* in Fig. 2). For example, Hultman et al. identified that, with the ten-day cSDS paradigm, beta-band activity synchronization across the MPFC/NAC–AMY/VTA–ventral HIP pathway increased in future SUS individuals (Hultman et al., 2018). Human longitudinal studies also revealed that individual AMY activity predicted PTSD symptoms 18 months later (Admon et al., 2009). Moreover, both higher brain activity in the LC and higher functional connectivity between the LC and AMY predict anxiety and depression levels several (3 and 6) months later (Grueschow et al., 2021). Both longitudinal studies indicate the involvement of the AMY in stress vulnerability. Another longitudinal study indicated that greater activation in the left VLPFC before trauma could buffer the future development of PTSD symptoms (Kaldewaij et al., 2021). These findings suggest the involvement of the neural mechanisms of emotion regulation as suppressive control of AMY activity through the PFC (Ochsner and Gross, 2008; Watanabe et al., 2019a,2019b). Indeed, both MDD and PTSD symptoms are characterized by difficulties in regulating negative emotions (Ehring and Quack, 2010; Joormann and Stanton, 2016).

Stress vulnerability also affects the peripheral physiological systems. An important finding is that the circulating leukocyte concentration and IL-6 releasing ability of leukocytes are significantly higher in future SUS mice compared to RES mice before cSDS (Hodes et al., 2014). Studies on human patients support the finding that the genetic variants controlling IL-6 expression accelerate depressive symptoms and are increased in patients with MDD (Tartter et al., 2015; Udina et al., 2013).

3.2. Minutes-to-hour scale factors for stress susceptibility and resilience

Immediately after exposure to the stressor, multiple peripheral physiological systems are quickly driven to adapt to the environment (*Minute and Hour columns* in Fig. 2). The first response is driven by catecholamines (adrenaline and noradrenaline). It is activated within a minute and subsequently decreases to baseline levels within 10 min (Sapolsky et al., 2000). Cardiac dynamics are affected by this system. Indeed, the increase in heart rate driven by acute stress was larger in high-resilient human individuals than in low-resilient individuals (Lü et al., 2016; Souza et al., 2007,2013). Although their results also imply that the heart rate decreases rapidly after stress, they have not tested this

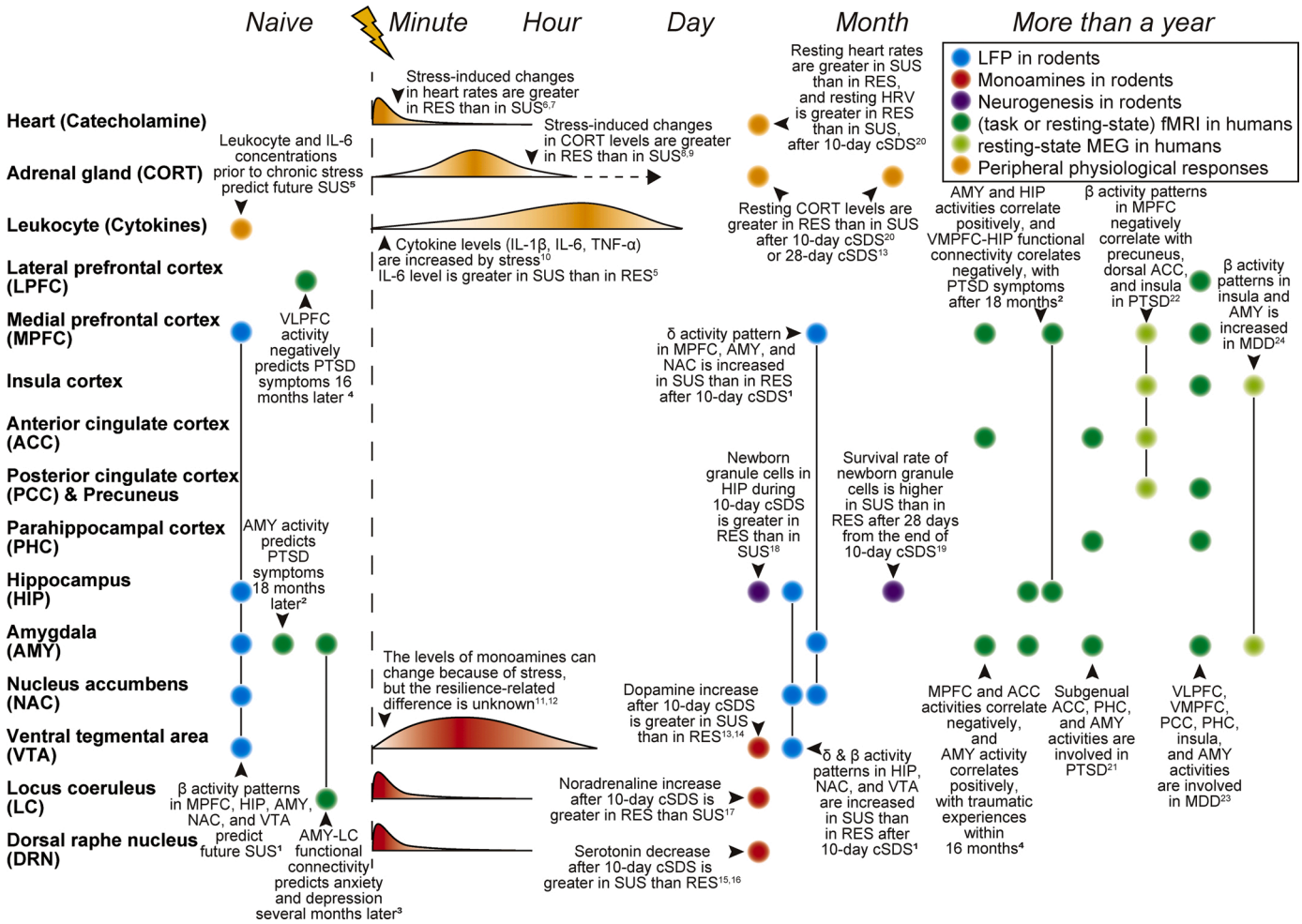

Fig. 2. Temporal dynamics of neurophysiological resilience. Neurophysiological resilience factors are sorted based on the time axis. Circles in *Naive* indicate stress-vulnerability factors that were already represented before stress exposure. Curved line graphs in the figure indicate the time course of peripheral physiological responses and monoamines during the minutes-to-hour scale. Of note, the knowledge between '*Hour*' and '*Day*' (more-than-one-hour window) is still elusive. Abbreviations: cSDS, chronic social defeat stress; fMRI, functional magnetic resonance imaging; HRV, heart rate variability; IL, interleukin; LFP, local field potential; MEG, magnetoencephalography; MDD, major depressive disorder; PTSD, post-traumatic stress disorder; RES, resilient individuals; SUS, susceptible individuals; References: 1. Hultman et al. (2018); 2. Admon et al. (2009); 3. Grueschow et al. (2021); 4. Kaldewaij et al. (2021); 5. Hodes et al. (2014); 6. Souza et al. (2007, 2013); 7. Lü et al. (2016); 8. Kim et al. (2013); 9. Galatzer-Levy et al. (2014); 10. Marsland et al. (2017); 11. Holly and Miczek (2016); 12. Carrasco and Van de Kar (2003); 13. Krishnan et al. (2007); 14. Cao et al. (2010); 15. Challis et al. (2013); 16. Zou et al. (2020); 17. Isingrini et al. (2016); 18. Anacker et al. (2018); 19. Lagace et al. (2010); 20. Morais-Silva et al. (2019); 21. Koch et al. (2016); 22. Brunetti et al. (2017); 23. Drysdale et al. (2017); and 24. Nugent et al. (2015).

point.

The second response is glucocorticoids (CORT), which are activated several minutes after exposure to stress, peak at 25 min, and return to baseline levels approximately one hour after exposure (Goodman et al., 2017; Schwabe and Schächinger, 2018). Some studies have reported that the peripheral CORT response to stress is more robust in high-resilient than low-resilient individuals among both rodents and humans (Galatzer-Levy et al., 2014; Kim et al., 2013). Furthermore, CORT still works in the brain for more than two hours and modulates neural dynamics in several regions, such as the HIP, AMY, and hypothalamus (Joëls et al., 2007). This slow modulation regulates neuron firing in each brain region (Karst et al., 2005, 2010) and potentially affects various cognitive functions, such as memory consolidation (Schwabe, 2017). The dysfunction of this modulation may reduce the capacity to adapt to stressful environments (Joëls, 2018). Although some studies quantified the CORT responses every 20 min (e.g., Galatzer-Levy et al., 2014; Kim et al., 2013), more detailed observations focusing on both amplitude and timing with better temporal resolutions are warranted to understand the temporal dynamics of individual resilience.

The third response is the immune system. The concentrations of different cytokines, such as IL-1β, IL-6, and TNF-α, are increased in the body and brain. Although these increases occurred immediately after exposure to stress (Sapolsky et al., 2000), some cytokine responses persisted, peaked at 40−90 min, and possibly continued for more than one day in humans (Marsland et al., 2017). While the relationship between psychological resilience and immune responses has not been systematically investigated in humans, one study in mice under the cSDS paradigm reported that IL-6 strongly increased within 20 min after an acute stressor in SUS mice compared with RES mice (Hodes et al., 2014). IL-6 also directly affects the brain dynamics around the NAC through infiltration from the blood-brain-barrier (BBB: Menard et al., 2017). Additional studies are required to confirm the role of immune reactions in individual stress resilience, especially in humans.

It is also known that monoamines (DA, 5HT, and NA) are strongly elevated immediately after acute stress (Carrasco and Van de Kar, 2003; Holly and Miczek, 2016). Particularly, a sustained DA increase in the NAC and MPFC for more than one hour has been found in rodents (Holly and Miczek, 2016). However, their temporal dynamics have not been investigated in the context of the differences in psychological resilience

(e.g., future RES vs. SUS) (Fig. 2, *curved red line graphs in Minute and Hour columns*).

3.3. Days-to-month scale factors for stress susceptibility and resilience

Ten-day scale factors have been well investigated by the cSDS paradigm in rodents. One noticeable factor during this time window was changes in balance among monoamines (Fig. 2, *red circles between Day and Month columns*). After ten-day cSDS, SUS mice showed an increase in DA in the VTA (Cao et al., 2010; Krishnan et al., 2007) and a decrease in 5HT in the DRN (Challis et al., 2013; Zou et al., 2020) compared with RES mice or non-stressed controls. In contrast, RES mice after cSDS exposure showed an increase in NA release from the LC to the VTA compared with SUS and non-stressed controls (Isingrini et al., 2016). These monoamine dynamics can affect the ensemble neural activity in the brain. In fact, after ten-day cSDS exposure, the delta and beta synchronization across the NAC, HIP, and VTA, as well as the delta synchronization across the MPFC, NAC, and AMY increased in SUS mice compared with those in RES mice (Hultman et al., 2018) (Fig. 2, *light blue circles*). Neurogenesis during this time window may also be essential to prevent the development of depression. Anacker et al. showed that enhancing newborn granule cells in the ventral dentate gyrus prevented depression after ten-day cSDS exposure (Anacker et al., 2018), while after four weeks from the end of cSDS, the survival rate of newborn granule cells was higher in SUS mice than in RES mice (Lagace et al., 2010) (Fig. 2, *purple circles*). Ten-day scale physiological changes in RES individuals showed lower resting heart rates with higher resting HRV and sustained increases in resting CORT levels (10 days: Morais-Silva et al., 2019; 38 days: Krishnan et al., 2007).

Almost all cSDS studies investigating days-to-month scale factors compared the pre-cSDS baseline levels of neurophysiological resilience with those at the endpoint of cSDS. Thus, the day-by-day temporal dynamics of these factors during cSDS remain unclear. Future studies are required to unravel how the balance of monoamines or neurogenesis gradually changes during the ten-day chronic stressor experience.

3.4. Months-to-years scale factors for stress susceptibility and resilience

Longer temporal dynamics from months to years have mainly been investigated in human studies using fMRI or MEG (Fig. 2, *dark green and light green circles between Month and More than a year columns*). Although there is still no integrated view of the findings, it is likely that the default mode network (DMN) and salience network (SaN) are involved in the temporal dynamics of this timescale (Menon, 2011; van Oort et al., 2017). For example, after 18 months of engagement in the army, increases in PTSD symptoms were positively correlated with AMY (in SaN) and HIP (in DMN) activation and negatively correlated with HIP-VMPFC (within DMN) functional coupling (Admon et al., 2009). Another study also reported that, after 16 months of work as police officers, increases in traumatic episodes were associated with decreased ACC and MPFC (in DMN) activation and increased AMY (in SaN) activation (Kaldewaij et al., 2021). A meta-analysis of rsfMRI data of patients with PTSD confirmed these observations and the involvement of the subgenual ACC and PHC (in DMN) and AMY (in SaN), as compared with healthy controls (Koch et al., 2016). Moreover, the CD-RISC score, including those from patients with PTSD, was negatively correlated with MEG beta synchronization in the precuneus in DMN and dorsal ACC and insula in SaN (Brunetti et al., 2017). The involvement of PCC, PHC, and VMPFC (in DMN), insula, and AMY (in SaN) has also been demonstrated in patients with MDD along with rsfMRI (Drysdale et al., 2017). Partially consistent with this finding in patients with MDD, another MEG study reported an increase in insula and AMY (within SaN) synchronization in the beta-band in patients with MDD (Nugent et al., 2015). Although it is still challenging to reach consistent conclusions, briefly, decreased DMN relative to increased SaN might enhance stress susceptibility in the months-to-years scale.

3.5. The unexplored time window (more-than-one-hour scale)

As described above, we have re-organized previous findings related to neurophysiological resilience based on the temporal axis (Fig. 2). This figure notices the important fact that knowledge on the more-than-one-hour scale remains elusive. Although the glucocorticoid, immune, and dopamine systems activated by stress exposure are still active during this time window, the relationship between these systems and individual differences of psychological resilience has not been clarified. Other reviews have also predicted the importance of this time window from the viewpoint of slow CORT dynamics (Hermans et al., 2014; Joëls, 2018).

As shown above, each resilience-related factor is activated in different time windows, thus supporting a "difference-in-time" possibility. However, it is notable that these factors do not work independently. Instead, they are reciprocally affected in a complex manner. For example, catecholamines, CORT, and immune reactions mutually influence each other (Marsland et al., 2017; Sapolsky et al., 2000). In addition, DA, 5HT, and NA interact in the brain (Isingrini et al., 2016; Zou et al., 2020). Therefore, it is not sufficient to track the temporal dynamics of a single factor to understand the temporal resilience dynamics. Rather, it is necessary to clarify the interaction between factors in the time domain to fully understand resilience dynamics.

4. Future insights for human resilience studies

We have discussed the importance of tracking the temporal dynamics of neurophysiological factors to fully understand psychological resilience. However, most previous studies have not addressed this matter. For example, previous human resting-state neuroimaging studies in which questionnaires were used to assess psychological resilience did not apply any stress perturbations during experiments. Such studies may be insufficient to capture resilience-related neural activity because they did not study temporal dynamics after actual stress exposure.

Although the resilience-related more-than-one-hour dynamics after acute stress have not been assessed in previous studies, some rsfMRI studies have suggested that acute stress drives large-scale functional connectivity (Maron-Katz et al., 2016; Zhang et al., 2019). Moreover, stress-driven connectivity did not return to pre-stress levels within an hour but continuously changed following one hour (Quaedflieg et al., 2015; Vaisvaser et al., 2013). Thus, a new experimental paradigm, which investigates whether the temporal dynamics of acute stress-induced brain-wide functional connectivity is different between high- and low-resilient participants, is warranted to elucidate the neurophysiological underpinnings of psychological resilience.

Additionally, a study comprising MDD model mice by Dzirasa laboratory revealed the importance of the brain's rhythms on stress resilience (Hultman et al., 2016, 2018; Kumar et al., 2014) and suggested that depression-like behavior is characterized by differences in temporal oscillatory patterns of neural activity within the functional network. Although similar neural implementation may also exist in the human brain, conventional measurements by using neither fMRI nor electroencephalography (EEG) (or MEG) alone can detect similar dynamics because of low temporal or low spatial resolutions. To overcome these limitations, several techniques, such as "simultaneous fMRI/EEG recording" and "fMRI/EEG fusion," are gaining attention (Huster et al., 2012; Philiastides et al., 2021). These experimental approaches allow us to investigate neural oscillatory synchronization at the whole-brain scale with sufficient spatiotemporal resolution. Additionally, considering that both EEG and LFP originate from extracellular biophysical processes (Buzsáki et al., 2012), EEG findings can be directly compared with those of previous LFP studies in rodents. Moreover, these techniques are suitable for examining the human-specific characteristics of resilience. Human psychological resilience is considered to include several high cognitive functions, such as positive reappraisal of the stress event, persistence/tenacity, and a sense of self-efficacy (Carlson et al., 2012; Connor and Davidson, 2003), which are quite difficult to

investigate in rodents.

We herein propose the use of combined fMRI/EEG measurements to investigate the neurophysiological underpinning of psychological resilience. With this data collection technique, we can approach the resilience dynamics during the unexplored more-than-one-hour time window. The findings obtained in this window will help fill the gaps of knowledge between rodent and human studies and provide new insights into both fields.

Funding sources

This work was supported by Grant-in-Aid for Scientific Research on Innovative Areas, "Constructive understanding of multi-scale dynamism of neuropsychiatric disorders." for Japan Society for the Promotion of Science Receiver: Noriya Watanabe [grant number: 21H00211], Grant-in-Aid for Scientific Research (C) for Japan Society for the Promotion of Science Receiver: Noriya Watanabe [grant number: 21K07262], Research Grant for Public Health Science (2020–2021) Public Health Research Foundation Receiver: Noriya Watanabe, Grant-in-Aid for Scientific Research (A), Japan Society for the Promotion of Science Receiver: Masaki Takeda [grant number: 20H00521], Grant-in-Aid for Challenging Research (Exploratory) for Japan Society for the Promotion of Science [grant number: 21K18267], and Research Grant for Life Science (2020–2021)from Takeda Science Foundation Receiver: Masaki Takeda.

Data statement

Not applicable.

Declaration of Competing Interest

None declared.

Acknowledgments

We are grateful to the members of the Research Center for Brain Communication for their helpful discussions. We also thank Wanqin Ma (M.S.) for providing illustrations for the figures.

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NEA News

Peer Programs Helping Schools Tackle Student Depression, Anxiety

More schools are leveraging peer counseling and mentoring programs to supplement suicide prevention and trauma-informed strategies.

neaToday

By: Tim Walker

Published: 11/14/2019

According to new data released last month by the Centers for Disease Control, the suicide rate for young people age 10-24 soared by a staggering 56% between 2007 and 2017.

In the absence of comprehensive mental health supports in schools, signs that the stifling pressure, anxiety or trauma have become too much for a student can be hazy, often undetectable. How and when do suicidal thoughts or ideation lead to suicide attempts?

In California, the number of high school students who are *thinking* about suicide is alarming: one in five, according to the 2019 School Climate, Health, and Learning Survey.

"We're racing against the clock with a lot of our students," says Gavin Santillan. "It doesn't take much before they decide to take that step, that sudden act. And the masks they wear obscure what they're really feeling inside. It's fortunate that we have a space at our school where many students feel safe and can talk."

That space is Room 401, the Peer Counselor Center at Garey High School in Pomona, California. Any time during the school day, a student who is struggling can walk into this comfortable, uncluttered suite and sit with a fellow student who is there to empathize, ask questions - most importantly, to listen.

Although no student has committed suicide over the past five years, the school's student population is far from immune to the stifling pressures and anxieties that have plagued U.S. teenagers across the nation, says Santillan, Garey's peer counselor advisor. "Too many of our kids are in crisis."

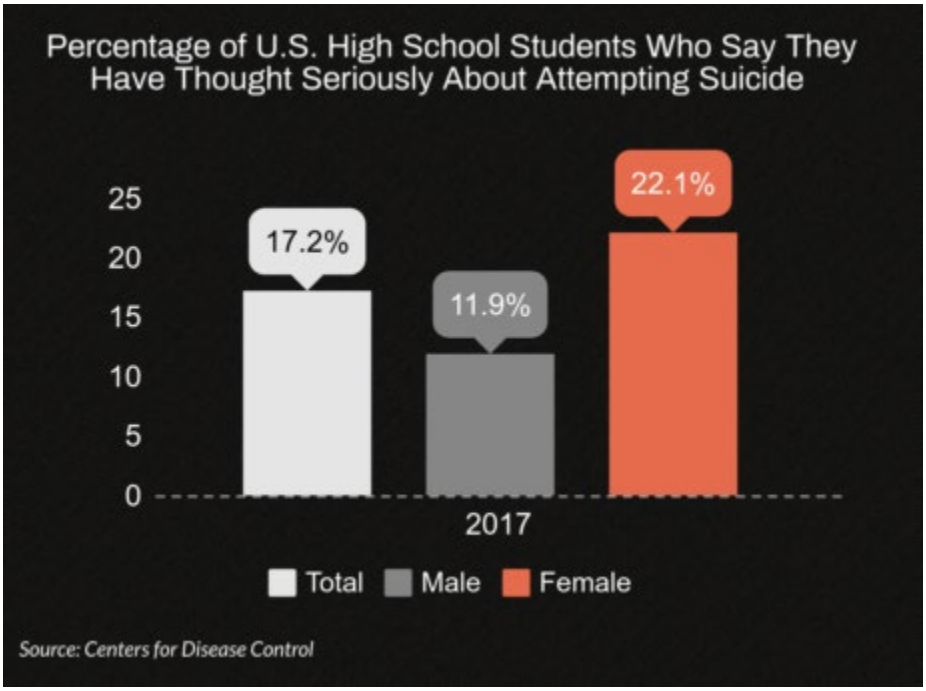
Roughly one-third of the 1800 student body has used the program over the past school year. For some, peer counseling became the last line of defense.

"A couple of students have told us that they were on their way off campus to take their own life," Santillan recalls. "But they stopped into the office on their way out, just curious enough to see if this was a place where they would hear something different.

"Luckily, it was."

Just Talk to Someone

Leveraging students as sources of support for other students is hardly a new idea. The increasing suicide rate and emerging focus on student anxiety and trauma, however, has sparked new interest in peer-to-peer programs. Furthermore, budget cuts, a lack of trained counselors and other mental health professionals - along with lingering stigmas around mental health - has districts scrambling to close the "treatment gap."



That's a burden students shouldn't be taking on, says Margo Ross of the Center for Supportive Schools. Where students can and should make an important difference, however, is closing the "mentoring gap."

"Peer mentoring helps schools create safer and more nurturing school environments to help support students' social and emotional needs and general well-being," Ross explains.

Santillan makes sure students interested in participating in the program understand the boundaries of their role. It's not the peer counselor's job to fix the students' problems; it's to listen, ask questions, and, if necessary, refer them to an adult who can help.

"They don't dispense advice, or offer solutions," Santillan says. "That's not our business. We drill that into the students on day one."

Students do have a way, however, of creating trust and putting at ease their colleagues who may be struggling. "We've had students that refuse to talk to anyone else - parents, adults. They want to talk to us. So we take time with them to make sure trust is established," said Garey peer counselor Lyann.

Garey has a formidable team of between 80 and 90 peer counselors, each one handling ten clients. Each undergoes training in empathy, active listening and basic social and emotional skills. The school invites Pomona County mental health agencies to speak to the students, and local parent groups are brought in to talk about red flags and warning signs that can be easy to miss. "We do a lot of role-playing," Santillan says.

A peer team often includes students who have struggled with anxiety or depression themselves, but who have since overcome their problems. "I went through a lot early in high school and I wanted to make sure that other student goes through it alone," says Lyann.

During the school year, between 80-90 students at Garey High School serve as peer counselors.

When Red Flags Appear

The students who need peer counseling don't fit one particular profile. "They come from different social groups, different academic backgrounds and have different issues," says Santillan. "Sometimes it's just student who is having a bad day, just needs a time-out. But then it can move into darker territory and we're dealing with self-harm, suicide ideation."

Students who need help come to the program through referrals from teachers, counselors, or they just walk into the office asking for help.

"Walk-ins have increased dramatically," Santillan reports. "We do everything we can - posters, flyers, word-of-mouth - to let every student know that we are here, and they can come in anytime."

"This is invaluable resource for our students because they often have an easier time talking to their peers," says Liliana Fasting, one of Garey's four school counselors. "But conversations can get tricky. If red flags appear, then a staff member gets involved."

Santillan sees himself as the "air traffic controller" when additional support and resources are required. Should a counselor be brought in? Should the district mental health office or a county program be contacted?

Psychology interns from nearby Claremont Colleges volunteer their time every week. "They take some of our tougher cases, students who have just returned from hospitalization," says Santillan.

Being alert and responsive to individual student needs doesn't prevent more strategic approaches to ongoing challenges.

Last year, Santillan distributed students who had at least 3 F's among the peer counselors to help identify what was going outside of school that was disrupting their schoolwork.

The failing grades were a symptom of " the bad things that were happening in their lives," says Ashley, a peer counselor.

What comes next may involve interventions that don't involve the peer counselor, but the importance of the work in helping colleagues open up can't be overstated, adds Santillan.

"That's where it can start: students just talking to students."

Breaking the Silence

Student leadership was instrumental in getting a peer-to-peer program off the ground at Brusnwick High School in Brunswick, Maine. Junior Nicco Bartone brought the idea to his guidance counselor, who then reached out to Sources of Strength, a suicide prevention program that trains "peer leaders" to work with adult advisors in schools to help students deal with difficult issues, or as founder and executive director Mark LoMurray says, "the rough stuff."

In 2018-19, Sources of Strength trained 30 Brunswick students to serve not only as resources for their peers, but to design school awareness campaigns around trauma, mental health, and suicide

prevention. At Brunswick High School in Maine, peer leaders create mental health awareness campaigns. (Photo: Maine Public)

The idea, explains Brunswick counselor Mary Kunhardt, is to help create a positive school culture that breaks the silence around these issues and "recognizes that everyone has ups and downs. Peer leaders listen, connect to adults and spread hope."

The Sources of Strength program identifies potential student leaders from every school social group. "We know that students most likely talk with their friends before talking with adults," Kunhardt says. "So, if at least one friend from each group has ears on their peer group, they will be the first to hear if a person is struggling."

Sometimes students are more peer "advocates" than peer "counselors." That's the focus of the program designed by the Depression Center at the University of Michigan.

In 2009, staff members teamed up with Ann Arbor public schools to launch the Peer-to-Peer Depression Awareness Campaign.

Every year, ten to 20 students from participating schools attend an all-day group training session led by social workers and psychiatrists. In addition to learning about mental health, coping skills, and active listening skills, the students are also trained in social marketing and communication strategies.

Students team up with mental health professionals to create publicity campaigns, which are presented and displayed throughout the school. The goal, says program manager Stephanie Salazar, is to find "creative ways to convey their knowledge about these issues throughout the school and help reduce stigma and remove barriers to help-seeking."

After a campaign, says Salazar, schools have seen noticeable shifts in school climate and students' comfort level in talking about mental health with their peers. "Year after year, their knowledge about these issues improves and students say they are more likely to seek help."

"We Will Always Need This Program"

Some peer programs - an outreach campaign to students, for example - can be implemented at a relatively low-cost and with minimal hassle, says Salazar. Challenges inevitably arise, however, around creating the infrastructure necessary to sustain them long-term. Are staff members trained? Are they committed to the program? Are the resources that started the program always available?

Gavin Santillan taught English and Drama for 23 years before becoming Garey High School's peer counselor advisor in 2017.

A lack of program advisors and scheduling obstacles can make prevent schools from "providing the appropriate frequency and dosage of program activities to see a significant impact," says Margo Ross at the Center for Supportive Schools.

"Effective student peer counseling programs, while cost effective, do require a deep investment by schools into training both the mentors and the adults who support them."

Still a relatively new resource, Garey's peer counseling program is bolstered by deep support inside the school and in the community. Parents in particular have been encouraged by positive changes they have seen in their children.

Encouraged by the program's impact, Santillan flinches a bit when he hears the word "success."

"It's just sobering to think about," he says. "I wish they didn't need to, but more and more students are using peer counseling. We've seen an increase in walk-ins. We had more hospitalizations in the last school year. The wheels are turning. So we're helping catch them."

"It would be great if we could double or triple the number of psychologists and counselors in our school," Santillan adds. "But if we want to reach all our kids who are in crisis, we will always need this program."

Student Development Through Involvement: Benefits of Peer Support Arrangements

Andrew Scheef and Beth Buyserie

Abstract: *Peer support arrangements are strategies implemented by schools to provide structured opportunities for students without disabilities to work alongside peers with disabilities, often intellectual and developmental disabilities. Although the benefits of this practice for students with disabilities is well documented, there is limited literature describing the impact of the experience on the peers without intellectual and developmental disabilities. To address this, a content analysis of reflection papers written by 24 high school students without intellectual and developmental disabilities was conducted to better understand the benefits of the peer support arrangements. Six themes to emerge from the reflections include: Emotional Benefits, Skill Development, Understanding Disability, Personal Reflection, Comfort with People with Disabilities, and Ongoing Commitment. Of particular interest is the theme Emotional Benefits, which featured student descriptions of how the mentorship experience increased attendance and school engagement. These findings are discussed and implications for practice and future research are provided.*

To meet the mandate of educational placements for students with disabilities in the least restrictive environment (LRE) as described in the Individuals with Disabilities Education Act (IDEA, 2004), schools seek strategies to provide successful inclusive educational opportunities. This may be particularly challenging when designing inclusive instructional programs for students with intellectual and developmental disabilities (IDD), who are generally educated in a more restrictive environment than their peers with high-incidence disabilities (U.S. Department of Education, 2018). To support inclusive classroom and culture, schools may implement peer-support arrangements to provide students with opportunities to promote inclusion (Olson et al., 2015). Although the benefits of these arrangements for youth with IDD are well-documented in existing literature (e.g., Brock & Huber, 2017; Carter et al., 2016), limited research regarding the benefits for peers without disabilities has been conducted. As such, this study sought to explore benefits experienced by those students who provided supports to peers with IDD.

Peer Support Arrangements

Peer support arrangements are a form of peer-mediated intervention, a broad term that describes situations in which students with disabilities (often IDD) are provided with supports that are delivered by peers (students without IDD) to increase skill development and inclusive education opportunities (Brock & Huber, 2017). Peer support arrangements differ from other peer-mediated approaches in that they (a) include an emphasis on providing social supports and engagement in a social experience, (b) allow for a support structure that may be influenced by the strengths and interests of each involved party, (c) generally involve a smaller number of students, (d) are usually focused on supporting students with low-incidence disabilities or students with more significant needs, and (e) focus on delivery in an inclusive environment (Carter et al., 2009).

Although many adult paraprofessionals, or paraeducators, support students with disabilities in the classroom, peer support arrangements deviate from this traditional service delivery model (Fisher & Pleasants, 2012). Students providing the support receive training and guidance from school staff members to increase quality and integrity of the arrangements (Rossetti & Goessling, 2010). When using peer support arrangements, the role of the adult staff changes to a more indirect support role by providing guidance to the peers without disabilities (Brock & Carter, 2016). This shift provides alternative classroom support opportunities for students with IDD, who until this peer support experience may have been supported only by an adult paraprofessional to achieve academic and other individualized goals (Milley & Machalicek, 2012). Carter et al. (2009) described the unintended consequences of the overuse of one-on-one paraprofessionals to support students in the classroom. These unintended consequences include: (a) reduced interactions with peers, (b) stigmatization, (c) fewer interactions with certified teachers, and (d) development of unhealthy interdependent relationships between students and paraprofessionals.

Benefits to Students with Disabilities

The benefits of peer support arrangements for students with disabilities is well-documented in existing literature. Carter et al. (2016) studied the impact of peer support arrangements for high school students with significant disabilities, including social benefits (e.g., increased interactions with a wider variety of peers, more significant progress in working towards social-related goals) and positive influence on classroom inclusion (e.g., increased opportunities to participate in the same classroom activities as nondisabled peers, heightened level of engagement, more time in the physical classroom).

Brock and Huber (2017) reviewed relevant literature on peer support arrangements and identified the practice as "evidence-based" for promoting social interactions. Peer support arrangements may also have social benefits for students who use augmentative and alternative communication (AAC) devices (Biggs et al., 2017). Although long-term impacts are unknown, Carter et al. (2016) found that peer support arrangements can expand the social network of a student with a significant disability by providing an opportunity for the development of friendships.

These social interactions may occur outside the designated time frame, both during and outside of school, and may exist for an extended duration (Asmus et al., 2017). Peer support arrangements may also be beneficial to support positive postschool outcomes for secondary students with disabilities (Scheef et al., 2018).

Benefits to Students Without IDD Engaged in Peer Support Arrangements

Although the benefits to students with disabilities may be at the forefront of efforts to develop peer support arrangements, the benefits of peers without disabilities should also be considered. These kinds of experiences with peers are important for developing positive perceptions and experiences with people with disabilities; they are the future generation of co-workers, employers, and community members. The benefits to peers without IDD engaged in a peer support arrangement has not received nearly as much attention in the literature, with most studies being 15 or more years old (e.g., Copeland et al., 2004; Cushing & Kennedy, 1997; Kamps et al., 1998). Carter et al. (2009) summarized this early body of literature by describing peer benefits. These peer benefits include: (a) personal growth, including a deeper self-understanding; (b) enhanced views regarding people with disabilities; (c) increased views of value of diversity; (d) development of advocacy skills; and (e) friendship.

Although exploring benefits for peers was not the primary focus, two more recent studies also described these benefits for peers. In one such study, Carter et al. (2011) interviewed six students who worked alongside a peer with IDD to measure social validity of research featuring peer support arrangements. Each student reported positive experiences and noted that they would recommend the opportunity to other students. In the interview, the six students identified personal benefits from the arrangement, including (a) additional opportunities to develop friendships, (b) better awareness of the contributions of students with disabilities, (c) increased understanding of disability, and (d) enhanced social skills. Through interviewing teachers who have implemented peer support arrangements, Leigers et al. (2017) found similar results. Additionally, they found that peers without disabilities felt a greater connection to their school community and had the opportunity to develop skills relevant to their desired profession.

Schaefer et al. (2016) conducted a review of literature to identify the extent to which peer-mediated interventions (including peer support arrangements) benefit the partner student without disabilities. After reviewing 53 studies, the authors concluded that "these studies suggest that the focus on the outcomes and perspectives of peers has been secondary to the outcomes of students with [IDD], with few studies targeting peers as the primary focus" (p. 352). To address this need, the authors called for additional research focused on peers without disabilities engaged in peer support arrangements. As such, the purpose of this qualitative content analysis study is to better understand how peer support arrangements benefit peers without IDD. The following research question has been explored using qualitative methods: What are the perceived benefits to high school students who participate in peer support arrangements with students with IDD?

Methods

To answer the research question, a qualitative study was conducted involving students without IDD who were enrolled in a credit-bearing course that included peer support arrangements.

Research Design and Procedures

After the peer support experiences, all students enrolled in the course wrote a reflection paper at the end of the semester to fulfill a course requirement. Written data sources are beneficial to researchers in that they accurately represent the actual language of the participants and represent work that the participants have taken the time to thoughtfully create (Creswell, 2014). Students were provided with a list of questions by the special education teacher to guide their reflection paper. These questions included:

- What did you learn in the process?
- Did you find out something about yourself?
- What made you want to be a peer mentor?
- How have your thoughts changed or not changed?
- Did it change anything for the future for you?
- Would you recommend being a peer mentor to a friend? Why? Why not?
- What would you change about the class, if anything?

Completed student reflection papers were collected and anonymized for data analysis.

To collect data that presented the perspectives of the students and did not limit student responses, exploratory qualitative methods were an appropriate choice for this study (Creswell, 2014). Specifically, content analysis was used to answer the research question through understanding and analyzing materials included in the student essays. This method is generally characterized by a systematic analysis of material to better understand occurring themes and patterns (Saldaña, 2011).

Participants and Setting

This study included 24 high school-aged students without IDD who attended a school with a student body of approximately 760 students in the northwestern United States. As all identifying information was removed from raw data, demographic information of participants (e.g., age, race, experience) was not collected. All of the participants were enrolled in a credit-bearing course in the Fall 2018 semester that provided opportunities to engage in peer support arrangements with a student with IDD. Peer partners worked together each time the class met, four times a week for approximately one hour each session for an entire semester. Partnership assignments were made by the special education teacher, who considered the goals, schedules, strengths, and needs of both students. The

activities primarily occurred in the general education setting, but also included occasional opportunities in community, vocational, or special education settings. Students provided supports to peers with IDD in relevant skill areas (e.g., academic, social, independent living, self-determination) while also engaging in activities that promoted more inclusive classrooms and the greater school community. Unlike some peer support arrangements, students were not recruited from within specific classrooms (i.e., peers were not concurrently enrolled in the course in which the student with IDD was enrolled).

Students who participated in the peer support arrangement course were trained by school staff and faculty to work with individuals with disabilities; the peers were also trained to work with their specific peer partners. After a one-hour general orientation, students were given targeted and ongoing training to provide support for specific students in the relevant context or environment. This allowed the students without IDD to better understand the individualized strengths, needs, and goals of their partner with IDD. In addition to the hands-on experience, students enrolled in the course completed various assignments to better understand disability and the disability community.

Data Analysis and Credibility

Data analysis was guided by the process of Thematic Analysis as described by Braun and Clarke (2006) and featured each of the six steps that constitute this process. These included

1. familiarization with the data
2. identification of initial codes
3. review of coded content for themes
4. evaluation of themes identified in the previous step
5. development of definitions and names for each theme, and
6. production of the written report.

The first author, who has expertise in special education and qualitative research, individually coded the student papers. This was done using a theoretical approach, a process that involved labeling information with a specific research question in mind (Braun & Clarke, 2006). Based on the recommendation of Saldaña (2011), the content analysis involved seeking content through both manifest meaning (i.e., surface-level, directly stated) and latent meaning (i.e., subtext, suggestive). Through this process, an initial codebook that included the specific descriptive and values codes, related definitions, and usage examples used by the first researcher was developed and refined. Using a codebook in this qualitative research analysis increased the efficiency of the coding process (Guest et al., 2012).

Because researcher triangulation increases the credibility of research findings (Brantlinger et al., 2005), the uncoded student papers and the initial codebook were next given to a second researcher, who also has expertise in qualitative research methods. The second researcher then separately read and coded the participant writing, modifying the codebook as necessary. The two researchers then convened to discuss their separate codes, review the codebook, and develop a common coding system. Per Saldaña (2011), this dialogue on the codes was integral to both the credibility of the research findings and the continued analysis of the data. Then, the two researchers collaboratively reviewed the student writing page by page to come to a consensus regarding the coded data. Once this process was complete, the two researchers reviewed the coded data extracts to identify themes that describe the nature of the content. Content was reviewed to ensure each item's relevance to its assigned theme. Coded data extracts were then reviewed again by both researchers to verify their fit and relevance to the theme.

Ethical Considerations

Data sources were provided by the classroom teacher and identifying information was removed before being presented to the researchers. As such, participant identity was unknown by the researchers as the stripping of personal information allowed for anonymity.

Results

The present study sought to answer the research question: What are the perceived benefits to high school students who participate in peer support arrangements with students with IDD? Fifty-eight pages of typed text written by 24 unique high school students without IDD who engaged in a peer support arrangement were analyzed. Through the analysis of the data, six themes emerged. These themes included: Emotional Benefits, Skill Development, Understanding Disability, Personal Reflection, Comfort with People with Disabilities, and Ongoing Commitment. Table 1 includes the codes associated with each theme, the number of students whose essay responses included each code, and an operational definition for the code. To represent magnitude, themes have been presented based on the number of students whose work included each code (highest to lowest).

Table 1

Emergent themes with related codes

Theme	Code	Number of Students	Description of the Code
Emotional Benefits	Enjoyment	18	Enjoyment of the peer mentoring experience
	Spirit lift	14	Experience has a positive impact on peer mentor's emotions
	Pride	5	Expression of pride in peer's accomplishments as a result of the experience
	Inspiration	3	Peer mentor has been inspired to do better
	Mutual benefit	1	Both students benefitted from the experience
Skill Development	Problem solving	8	Increased ability to solve problems
	Flexibility	8	Increased ability to be flexible
	Patience	6	More patient when working with others
	Leadership	5	Development of leadership skills
	Hands off	4	Recognition that people need to do things for themselves to learn
	Learning	4	Learning new skills (e.g., cooking)
	Communication	3	Improved communication skills
Understanding Disability	Awareness	14	Understanding of disability and perceptions of disability
	Ability of people with disabilities	8	Recognition that people with disabilities have skills and talents
	Whole person	5	Recognizing a person as being more than their disability
Personal Reflection	Personal growth	15	General self-improvement resulting from the experience
	Personal awareness	8	Realization of personal preferences, biases, skills, interests, or abilities
	Compassion	3	Increased compassion
Comfort with People with Disabilities	Friendship	12	Friendships developed from the experience
	Comfort	9	Increased comfort around people with disabilities
Future Commitment	Continued commitment	9	Expression of eagerness to continue working with people with disabilities
	Career	5	Increased interest in careers with people with disabilities
	Advocacy	5	Increased commitment to support the rights of people with disabilities

Note: 24 total students; "Number of Students" represents the number of students whose writing included this particular code.

Theme: Emotional Benefits

Although student response papers included many benefits, the theme Emotional Benefits mostly included statements related to their personal enjoyment of the experience. In fact, the code "Enjoyment" was identified in more student essays than any other code. One student explained, "I knew that I would love this class. Now that I have gone through a semester, I can only say that this is an understatement. This class is easily my favorite." This sentiment was echoed by other students in their reflective writing; overall, students enjoyed the experience. Another student wrote, "Throughout the day, after second period, I often find myself looking forward to the next day just so that I can go back."

Theme: Skill Development

In their writing, students described how the peer support arrangements offered opportunities to develop a variety of skills. Although many specific skills were mentioned, the most prominent involved those related to problem solving and flexibility. One student explained, "I learned how to approach harder situations in an appropriate way ... there were a few challenging instances throughout the year where I previously would have had not a single clue on how to handle them." One student also described their sense of responsibility to problem solve by noting, "I have more responsibility put on myself, and more self-reliant to problem-solve and think of ways to help the student." This problem-solving may involve the need for flexibility, which was described by one student who wrote, "I've learned that sometimes things just don't work, and there's nothing wrong with that. While it may be frustrating, it happens, and it happens a lot. This just opens the doors for new ideas." Students also described the development of skills related to patience ["one thing that I have a hard time with is having patience, and I definitely had to be patient in this class"], leadership ["this class has given me skills that I am able to carry over to cheerleading being a captain"], hands-off teaching ["I learned how to take a step back and let the students learn from their own mistakes"], and communication ["it has immensely helped with my people skills"].

Theme: Understanding Disability

Through the peer support arrangement experience, students gained a better understanding of disability. The most prominent aspect of this theme involved disability awareness and a change in personal perceptions of disability. One student wrote that the experience has "opened my eyes to a new point of view on how to approach people [with disabilities]." Another student discussed the experiences working with a student with IDD and explained, "I have also learnt about the challenges a person like him faces, and that has made me more empathetic."

Recognizing that peers with IDD are young adults just like themselves, one student explained that they learned simply to "treat them like normal people." Students talked about being able to look beyond disability to see their peers for the people they are. One student wrote, "I also learned a lot about [my peer] as a person. I learned that even though she can be stubborn sometimes, she's a really kind person and likes making everyone around her happy."

This increased understanding of disability also included statements that demonstrate a heightened awareness of the ability of people with disabilities. One student wrote, "Most people assume that if you have a disability you lack intelligence and so they are treated differently because of it ... These kids are so intellectual and it is so amazing to watch them prove the standard opinion wrong." Another student was surprised to learn that many of the students with IDD "are super independent, smart, and really rarely need help."

Theme: Personal Reflection

Student essays included statements that demonstrated how the peer support arrangement provided opportunities for personal growth and a heightened sense of personal awareness. Some broad student statements reflected on this personal awareness: "I have grown so much as a human with this class," "I never thought it would be the class that would completely change my daily outlook," and "[friendship with the peer] has changed my whole view on the world". Another student was especially impacted by the experience and noted, "Without this program of class I would not be who I am today, and I truly believe that." Students also made specific mention of how the experience allowed them to become more self-aware. While one student wrote, "I learned that I really really love being there for people," another student explained that "something that I have found out about myself is I personally do not like working with others." The experience working with students with IDD allows some students to better understand their own learning barriers. One student wrote, "I learned techniques that can help with my ADHD ... This class helped me with myself and how I learn how to help myself with my ADHD."

Theme: Comfort with People with Disabilities

The peer support arrangements provided students with an opportunity to become more comfortable being around people with disabilities. Although the school offers inclusive classroom experiences for students with IDD, some students enrolled in the peer support arrangement still had limited interactions prior to enrolling in the course. These limited opportunities for engagement resulted in a discomfort, which was reduced by the peer support arrangement. One student explained:

> Before taking this class if a kid with autism was talking to me, I would be nervous about saying something that might make them really upset or doing the wrong thing. But really you don't have to worry about those things; you just treat them how you treat your friends.

This increased comfort was exemplified by many students who wrote about friendships with peers with IDD that blossomed as a result of the experience. One student

wrote, "I have created a friendship that will stay with me for the rest of my life." Several students discussed how the relationship morphed from arranged sessions into genuine friendships. One student explained, "We became close friends throughout the semester. It didn't feel like I was her peer mentor; it felt like I was just one of her friends helping her out and I am so thankful for that." Students wrote about these relationships extending beyond the school. One wrote, "Most of the students with IDD enjoy spending time with their mentors outside of school, and I did that quite a few times, and I hope to continue to keep having the opportunity to do that."

Theme: Ongoing Commitment

The benefits described in the aforementioned themes perhaps supported student interest in continuing to work with individuals with disabilities. This interest ranged from wanting to continue with the peer support program to expressing interest in engaging in disability work/advocacy in the future. On the more local level of the peer support program, one student wrote, "I am excited to [be a peer mentor] for another semester" while another lamented that "I am very sad I only have one semester left, but I plan on coming to visit still." The continued commitment was described broadly by some, while others were more specific with their goals and interests. One student wrote that the experience "has given me a passion that I know I will carry with me for my entire life—no matter what I choose to do." Another wrote, "One thing I know is that in the future if I do have an opportunity to work with [people with IDD] I will immediately take advantage of it." Other students described how the experience has impacted their career goals. One wrote that the experience "has opened my eyes to a potential career path that I hadn't considered up to this point." Another wrote, "After taking this class I think that possibly going with some sort of career where I can work with this community would be really awesome." Students also spoke about the continued commitment through advocacy with statements such as "Being a peer mentor has helped me learn to take a stand when needed" and "I would hope to become a major advocate for integration." Another wrote that as a result of the experience, they will "make a bigger effort than I have before to include any and everybody in activities or anywhere I am."

Thematic Analysis of the student essays showed a variety of benefits experienced by those without IDD who engaged in peer support arrangement. Six themes emerged from this systematic analysis. Listed in order of magnitude of presence (most to least), they include: Emotional Benefits, Skill Development, Understanding Disability, Personal Reflection, Comfort with People with Disabilities, and Ongoing Commitment.

Discussion

Reflection papers written by 24 high school students who support a peer with IDD were analyzed using qualitative methods. Specifically, this study sought to better understand the benefits experienced by these students without IDD as a result of the experience. Six themes describing a variety of benefits emerged through the thematic content analysis. Two of the themes (Understanding Disability and Comfort with People with Disabilities) describe benefits that have been documented in previous literature. Three other themes (Skill Development, Personal Reflection, and Future Commitment) have been broadly described in previous literature; however, findings from this study provide greater understanding on the benefits peers with IDD might experience. One final theme (Emotional Benefits) represents content that has not been revealed in existing studies.

Emotional Benefits

The theme Emotional Benefits was represented with the greatest magnitude and described benefits not included in existing literature related to peer support arrangements. Remarks about enjoyment of the activities were quite common in the student papers. Many students went beyond simply describing having fun. For many students, the experience was a highlight of their day, with several noting that meeting with their peer encouraged them to keep coming to school. These benefits may be of particular importance to high school students at risk of dropping out of school. In a widely distributed report, Bridgeland et al. (2006) surveyed individuals who dropped out of high school to identify the reasons for their decision to end high school before obtaining their degree. Nearly half of respondents explained that the primary reason for dropping out was a lack of interest in classes and course content (i.e., boredom). In contrast, this study highlights reasons why students might be encouraged to stay in school. Student participants clearly stated that getting through their day would have been a struggle without the peer support arrangement.

Additional Themes

Content related to the themes Understanding Disability and Comfort with People with Disabilities has been represented in previous literature (e.g., Carter et al., 2011). In addition, a large body of literature exists detailing the increased understanding of disability and comfort around people with disabilities resulting from contact and interaction (e.g., Morin et al., 2013; Ouellette-Kuntz et al., 2010). As such, it is perhaps not surprising that these themes emerged from the student writing as benefits. Similar to findings from previous studies (e.g., Leigers et al., 2017), students without IDD in this study identified friendship development as a benefit of the peer support arrangements. Content related to friendship development was included in the theme Comfort with People with Disabilities because we viewed this as an indicator of comfort; one cannot be friends with someone they are not comfortable with. This finding suggests that the peer support arrangements can be effective in not only including students with IDD into an existing network, but also in shaping the perception/confirming that students with IDD can be and are an integral part of valued friendships, at least at an individual peer-to-peer level.

Although Carter et al. (2011) noted a perception of increased social skills for students without disabilities, the student papers in this study described development in many more domains. Perhaps most noteworthy in the Skill Development theme are those related to problem solving and flexibility, the two skill areas most present in student papers. As these are skills highly valued by employers (National Association for Colleges and Employers, 2019), students who serve as peer mentors will likely be increasing their capacity to find and maintain employment in a desirable field. The theme of Personal Reflection was also touched upon in existing literature (e.g., Carter et al., 2009). However, student papers in this study identified substantial gains in personal growth (e.g., general self-improvement) and personal awareness (increased understanding of one's self). The benefits associated with Personal Reflection may lay the foundation for the perceived benefits related to statements categorized under the theme Future Commitment. Similar to the findings presented by Leigers et al. (2017), students in this study described how the peer support arrangement helped guide career interests. More common in this study was a general commitment from students to continue spending time with people with disabilities in some capacity. This represents the extent to which the experience had a profound impact on many students.

Limitations of the Study

When considering the findings of this study, several limitations must be considered. The student work samples presented in this paper represent perceptions of one program in a single school. As such, the findings only represent the perceptions and beliefs of one program. As there is not a standardization of peer support programs, students who participate in similar programs in other schools might find different benefits. It should also be noted that the writing prompts given to students in their reflection essay encouraged responses that included a description of benefits. As this sample was collected a priori, this was not an intentional design component of the study, but rather the nature of the acquired data. In addition, readers should consider that students were not all assigned the same types of tasks with their peer partners. While some supported students in the general education setting, others worked in other settings (e.g., the community, special education classroom). A student's specific placement may have impacted their perceived benefits.

Significance of the Study

Findings from this study suggest that opportunities to support students with IDD may be beneficial to at-risk high school students. Perhaps most notably, these kinds of opportunities may increase interest in attending school on a regular basis; participants in this study described the experience as a primary reason they continue to attend school. Students who deliver supports to students with IDD may also experience personal growth, including skill development and perhaps greater focus on a potential career. Students may also recognize strengths or personal attributes of which they were previously unaware.

Schools that seek positive inclusion models and that do not yet have opportunities for students to engage in peer support arrangements should consider developing such programs. Although the benefits for the students with IDD may be apparent, schools should also view these opportunities as development opportunities for peers without disabilities. Indeed, the peer support arrangement appears to be mutually beneficial, potentially defining the purposes and goals of a traditional inclusion model. This may be particularly important for students at the secondary level who are perhaps more focused on exploring personal interests and better understanding career possibilities. In addition, students at this level may have more flexibility and individuation with their course schedule, thus allowing them opportunities for regular and sustained interactions. Practitioners interested in developing peer support programs should consider exploring the recommendations provided by Carter et al. (2015).

When selecting students without IDD to participate in peer support arrangement, school counselors and teachers may consider the appropriateness for selecting at-risk students. Although Carter et al. (2009) explains that selecting peers with regular school attendance is important, there is also value in considering at-risk students in need of positive school experiences. A potential unintended benefit of engagement in peer support arrangements for at-risk students is the regular interaction with adults; an essential feature of peer support arrangements is teacher and paraprofessionals training for students delivering interventions and instruction. In their school dropout report, Bridgeland et al. (2006) recommend that schools ensure that each student develop a strong relationship with at least one adult in the school community. Peer support arrangements, which inherently include both peer and adult interaction, are one such way schools can meet this goal.

Future Implications of Research

To build on these findings, future research may include a quantitative study of students who engage in peer mentoring experiences. These studies may focus on perception change as a result of the experience. A longitudinal study that explores career choices for peers may help better understand how these experiences impact the professional trajectories. A survey of current special education professionals who engaged in peer mentoring experiences while in high school may lead to an expanded understanding of how the experience impacted their interest in special education or their ability to be successful in their career. As findings from this study indicate that peer arrangements may positively impact a peer without IDD's interest in school and attendance, research that focuses specifically on students at risk for school dropout would be beneficial. It might also be interesting for future researchers to explore some of the codes that were identified less frequently in this study. Probing these specific items (e.g., Communication) may yield interesting findings that were not addressed in this manuscript.

Conclusion

Peer support arrangements are an effective strategy to support classrooms and school communities that are inclusive of students with IDD. Although gains for students with IDD may be the primary consideration for implementing peer support arrangements, students without disabilities may also reap benefits in multiple areas from these arrangements. The findings from this study support and expand on previous research. Perhaps most notable is the emergence of a theme related to how the experience can have a positive impact on a student's school experience and interest in school attendance. To support student development, schools without peer support arrangements should offer this experience to augment the education experience for all students in the school.

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Harnessing the Therapeutic Potential of Music

October 28th, 2021

"Music, uniquely among the arts, is both completely abstract and profoundly emotional. It has no power to represent anything particular or external, but it has a unique power to express inner states or feelings. Music can pierce the heart directly; it needs no mediation."
-Oliver Sacks, MD, Musicophilia: Tales of Music and the Brain

During my sub-internship stint at the neonatal intensive care unit (NICU) in New York's Mount Sinai hospital as a visiting international medical student, I witnessed board-certified music therapists using interventions such as a wooden Gato box and Ocean disc for premature babies to emulate the sound of maternal heartbeats and timbre of the whooshing amniotic fluid as how they would listen within utero. I was rather flabbergasted by the Ocean disc and at how the music therapist adjusted the pace of the flow of beads within the disc. It was simple, yet impactful! The Ocean disc and Gato box, along with parent-preferred lullabies, positively influenced the infants' autonomic nervous responses, reduced the heart rate and respiratory rate, and increased the sucking behavior in premature babies. Researches report that music modulates heart rate, pulse, and blood pressure, explaining the

possible underlying mechanism behind the calming effect of soothing music. In a 2021 study, researchers observed that live music interventions may be more effective than recorded music interventions in reducing pain and anxiety in pediatric critical care patients. There was a significant reduction in heart rate among infants who received live music, immediately after the intervention and was sustained at 60 minutes after the intervention. The effect of sound/music in the autonomic nervous system is further utilized to extend comfort to patients undergoing surgery by reducing the heart rate and blood pressure. It's also used in coronary heart disease and stroke rehabilitation. Evidence points to the therapeutic quality of music.

History

In 2008, a team of archeologists discovered a griffon vulture-bone-flute with five finger holes and a V-shaped mouthpiece from southern Germany, dated around 35,000 years ago, demonstrating the presence of a well-established musical tradition. Music is a unique human expression whose appreciation seems to be a primitive and innate trait: intimate, persuasive, emotional, engaging, and personal. Throughout human evolution, every known culture has given music an illustrious position, both for its aesthetics and potential therapeutic properties. There have been historical mentions of contextual use of music in medicine as early as 4000 BCE. During the Second World War, Harriet Ayer Seymour, a pianist and teacher who, along with her students, helped hundreds of wounded soldiers regain mental health-mentioned, "*We know that the right music will change fear into faith, and despair into courage, because we have seen it happen.*" Seymour later founded the National Foundation for Music Therapy in 1941 and authored the first music therapy textbook published in the United States. The beginning of the 20th century witnessed critical advances in learning the neural correlates of music. Along with the growing understanding of the underlying mechanism behind music's influence on people, scientists have also measured the clinical impact of music-based interventions.

The official definition of music therapy provided by the American Music Therapy Association (AMTA) is the clinical & evidence-based use of music interventions to accomplish individualized goals within a therapeutic relationship by a credentialed professional who has completed an approved music therapy program. There are two types of music therapy; clinical and therapeutic. Whereas clinical music therapy is a research-based, professional discipline that is practiced by credentialed music therapists, therapeutic music therapy includes patients listening to their favorite music on their headphones or musicians singing or playing an instrument bedside. Music-based interventions are not a stand-alone treatment but, when utilized *with* standard treatments, music-based interventions may have a beneficial

impact on anxiety, depression, movement disorders, epilepsy, stroke rehabilitation, and dementia-related disorders.

Clinical impact

Randomized controlled trials suggest listening to vocal music is a successful intervention to support cognitive recovery following stroke. Interestingly, music's ability to provide solace has origins in endocrinology as well. Studies report that exciting music can raise plasma cortisol (a stress hormone) in patients, and soothing music – when played postoperatively – can lower serum cortisol.

Musical interventions have been increasingly used to help patients cope with stress. Striking data from functional imaging shows that music modulates the activity of specific regions in the brain whose abnormalities may result in pain, anxiety, and depression, suggesting music's positive influence on them. Music therapy interventions, specifically tailored to the patient's needs, have been shown to remarkably lower anxiety, depression and aggressiveness in patients suffering from Alzheimer's disease. A clinical study among women undergoing ambulatory breast surgery for cancer diagnoses and treatments illustrated that music had been a safe and effective intervention that may help manage preoperative anxiety. In separate studies, music therapy was also observed to significantly lower anxiety and distress in patients receiving simulation of radiation therapy, decrease pain in adult surgical patients, reduce mood disturbance, and help in pain management among patients undergoing high-dose therapy with autologous stem cell transplantation.

A meta-analysis that reviewed ten randomized controlled trials provides evidence that musical interventions may improve verbal and non-verbal communication, social interaction, initiating behavior, and social-emotional reciprocity in children with autistic spectrum disorders (ASD). Furthermore, musical interventions might contribute to enhancing social adaptation skills and improving the parent-child bond. Another study observed that listening to Mozart K-448 reduced the frequency of epileptiform discharges in children with refractory epilepsy.

Future directions

Music’s therapeutic potential has been evident since the earliest days of humankind, but it wasn’t until the later part of the 20th century that music therapy heralded the beginning of an impactful new profession. Currently music therapy is an established healthcare profession in several countries including the United States, the United Kingdom, Australia, and Canada. It

has been 70 years since the United States has inculcated music therapy into the academic curriculum and currently, there are about 8,000 therapists who are board-certified across the US. Although music therapy is a burgeoning field, many countries lack accredited music therapy training programs, despite having extensive indigenous musical repertoires, which leads to a dearth of board-certified music therapists. As the horizons of music therapy are expanding in both frontiers of research and clinical applicability, we can hope that soon more countries embed music therapy into their respective healthcare infrastructures and utilize the transformative power of music.

***Feature photo by Lorenzo Spoleti on Unsplash*

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Hindawi
Evidence-Based Complementary and Alternative Medicine
Volume 2022, Article ID 9001828, 11 pages
https://doi.org/10.1155/2022/9001828

Research Article

The Effect of Inner Engineering Online (IEO) Program on Reducing Stress for Information Technology Professionals: A Randomized Control Study

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Received 13 September 2021; Revised 10 December 2021; Accepted 13 December 2021; Published 4 January 2022

Academic Editor: Duygu Ağagündüz

In recent years, mindfulness-based interventions (MBIs) are rapidly growing in the workplace. Several meta-analyses conclude that overall MBIs have a moderate effect of alleviating deficit-based experiences, such as burnout and stress, but a small to no effect of promoting asset-based experiences, such as positive affect and well-being. While workplace MBIs vary greatly in their content, format, and duration, the dominant format is still face to face in a group setting, which limits scalability. Our study introduces an emerging workplace intervention called Inner Engineering Online (IEO) and evaluates its effect on reducing stress, burnout, depression, and anxiety and increasing mindfulness and joy. Drawing on the classical yogic science, IEO is a comprehensive web-based multicomponent intervention that utilizes dialectic discourse, meditation, and yogic practices designed to improve physical, mental, and emotional health. Utilizing a randomized active control cross-over experimental design with a sample of 71 employees of an Information Technology company, we tested our hypothesis that IEO training and regular daily yogic practice are likely to lower the stress levels, prevent burnout, and alleviate anxiety and depression, while at the same time promotes positive affect for employees. The results show that IEO program significantly reduces stress only among those who adhere to recommended daily yogic practices. The study is limited by its small sample size. Future research using a large sample is recommended to reexamine the effect of IEO training on occupational health. This trial is registered with NCT04126564.

1. Introduction

Burnout, stress, and mental ill-health and their adverse effects on individuals, organizations, and society have been persistent and growing among employees and employers across various occupations globally [1]. Additionally, burnout incurs organizational costs resulting from decreased productivity, high employee turnover [2], and sickness absenteeism [3]. In the United States, workplace stressors result in 120,000 deaths each year [4]. When neglected, chronic workplace stress often leads to several health problems, such as cardiovascular diseases, mental disorders, musculoskeletal pain, fatigue, and insomnia [5]. In 2008, the total healthcare cost associated with workplace stressors represented 5 to 8% of the national healthcare spending with an expenditure of $190 billion a year [4].

Given this harmful ripple effect of burnout and stress, health promotion targeting burnout and stress has become imperative at workplace. In recent years, mindfulness-based interventions (MBIs) or mindfulness-based programs

(MBPs) in the workplace are growing exponentially and showing encouraging results [1]. In 2018, about 60% mid- to large-sized US companies reported offering mindfulness, yoga, or meditation courses to their employees [6].

The current explosion of interest was sparked by Jon Kabat-Zinn [7], who introduced mindfulness meditation into the field of behavioral medicine and medical research four decades ago. To date, MBSR remains the gold standard of intervention in clinical and nonclinical settings and also spurs the growth of numerous offshoot modified programs for application in a variety of contexts, including occupational and organizational contexts [1, 6, 8].

Multiple studies on workplace MBIs have concluded that overall MBIs show encouraging evidence in alleviating undesirable "deficit-based" mental health outcomes, such as stress, anxiety, and depression but present less conclusive or small effect on "asset-based" well-being outcomes, such as positive emotion and life satisfaction [1]. Among the MBIs, MBSR has demonstrated strong evidence in reducing stress in healthy adult population [8]. The progress of MBIs in occupational and organizational contexts brings challenges as well as opportunities. The present study aims to contribute to the existing literature of MBIs by tackling some of these challenges and responding to some of the opportunities.

The workplace mindfulness-based interventions (MBIs) or programs (MBPs) are highly heterogeneous in intervention content, dose, and mode. Vonderlin et al. [6] observed that several curricula are idiosyncratic, which "couple mindfulness elements with other training, such as emotion regulation, compassion, or physical exercise to produce beneficial synergistic effects" (p. 1581). Modified MBIs often do not disclose what principles and methods underlie the modified program content and the qualification of the program designers and instructors. Furthermore, the scientific foundations of modified programs are not well understood, which is likely to affect the effectiveness of the programs and lead to variation of effects [8]. The modified doses include shortened classes and meditations, ranging from 10 min self-guided meditations 5 days a week with no classes to 42 hr class time over 8 weeks, with 25 min daily practice [8]. Vonderlin et al. [6] note that, on average, the programs involved 16.9 hours of attendance and were offered over a period of 1 to 16 weeks, with an average time span of 7.5 weeks.

Next, flexible delivery methods have been examined, and Vonderlin et al. [6] observed that 79% of the programs are delivered in-person, followed by online programs (13%), combinations of online and in-class elements (7%), or via audio records (1%). A recent review of online MBSR in nonwork settings finds equivalent effects of online to those of face-to-face class-based training [1]. However, flexible delivery modes, such as online or app, have been underinvestigated in the work settings. This presents an opportunity for researchers to examine the effectiveness of online or app-based programs.

Overall, workplace MBIs demonstrate moderate effects on "deficit-based" outcomes such as stress, anxiety, and distress but are less conclusive for depression and burnout [1, 8]. The effects of MBIs are small on "asset-based" outcomes, such as health, job performance, compassion and empathy, mindfulness, and well-being, while no effect on emotional regulation [1, 8]. Follow-up data for a period up to 12 weeks after postmeasurement were reported in 18 studies (34%), with a mean time lag of 9.11 weeks [6]. Therefore, there is an opportunity to explore other underresearched science-based yogic methodologies for workplace applications that offer shorter duration, flexible online self-paced format, and scalability. Additionally, a need to move beyond MBIs developed in clinical setting and to explore other established methodologies or those designed specifically for the workplace has also been identified [1].

With this study, we seek to contribute to the current understanding of the effectiveness of body and mind interventions in the workplace by introducing a yogic methodology called "Inner Engineering Online" (IEO). Drawing on the classical yogic sciences, this program that originated in India has increased demand in the general population worldwide as well as in the corporate context in North America. IEO has been piloted in Fortunate 500 and technology companies. IEO expands the current repertoire of MBIs in the workplace by offering multilinguistic, web-based, self-paced, and comprehensive features.

Second, our study expands the occupational samples of MBIs by including the Information Technology professionals, a fast growing but understudied profession in workplace MBIs research. Consequently, by surveying the Information Technology professionals, the study also adds diversity (more men) to the current pool of workplace MBIs research participants (predominately women). The work culture in technology companies is demanding and highly stressful, often requiring employees to work long hours with irregular schedules to meet the targets [9, 10]. Entrepreneurs in technology startups often work in competitive, chaotic, and unpredictable environments that test their adaptive and innovative abilities with little room for errors. Working in such demanding environments can lead to high-stress levels, sleep disturbances, and social isolation, depleting the innate coping mechanisms to handle stress [11]. Besides, they are often underappreciated for meeting these work expectations; predisposing individuals to low self-esteem and burnout [11]. Previous studies have shown a positive association between work-related stress and poor health outcomes among the IT industry employees [12, 13]. Lastly, our study answers the call for using an active control group in meditation and yoga studies, which is a more robust research design [14, 15].

The evidence so far suggests that workplace MBIs have a moderate effect on these "deficit-based" dysfunctional outcomes such as stress, anxiety, and distress, but the evidence is less conclusive for depression and burnout [1, 8]. The aim of MBIs is to enhance mindfulness, which in turn ameliorates dysfunctional symptoms such as stress, anxiety, and depression [1, 8]. Although there are external stressors or stimuli for anxiety, one's own thoughts, emotion, and physiology are also significant sources of internal stressors and stimuli [16]. The intellectual self-inquiry aspect of IEO is to recognize both external and internal stressors, accept their

inevitability at the present moment, bring a sense of curiosity to investigate their causes, and finally unroot the cause of stress by not identifying with one's own thoughts, emotions, or bodily sensations [17]. The guided meditations and physical and sound yoga aspects of IEO further assist in alleviating mental distress by improving physiological and chemical functioning [18]. Thus, we hypothesize that the synergistic effect of IEO's multicomponents of didactic inquiry of human experiences, Upa Yoga, and meditations will produce the following effects:

Hypothesis 1: the practice of IEO intervention will result in higher levels of mindfulness and joy

Hypothesis 2: the practice of IEO intervention will lower levels of stress, anxiety, depression, and burnout

2. Method

2.1. Participants and Procedure. Participants were recruited from a midsize Information Technology company located in the United States. The opportunity to enroll in IEO and participate in the study was offered to employees through a company-wide awareness drive. This is similar to the common recruitment method of MBI studies in which participants were mostly self-selected into the study in response to invitation campaigns [8]. Eighty-two employees expressed interest. After being screened for eligibility (aged 18 years or older, proficiency in English, and US residency), 71 employees were eligible and enrolled in the study by signing electronic consent forms. These participants completed their baseline surveys and were randomized based on a sequence of computer-generated random numbers into the two study groups: the intervention and the active control group. Table 1 describes the sociodemographic and medical characteristics of these participants at baseline.

Table 1: Demographic and health characteristics of participants.

Characteristics	Intervention group ($n = 35$)		Control group ($n = 35$)	
	Mean	SD	Mean	SD
Age	40.5	(30–51)	38.7	(28.7–48.7)
	n	(%)	*n*	(%)
*Gender**				
Male	16	(45.7)	18	(51.4)
Female	18	(51.4)	17	(48.6)
Education				
High school	0	(0.0)	1	(2.9)
Graduate	27	(77.1)	16	(45.7)
Postgraduate Ph.D./doctorate	8	(22.9)	18	(51.4)
Health condition				
Hypertension	3	(8.6)	5	(14.3)
Diabetes mellitus	1	(2.9)	2	(5.7)
Coronary artery disease	0	(0.0)	1	(2.9)
Smoking				
Active	2	(5.7)	0	(0.0)
Recent nonsmoke	1	(2.9)	0	(0.0)
Never	31	(88.6)	35	(100.0)
Alcohol consumption				
Social	19	(54.3)	24	(68.6)
Regular	4	(11.4)	0	(0.0)
Prior experience of meditation				
Yes	10	(26.8)	8	(22.9)

*Missing data in intervention group.

2.2. The Inner Engineering Online (IEO): The Intervention. Inner Engineering Online is a 4-week self-paced multicomponent program available online and via an app in ten languages. The program was created in 2011 by Sadhguru Jaggi Vasudev, a mystic, yogi, who founded the Isha Foundation, through which the IEO program is offered. Based on the distilled essence of yogic science, IEO consists of comprehensive methods that include conducting intellectual inquiry (resulting in cognitive reappraisal), generating positive emotions, learning Upa Yoga (preparatory Hatha Yoga involving body movement and breathwork), and activation of inner energy (sound and postural yoga).

IEO's first component is the seven online lessons (90 minutes per session) employing logic-based self-inquiry and investigation of everyday human experiences and accompanied by humorous wisdom-based stories. These didactic sessions explore Inner Engineering principles that participants are encouraged to review multiple times daily mentally. By gaining the ability to reappraise one's internal mental and physiological processes and external situations and social relations, one encounters reduced automatic reactivity to internal and external stressors.

The second component of IEO is learning and practicing a system of "Upa Yoga" ("pre" or "sub" yoga), introductory practices as part of the classical Hatha Yoga. No previous yoga or meditation experience is required, nor is physical agility. Participants learn six Upa Yoga practices that activate the joints, muscles, and energy systems and stimulate the parasympathetic nervous system. Beyond awareness of breathing as part of mindfulness meditation, Upa Yoga includes volitional control of breath (pranayama). Recent studies show that volitional control and awareness of breathing activate overlapping but distinct regions of neural network [19] and that the rhythm of breathing creates electrical activity in the brain that enhances emotional judgement and memory recall [20].

IEO also includes meditative practices that involve sound (sound yoga). Studies indicate that listening to the "AUM" sound generates emotional empathy [21] and chanting these three sounds brings physiological relaxation and mental alertness [22]. Combining cognitive reappraisal with the yoga of sound (AUM chanting) produce synergistic effects in relaxation and mental alertness and induces positive emotion such as joy. The at-home practice of Upa Yoga, sitting quietly and reviewing IE principles, and AUM chanting takes about 30 minutes daily.

The third component of IEO is guided meditation, awareness questions, and reflective writing at the end of each online lesson. The guided meditations incorporate

visualization, body, and breathwork. The awareness questions and reflective writing provide participants an opportunity to contemplate on lessons learned, apply these insights to daily life examples, and deepen awareness.

Preliminary pilot results suggest that IEO enhances employee well-being (energy, joy, mindfulness, wholeness within oneself, and connection with colleagues) and positive organizational behaviors (meaningful work, psychological capital, and work engagement) [23]. Peterson et al. [24] found that completion of IEO when added with learning and practicing an additional 21-minute *Shambhavi* practice reduced perceived stress and general well-being. To our knowledge, this study is the first RCT that builds on this emerging line of research and used this comprehensive, low-cost, short-duration, multilinguistic, web-based, self-paced, and globally scalable body and mind intervention in an occupational setting.

For ease of understanding, the study has been described as phases. Following consenting and enrollment, baseline characteristics were measured (Time point 1). This phase is described as the *Enrollment Phase* in the consort diagram. Upon completion of their baseline surveys, participants were randomized based on a sequence of computer-generated random numbers into two groups: the intervention and the control group (also referred to as Active comparator group). Blinding and allocation concealment was not performed in this study. This phase concluded by taking measurement at the end of the 4th week (Time 2) wherein the intervention group finished receiving the IEO intervention while the control group was instructed to read a book of their choice for 30 minutes daily. This has been described as *Study Phase I* in consort diagram.

In the next phase of our study, there was a 4-week cross-over period when the intervention group performed no prescribed activity while the control group crossed over to receive IEO intervention. Participants took the third measurement at the end of the cross-over period (Time point 3). This phase was described as *Study Phase II*.

In the final phase, a 4-week follow-up (Time point 4) was conducted. This phase is also known as the *Follow-Up phase*. The total length of the study was 12 weeks. The study protocol was approved by the lead author's institution. Figure 1 details the various study stages.

2.3. Outcome Measures

(1) *Mindfulness*. Mindfulness was measured using the Brown and Ryan's (2003) 15-item Mindful Attention Awareness Scale (MAAS). Each item is coded 1 "never" to 5 "all of the time." The MAAS is one of the most commonly used mindfulness scales in the occupational setting and in general population [1]. This measure had strong reliability across study samples with Cronbach's alpha $\alpha = 0.92$ at baseline.

(2) *Stress*. Perceived stress was measured by the 10-item Perceived Stress Scale (PSS) [25]. Each item was coded as 0 "never" to 4 "very often." The PSS score ranges from 0 to 40. The PSS is the most common measure used in stress studies with well-established reliability and validity. It is also brief and easy to administer online. The reliability of PSS is consistently high across four points of measurement with $\alpha = 0.82$ at baseline.

(3) *Anxiety*. Anxiety was measured using PROMIS-Anxiety short form v1.0 scale consisting of 7 items. Each item was coded as 1 "never" to 5 "always." The PROMIS-Anxiety item banks assess self-reported fear (fearfulness, panic), anxious misery (worry, dread), hyperarousal (tension, nervousness, restlessness), and somatic symptoms related to arousal (racing heart, dizziness). The anxiety measures are universal rather than disease-specific and assess anxiety over the past seven days. This measure also had strong reliability across study measurements with $\alpha = 0.88$ at baseline.

(4) *Depression*. Depression was measured by the Center for Epidemiological Studies-Depression (CES-D) 20-item scale [26]. Each item was coded 1 "rarely or none of the time (less than 1 day)" to 4 "most or all of the time (5–7 days)." The CES-D scale has high reliability and validity and has remained a dominant measure for depression in community population. This measure had strong reliability across study measurement with $\alpha = 0.81$ at baseline.

(5) *Burnout*. The 16-item Maslach Burnout Inventory for General Survey (MBI-GS) [27] was used to measure burnout. The MBI-GS defines burnout as a crisis in one's relation with work and consists of three subscales: Exhaustion, Cynicism, and Professional Efficiency. The Exhaustion subscale measures both emotional and physical fatigue—one's feeling of being overextended and exhausted by one's work. Cynicism measures indifference or a distant attitude toward work. Professional Efficacy encompasses both social and nonsocial aspect of occupational accomplishments [27]. The MBI scale has high reliability across four points of measure throughout the study. Cronbach's alpha for the baseline is $\alpha = 0.82$.

(6) *Joy*. Joy was measured using the 6-item Dispositional Positive Emotional Scale—Joy (DPES-Joy) subscale [28]. Each item was coded from 1 "strongly disagree" to 7 "strongly agree." The scale measures a dispositional tendency to feel joy in life. This measure had strong reliability across study measurements with $\alpha = 0.87$ at baseline.

2.4. Statistical Analysis. The study was a feasibility trial with a minimum enrollment goal of 60 participants. Despite best efforts, we were able to enroll 71 participants in the study resulting in a small sample size in both the intervention group and the control group. The assumption of normality of sample data distribution was assessed using the Shapiro–Wilk test. The tests indicated skewed distributions of sample data; therefore, nonparametric Mann–Whitney U test was conducted to determine if IEO made a significant difference in outcomes between the intervention and control groups. Wilcoxon signed-rank test was conducted to

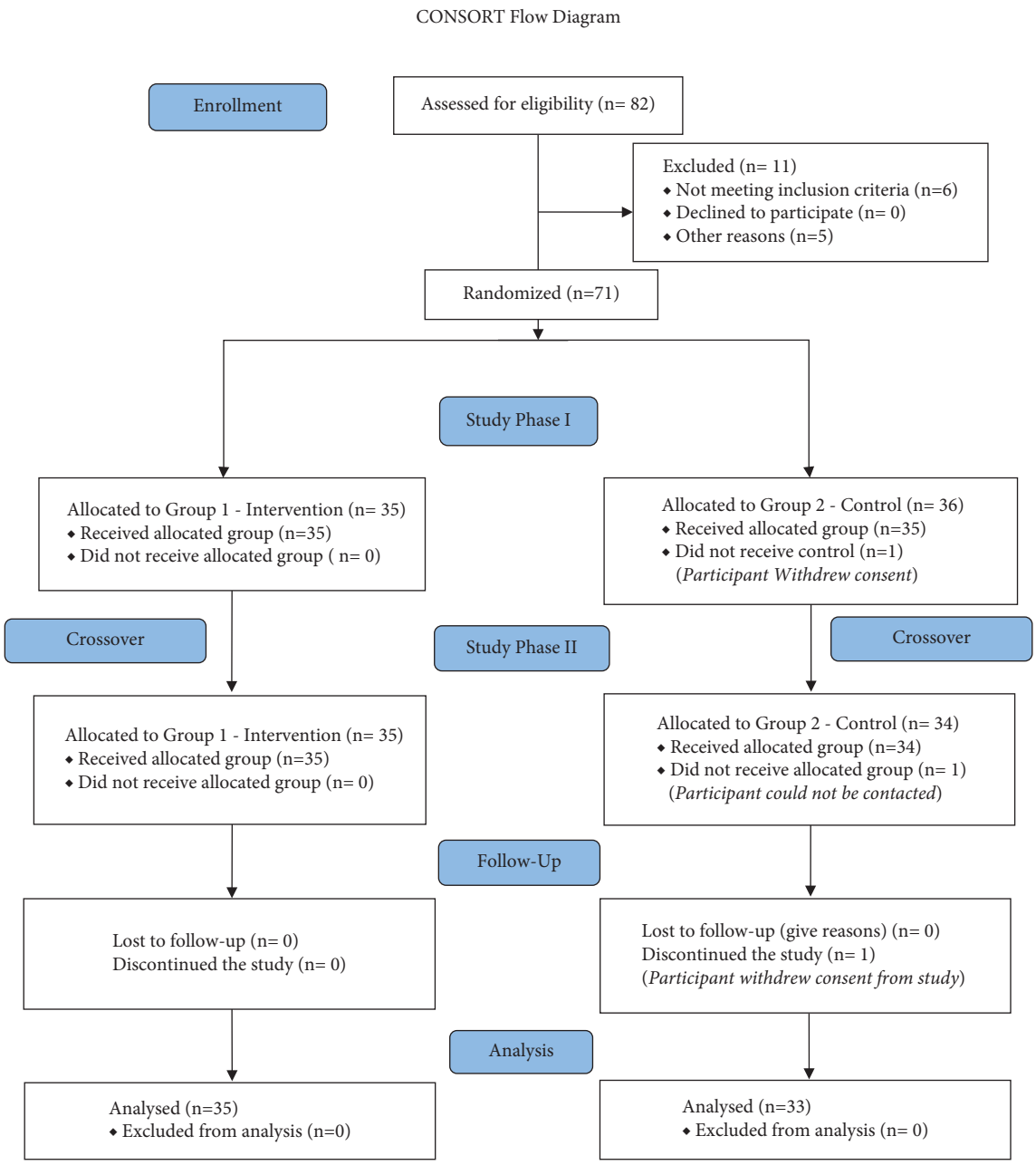

Figure 1: CONSORT chart.

examine the changes postintervention and during follow-up that participants experienced within their group. The median was used to indicate the central tendency of the outcomes. Categorical data were presented as frequencies and proportions and assessed using a chi-square or Fisher's exact test. IBM SPSS 25 (New York, NY, USA) was used for the analysis and two-sided p values were reported with a significance level at $p < 0.05$.

3. Results

Table 1 presents the demographic and medical conditions of participants at the baseline. Around 47% of participants in each group were males with mean ages ranging from 29 to 49, and more than half of each group had higher than a Bachelor's degree. Both the groups are comparable in their demographic profile and their baseline scores for health conditions and habits. Stress and other outcome measures showed no significant difference at study initiation. About 26.8% of participants in the intervention group and 22.9% in the control group reported prior meditation experience.

Table 2 presents the nonparametric Mann–Whitney U test results of intergroup comparison throughout the study duration. The results show that there was no significant difference between the intervention group and the control group in terms of median changes in stress (−3.0 *vs.* −1.5, p value = 0.19), anxiety (−3.0 *vs.* −2.0, p value = 0.3), depression (−1.0 *vs.* −1.5, p value = 0.79), burnout (Exhaustion

Table 2: Mann–Whitney U test results between intervention group ($n = 34$) and control group ($n = 34$).

Variables	Mann–Whitney U test results between intervention group ($n = 34$) and control group ($n = 35$) (intergroup analysis at different time points for primary and secondary outcomes)											
	Baseline (T1)–Week 4 (T2)				Week 4 (T2)–Week 8 (T3)				Week 8 (T3)–Week 12 (T4)			
	Intervention ($n = 35$)	Control group ($n = 33$)	Test stats (Mann–Whitney U)	p value	Intervention ($n = 35$)	Control group ($n = 33$)	Test stats (Mann–Whitney U)	p value	Intervention ($n = 35$)	Control group ($n = 33$)	Test stats (Mann–Whitney U)	p value
MBI-Exhaustion	−1.0 (−4.0; 2.0)	−1.0 (−3.0; 1.0)	597.5	0.81	−1.5 (−5.3; 1.0)	−1.0 (−3.3; 0.0)	558.5	0.89	−1.5 (−5.3; 1.0)	(−2.3; 2.0)	669.0	0.17
MBI-Cynicism	−0.3 (−0.9; 0.4)	−0.2 (−1.0; 0.3)	617.0	0.67	(3.3; 3.3)	−0.5 (−4.0; 3.0)	512.5	0.74	(−3.3; 3.3)	(−0.4; 3.0)	541.0	0.93
MBI-Professional Efficiency	0.5 (−2.0; 5.3)	0.0 (−2.0; 2.0)	530.5	0.55	(−3.0; 2.0)	(−5.3; 4.0)	593.0	0.66	(−3.0; 2.0)	(−3.0; 3.3)	586.5	0.73
PSS	−3.0 (−8.0; 0.0)	−1.5 (−4.0; 1.0)	703.0	0.19	−1.0 (−3.0; 2.0)	−2.5 (−6.0; 4.0)	488.0	0.27	−1.0 (−3.0; 2.0)	(−2.0; 3.0)	628.0	0.44
MAAS	0.3 (−0.1; 0.9)	0.4 (−0.1; 0.8)	587.5	0.93	(−0.4; 0.4)	0.1 (−0.2; 0.5)	675.0	0.28	(−0.4; 0.4)	(−0.2; 0.6)	697.0	0.17
DPES	0.3 (0.0; −0.8)	0.1 (−0.5; 0.7)	492.0	0.22	(−0.3; 0.8)	(−0.5; 0.7)	561.0	0.88	(−0.3; 0.8)	−0.2 (−0.8; 0.4)	469.0	0.17
CES-D	−1.0 (−5.0; 0.0)	−1.5 (−5.0; 3.0)	617.0	0.79	(−2.0; 4.0)	(−3.0; 2.0)	517.0	0.50	(−2.0; 4.0)	(−3.3; 2.3)	506.0	0.38
Anxiety	−3.0 (−7.0; 0.0)	−2.0 (−5.0; 0.0)	670.0	0.37	(−1.0; 3.0)	−0.5 (−4.0; 1.0)	405.5	0.03	(−1.0; 3.0)	(−1.0; 1.0)	544.0	0.72

subscale: (−1.0 *vs.* −1.0, p value = 0.81); Cynicism subscale: (−0.3 *vs.* −0.2, p value = 0.67); Professional Efficiency subscale: (0.5 *vs.* 0.0, p value = 0.55)), mindfulness (0.3 *vs* 0.4, p value = 0.93), and joy (0.3 *vs* 0.1, p value = 0.22) from baseline (T1) to Week 4 (T2). Similarly, there was no significant change in median scores of stress, burnout, depression, mindfulness, and joy between the intervention group and the control group from Week 4 (T2) to Week 8 (T3) (refer to Table 2 for scores). However, the control group showed a significant reduction in anxiety scores compared to the intervention group during the cross-over period supporting the theory that workplace MBIs demonstrate moderate effects on "deficit-based" outcomes such as stress and anxiety [1, 8] ((Phase I scores: −3.0 *vs.* −2.0, p value = 0.3) *vs.* (Phase II scores: 0.0 *vs.* −0.5, p value = 0.03)).

By taking into account the extent to which employees follow the recommended home practices routinely, we found a significant effect of IEO on the intervention group compared to the control group. Compliance was defined as 3 or more days of activity each week for at least 2 weeks out of the 4-week intervention period. Twelve (35.30%) of the intervention group participants and 23 (65.72%) of the control group participants showed sufficient compliance. We conducted further analysis to see if demographic and baseline conditions contribute to different levels of compliance but found no evidence of significant systemic differences.

Participants in the intervention group (−6.5 (IQR: −9.5, −1.5)) who practiced as instructed experienced a significant decline in stress compared to the control group (−2.0 (IQR: −4.0, −1.0)) between the baseline (T1) and the end of 4-week intervention (T2); (p value = 0.018) (see Figure 2). Once the control group participants were crossed over to receive the intervention, their stress scores also significantly declined compared to their own baseline levels ((−1.5 (IQR −4.0, −2.3)) vs. (−7 (IQR −5, −2)); p value = 0.085). This decline was synonymous with the decline noticed in intervention group participants during active intervention phase.

Table 3 reports the within-group, nonparametric, pairwise test (Wilcoxon signed-rank test) results. The intervention group experienced a significant decline in stress (−3.0 (IQR −8.0, 0.0), p value = 0.01), anxiety (−3.0 (IQR −7.0,0.0), p value = 0.001), and depression (−1.0 (IQR −5.0, 0.0), p value = 0.02) with a significant rise in both mindfulness (0.3 (IQR −0.1,0.9), p value = 0.01) and joy (0.3 (IQR 0.0, 0.8), p value = 0.03) between the baseline (T1) and the end of 4-week intervention (T2) measures. Similarly, the control group experienced a significant decline in stress (−1.5 (IQR −4.0, 1.0), p value = 0.04) and anxiety (−2.0 (IQR (−5.0, 0.0), p value = 0.002) with a significant rise in mindfulness (0.4 (IQR −0.1,0.8), p value = 0.03) between the baseline (T1) and the end of 4-week intervention (T2) measures. It is hard to ascertain the reason for this decline in the control group scores. It could be attributed to either "Placebo effect" as a result of participation in a research study or the positive effects of taking time off work and doing prescribed reading activity for the study duration.

During the cross-over period (from Week 4 to Week 8) when the control group received IEO training and the intervention group continued regular life as usual, there were no significant changes in any of the measured outcomes for the intervention group, except for a significant decline in Burnout subscale of Exhaustion (−1.5 (IQR −5.3, 1.0); p value = 0.04). We do not know whether the intervention group continued or discontinued the daily home practices and hence only speculate the reason for this decline in Exhaustion scores is due to an increased exposure to the IEO intervention. The control group, on the contrary, continued to experience a significant decline in anxiety scores (−1.0 (IQR −4.0,1.0); p value = 0.03) supporting our theory that workplace MBIs demonstrate moderate effects on "deficit-based" outcomes such as stress and anxiety [1, 8].

4. Discussion

The study seeks to contribute to the existing literature by introducing an emerging body-mind behavioral medicine intervention called "Inner Engineering Online (IEO)." The study evaluates the effect of IEO in alleviating dysfunctional experiences, such as burnout, stress, depression, and anxiety while promoting positive emotions among employees in an Information Technology company. We employed a randomized, active control group cross-over design. Though the overall results show that IEO did not have a significant effect on both negative and positive outcomes, there was a significant decline in perceived stress for the intervention group compared to the control group in the first phase in compliant participants. When the cross-over control group was subjected to IEO intervention, there was a significant decline in perceived stress compared to its own baseline. Below, we discuss plausible explanations of the findings.

First, similar to most studies of workplace MBIs, our study recruited participants through a company-wide awareness campaign that a well-being program was offered by the company. This open enrollment possibly resulted in a self-selection effect—the program offering attracted employees with relatively high baseline levels of negative states, such as burnout, stress, anxiety, and depression. The data show that baseline scores of these negative states were at the higher end for both the intervention and control groups. In contrast, the positive states such as mindfulness and joy were at the lower end of score range. In such cases, scores are usually subject to the effect of regression to the mean [8] for both the intervention and control groups. Our results show that both the intervention and control groups experienced significant amelioration of stress and significant improvement in mindfulness and joy, resulting in insignificant treatment effect.

Alternatively, burnout researchers may argue that there could be the "healthy worker's effect" [29], which is a well-documented selection bias in burnout research. It suggests that those who are ill, disabled, or have left the organization because of work-related stress are not included in the study sample. This might be the case for our study as the participants were recruited following an awareness campaign in the company helmed by the company's CEO. Since blinding was not incorporated, selection bias could be a limitation of our study.

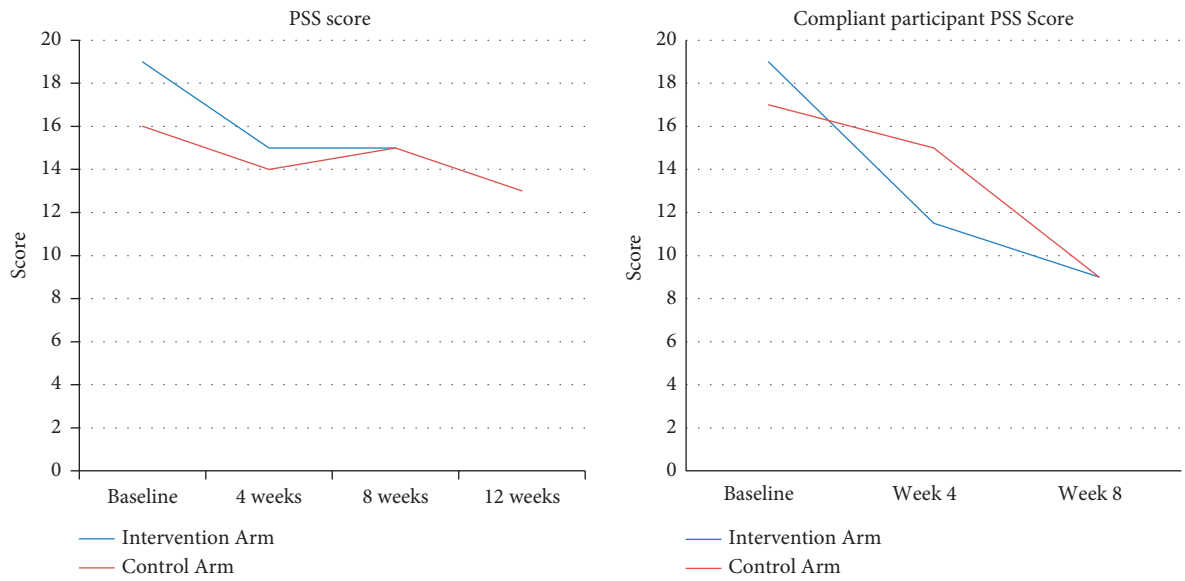

Figure 2: Time trend comparison between study participants.

Table 3: Wilcoxon signed-rank test for intragroup analysis between intervention group ($n = 34$) and control group ($n = 34$).

Wilcoxon signed-rank test results between intervention group ($n = 34$) and control group ($n = 35$) (intragroup analysis at different time points for primary and secondary outcomes)												
Variables	Intervention ($n = 34$)						Control group ($n = 34$)					
	T1–T2	*p* value	T2–T3	*p* value	T3–T4	*p* value	T1–T2	*p* value	T2–T3	*p* value	T3–T4	*p* value
MBI-Exhaustion	−1.0 (−4.0; 2.0)	0.11	−1.5 (−5.3; 1.0)	0.04	NA	NA	−1.0 (−3.0; 1.0)	0.09	−1.0 (−3.5; 0.0)	0.08	(−2.3; 2.0)	0.83
MBI-Cynicism	−0.3 (−0.9; 0.4)	0.13	0.0 (−0.7; 0.7)	0.79	NA	NA	−0.2 (−1.0; −0.3)	0.18	−0.2 (−0.8; 0.2)	0.40	0.0 (−0.4; 3.0)	0.59
MBI-Professional Efficacy	0.5 (−2.0; 5.3)	0.22	(−0.5; 0.3)	0.43	NA	NA	0.0 (−2.0; 2.0)	0.73	0.0 (−0.9; 0.7)	0.90	(−3.0; 3.3)	0.69
PSS	−3.0 (−8.0; 0.0)	0.01	−1.0 (−3.0; 2.0)	0.52	NA	NA	−1.5 (−4.0; 1.0)	0.04	−3.0 (−6.0; 4.0)	0.20	(−2.0; 3.0)	0.65
MAAS	0.3 (−0.1, 0.9)	0.01	(−0.4; 0.4)	0.70	NA	NA	0.4 (−0.1,0.8)	0.03	0.1 (0.2; 0.5)	0.13	(−0.2; 0.6)	0.08
DPES	0.3 (0.0; −0.8)	0.03	0.0 (−0.3; 0.8)	0.35	NA	NA	0.1 (−0.5,0.7)	0.40	0.0 (−0.6; 0.7)	0.66	−0.2 (−0.8; 0.4)	0.26
CES-D	−1.0 (−5.0, 0.0)	0.02	1.0 (−2.0; 4.0)	0.44	NA	NA	−1.5 (−5.0,3.0)	0.21	0.0 (−3.0; 2.0)	0.87	(−3.3; 2.3)	0.56
Anxiety	−3.0 (−7.0, 0.0)	0.001	0.0 (−1.0; 3.0)	0.30	NA	NA	−2.0 (−5.0,0.0)	0.002	−1.0 (−4.0; 1.0)	0.03	(−1.0; 1.0)	0.42

Second, the active control group design, a more gender-balanced sample, and the small sample size and nonparametric tests may contribute to the insignificant treatment effect. The most common type of comparison group in MBIs and yoga studies is the usual care or passive waitlist control where no changes were made to the typical activities of the participants [14, 30], which may result in exaggerated treatment effect [15]. Although an active control is a more robust design, it is challenging to design a "placebo" active control activity [14, 15]. Treatment effect is harder to detect with active control groups. Furthermore, some researchers argue that using passive waitlist control may actually spuriously amplify the treatment effect between the intervention and the control because participants assigned to the passive waitlist control may expect to *not* get better without receiving the treatment [15] and recommend using an active control group for yoga research [14]. However, it is challenging to design an active control activity that resembles a "placebo" to the body-mind intervention [15].

The participants of workplace MBIs to date are predominantly women (about 73%) [6]. The samples of MBIs studies heavily skew toward the healthcare professionals or educators and are overwhelmingly women (about 73%) [6]. There is a dearth of studies investigating other fast growing professions, such as the Information Technology professionals. Although influential technological companies

(e.g., Google and Intel) are among the pioneers in introducing MBPs at workplace [6], little evidence is available about the impact of these programs. The Bureau of Labor Statistics projects that employment in computer and information technology (IT) occupations will grow 11% from 2019 to 2029, much faster than the average growth of employment in all the other occupations together [31]. The IT professions are low in diversity—about 26% of them are women and 8% for African or for Latino Americans [32]. The lack of diversity in workplace MBIs calls for including participants who represent more diverse demographics and occupations [1]. Could a more gender-balanced sample result in the insignificant finding of treatment effect?

It is also desirable to diversify outcome measures of body and mind interventions beyond dysfunctional psychiatric issues (e.g., anxiety and depression). Positive outcomes such as emotional intelligence, positive emotions, vitality, flourishing, and life satisfaction and work-related outcomes such as job performance and work engagement await more research [1]. Unfortunately, the results show that IEO did not exercise a sustained significant effect on positive states, such as mindfulness and joy. This finding is similar to those of other MBIs that demonstrate small to no significant effect of workplace MBIs on emotional regulation and well-being [1, 8]. It is unclear why MBIs have small or inclusive effect on positive experiences. Fredrickson et al. [33] found that 7-week Loving-Kindness Meditation (LKM) training produced daily experiences of positive emotions, which in turn produced an increase in a wide range of personal resources, such as increase in mindfulness, purpose in life, and social support and a decrease in illness symptoms. Perhaps, positive emotions take longer time to develop. However, Zeng et al. [34] found that the length of LKM interventions and the time spent on meditation did not influence the effect sizes, but the studies without didactic components in interventions tend to have small effect sizes. Furthermore, a previous corporate pilot study found that IEO has a significant effect on vitality, joy, mindfulness, and work engagement [23]. Rangasamy et al. [35] found that learning and practicing a 15 minutes of Isha Kriya meditation (one of the introductory Inner Engineering methods) resulted in a reduction in mood disturbances such as tension, anger, fatigue, depression, and confusion. Further studies with a larger sample are needed to reexamine the effect of IEO on employee mental well-being.

Next, when compliance of daily practices is taken into account, IEO has a significant effect on reducing stress in the intervention group, compared to the active control group who engaged in reading a book during the 4-week intervention period. Similarly, IEO has a significant effect on reducing stress in the control group during their cross-over period, compared to their own baseline at the time cross over. The approach of body-mind behavioral medicine is to engage participants as stakeholders, who bear the responsibility of "doing the work" for their well-being. The caveat of this approach is that without doing the homework of daily practices, participants may not experience the intended effect of the intervention. Peterson et al. [24] found that adherence to Shambhavi Mahamudra Kriya (a 21-minute daily practice for which IEO is a prerequisite) resulted in decline in stress scores and improvement in well-being. Carmody and Baer [36] demonstrated a positive correlation between time spent in mindfulness practice and extent of improvement in measures of stress and well-being. In their systematic review on the role of home practice in mindfulness-based intervention, Lloyd et al. [37] found that four of the seven studies claimed that home practice predicted improvements in clinical outcome measures. These findings are consistent with our study's results that adhere to recommended home practices and have shown to play an important role in realizing the effect of the intervention on intended outcomes.

5. Conclusion

We attempt to contribute to the existing body-mind interventions in the workplace by introducing the novel IEO program and evaluating its effectiveness in reducing stress, burnout, anxiety, and depression and in inducing positive affect. Our study demonstrates that IEO has a significant effect on stress reduction only for participants who adhere to recommended daily yogic practices. These results point to the importance of participants' engagement in order to realize the benefits of mind-body interventions. Although our study has a rigorous experimental design by utilizing random assignment and active control, the study is limited by its small sample size. Future study may reexamine the effectiveness of IEO in promoting occupational health by using a larger and diverse sample.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

BS, VN, and TFC conceptualized the study; PU contributed to data curation and was involved in project administration/supervision; PU and VN performed analysis; and SH, PU, RS, and SK contributed to methodology . All authors are equally contributed in writing, reviewing, and editing the manuscript.

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The mediating role of resilience in the effects of physical exercise on college students' negative emotions during the COVID-19 epidemic

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Due to its suddenness and unpredictability, COVID-19 caused strife and effects on public mental health, resulting in a surge of negative emotions. The study explores the relationship between physical exercise and negative emotions in home-based college students during the COVID-19 epidemic, as well as the mediating role of resilience, thus providing a new basis for understanding the role of physical exercise in improving negative emotions in college students; A total of 1214 college students were investigated with the Physical Exercise Questionnaire, Negative Emotion Scale and Resilience Scale; Both physical exercise and resilience were significantly negatively correlated with negative emotions in college students ($r = -0.25, -0.33, P < 0.001$), and there was a significant positive correlation between physical exercise and resilience ($r = 0.47, P < 0.001$). Physical exercise had a direct effect on the negative emotions of college students ($\beta = -0.14, P < 0.001$). Resilience had a partial mediating effect between physical exercise and the negative emotions of the college students, with a mediating effect value of 0.14 and a mediating effect contribution rate of 50.00%; The study found that physical exercise not only directly affected the negative emotions of college students but also improved their resilience by slowing down their negative emotions and promoting their mental health.

The novel coronavirus disease 2019 (COVID-19), a hideous pandemic that emerged in 2019, has caused governments of heavily affected countries to limit activities outside the home to essential tasks or to impose stay-at-home orders on their citizens. As of 7 September 2021, 221,134,742 confirmed cases, including 4,574,089 deaths, have been reported to the World Health Organization (WHO)[1]. Due to its suddenness, contagion, unpredictability, and the associated information overload, COVID-19 has caused tremendous strife for public mental health, which has resulted in a surge of negative emotions including anxiety, depression, and lower mental well-being[2,3]. For students, a combination of extended vacations, long stays at home, reduced social activities, and changes in the environment have had a significant impact on their studies and personal lives, exacerbating the occurrence of negative emotions; these consequences have likely increased anxiety and depressive symptoms such as helplessness, hopelessness and worry[4–6]. An online survey administered to 405 Chinese college students revealed that the prevalence of anxiety and depressive symptoms was 44.0% and 42.2%, respectively[7]. A cross-sectional web-based survey suggested that college students living in Bangladesh have experienced heightened depression and anxiety, as well as an unparalleled growth of depression and anxiety under the current global pandemic situation compared to earlier research. In fact, approximately 15% of college students living in Bangladesh had moderately severe depression, whereas 18.1% suffered from severe anxiety[8]. Varma et al. conducted a global cross-sectional survey, and found that 59% of respondents met the criteria for clinically significant anxiety, and 39% reported moderate depressive symptoms[9]. Individuals' mental health in many countries has deteriorated compared to pre-COVID-19 trends[10–15]. According to emerging international evidence, anxiety and depression were common during the early stages of the COVID-19 epidemic[16,17]. As such, it is necessary to explore scientific strategies to prevent anxiety and depression in college students who have been confined at home during the COVID-19 epidemic.

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In the present study, physical exercise refers to leisurely physical activity that could improve cardiorespiratory capacity, muscle strength, body composition, and flexibility[18]. There is growing evidence that individual emotions are susceptible to physical exercise[19,20]. In particular, physical exercise has great potential in preventing and treating depression and anxiety[21–23]. Regular physical exercise can significantly reduce negative emotions such as pessimism, tension, anxiety, and restlessness[24,25]. Knöchel et al. proposed that physical exercise could relieve symptoms of depression and would be an innovative approach to improving quality of life and reducing physical illness[26]. Kim and Leem suggested that chronic exercise may improve the disturbance of hippocampal 5HT1A-regulated cAMP/PKA/CREB signalling in the depressed brain, thereby exerting an antidepressant effect[27]. In line with previous studies, Zschucke et al. indicated that physical exercise can activate the hippocampus, inactivate the prefrontal cortex, and inhibit the cortisol response to the Montreal Imaging Stress Task (MIST)[28]. Recent studies have largely described the positive role exerted by physical exercise to counteract prevalent anxiety and depression in self-isolated people during the COVID-19 epidemic[29–31]. They reported that leisure-time physical activity is more closely associated with positive mental health. Furthermore, 15–30 min a day of moderate to vigorous physical activity implies lower odds of prevalent depressive and anxiety symptoms. Importantly, prolonged stays at home can reduce physical exercise levels, which leads to a significant, negative impact on mental health and well-being[32,33]. Based on these scientific evidences, regular physical exercise is a key strategy for relieving anxiety and depression in college students, especially during the COVID-19 epidemic.

Resilience can be defined as the potential or ability to adapt effectively in the face of setbacks, which is crucial for mental and physical health[34,35]. Anxiety and depression among college students increased substantially during the epidemic[36,37]. Nevertheless, resilient individuals are equipped with the ability to handle negative emotions and crises successfully[38–40] and experience less psychological pain, thus exhibiting better mental health[41]. Resilience is negatively related to anxiety and depression[42–44]. Additionally, resilience may be an important factor in reducing depressive symptoms, internalising problems, externalising problems, and lowering general psychological distress, which helps individuals to maintain healthy and stable psychological states[45,46]. There is scientific consensus that physical exercise can improve one's level of resilience. Moreover, physical exercise is a critical path to promote resilience[41,47]. Accumulated evidence has found that brain-derived neurotrophic factor levels increase significantly with physical exercise, which protects neurons in the striatum of the brain and hippocampus under stress, thus enhancing resilience[48]. People with high levels of physical exercise are more likely to develop resilience[49]. Further, individuals who maintained regular physical exercise during confinement reported significantly high levels of resilience[50,51]. Consequently, physical exercise could alleviate anxiety and depression by improving the level of resilience among college students during the COVID-19 epidemic. Based on these evidences, resilience could be an internal mechanism that plays a mediating role in the relationship between physical exercise and negative emotions.

Although previous studies have shown that physical exercise, negative emotions and resilience are positively correlated with each other, they have not been examined as an interactive system. Therefore, we aimed to investigate the internal psychological mechanism of the effect of physical exercise on negative emotions in college students during the COVID-19 epidemic from the perspectives of cognition and coping methods. This research not only enriches the literature on sports psychology, but also provides new ways of thinking about prevention and intervention relative to anxiety and depression among college students.

Methods

Ethical statement. This study was approved by the Ethical Committee of the University of Shandong Youth University of Political Science. All participants were given a brief introduction to the study and informed of its purpose, as well as declarations of anonymity and confidentiality before participating, and provided informed consent. We conducted this study in accordance with the latest revised ethical guidelines of the Declaration of Helsinki.

Study design and participants. The participants completed an online questionnaire survey while isolating at home during the COVID-19 epidemic. The questionnaire survey was sent via a professional platform called 'Wenjuanxing'. Moreover, the form link was shared by the research group members and different student groups on We Chat. We collected data were collected from 15 to 20 March 2020. All universities were closed and all college students stayed at home during the epidemic. Thus, we used a simplified cluster sampling method based on a random selection of 1,260 students from three universities in the provinces of Shandong, Liaoning and Jilin. The sample comprised 210 students majoring in liberal arts and 210 students majoring in science from each university for each grade. Among the 1,260 college students who completed the questionnaire surveys, we excluded 46 because they provided incomplete or faulty data, yielding a final sample of 1,214 students. The return rate was 97.12%. The resulting 1,214 participants completed the entire questionnaire survey. There was a minor imbalance in gender 506 males (41.68%) and 708 females (58.32%)—and the mean participant age was 19.99 (SD=1.73).

Physical Exercise Questionnaire. To assess the effect of physical exercise in the Chinese population[52], Wu et al. revised items from an existing measure developed for Chinese college students[53]. The final scale comprised 8 items with a score ranging from 0 to 40, and entailed a 5-point scale ranging from 1 (totally disagree) to 5 (totally agree); it contained 2 dimensions: exercise adherence and exercise commitment. We summed the individual item scores to produce the total scores, with higher scores indicating greater physical exercise. However, in the present study, one item (work by fits and starts) under exercise adherence had a factor loading with an absolute value of 0.29, and was rejected because it did not meet the standard that factor loadings must have absolute

Variables	M ± SD	1	2	3
1. Physical exercise	23.01 ± 5.61	1.00	0.47**	−0.25**
2. Resilience	59.16 ± 14.62	0.47**	1.00	−0.33**
3. Negative emotion	6.83 ± 7.24	−0.25**	−0.33**	1.00

Table 1. Descriptive statistics and Pearson correlations coefficient of physical exercise, negative emotions, and resilience, N = 1214.

values of not less than 0.40[54]. Thus, we deleted the data for this item while performing statistical analysis. The Cronbach's alpha in the present research was 0.93, ranging from 0.83 to 0.91 across the two subscales.

Depression-Anxiety Scale. We used the 21-item assessment, which was extracted from the original 42-item scale, as a brief symptoms inventory to assess the previous week[55,56]. The scale was revised in 2012 to accommodate the Chinese population and then pilot tested. The revised scale includes three subscales: anxiety (7 items, α= 0.82), depression (7 items, α= 0.75), and pressure (7 items, α= 0.80); it has good reliability, validity, and applicability among Chinese adults[57]. We scored each item on a 4-point scale ranging from 0 (totally disagree) to 3 (totally agree). The total scores range from 0 to 42, with higher scores showing more severe negative emotions. However, we only used two subscales (anxiety and depression), to assess individual negative emotions. The Cronbach's alpha of this measure in the present research was 0.93, ranging from 0.86 to 0.87 across the two subscales.

Resilience Scale (CD-RISC). In 2007, Yu and Zhang modified the Connor-Davidson Resilience Scale, to measure resilience[58], which has acceptable reliability and validity among Chinese individuals. The CD-RISC is composed of 25 items with a score ranging from 0 to 100; assesses tenacity (13 items, α=0.88), strength (8 items, α=0.80), and optimism (4 items, α= 0.60)[59]. Each item is scored on a 5-point scale ranging from 0 (never) to 4 (always), with higher scores indicating greater resilience. Among the 25 items collected to explore the correlation in the present study, one item (had to act on a hunch) was rejected due to a low factor loading (absolute value 0.20). The specific reason has been described above. The Cronbach's alpha for the CD-RISC in the present study was 0.92, and for each of the three subscales, it ranged from 0.67 to 0.88.

Statistical analysis. We gathered the data and processed them using Excel software. We performed descriptive statistics, correlation analysis, and t-tests with SPSS version 22.0. Further, we adopted a statistical significance level of $p<0.05$. All variables are shown as the mean and standard deviation (SD). We used structural equation modelling (SEM) to investigate the mediating role of resilience in the impact of physical exercise on negative emotions, assuming that resilience and physical exercise from college students would be directly and indirectly associated with negative emotions. We carried out SEM analysis using the AMOS statistical program[60]. SEM is an appropriate method for investigating the relative effects of multiple predictors on multiple outcomes and controlling for measurement errors[61]. We first conducted exploratory factor analysis (EFA) for each scale (physical exercise, resilience, negative emotions) to check their dimensionality. Factors distilled from the EFA and filtered at a minimum loading threshold of 0.40 were the latent variables for the structural equation models[62]. We verified the measurement model using confirmatory factor analysis (CFA). In addition, we used the root mean square error approximation (RMSEA) to evaluate the model fit. We considered a RMSEA value of less than 0.05 to be a 'close fit', and a value between 0.05 and 0.08 to be an 'acceptable fit'; RMSEA values larger than 0.1 signalled a 'poor fit' [63]. The normal fit index (NFI), comparative fit index (CFI), non-normed fit index (NNFI), and adjusted goodness-of-fit index (AGFI) were also important indices; we considered a model with values greater than 0.90 to be a good one. Therefore, we focused on RMSEA, NFI, CFI, NNFI, and AGFI.

Results

Correlation analysis. Table 1 presents the descriptive statistics and Pearson correlation coefficients of physical exercise, negative emotions, and resilience. As shown in Table 1, the mean physical exercise of participants was low, at 23.01 (SD = 5.61). The mean scores on exercise adherence and exercise commitment were 9.86 (SD = 2.63) and 13.15 (SD = 3.30), respectively. The resilience of college students averaged 59.16 (SD = 14.62). The mean tenacity, strength, and optimistic scores were 29.83 (SD = 8.53), 8.15 (SD = 2.40), and 21.37 (SD = 5.12), respectively. Participants reported negative emotions with a mean score of 6.83 (SD = 7.24), and the mean scores of anxiety and depression were 3.52 (SD = 3.65) and 3.31 (SD = 3.77), respectively, on a 21-point scale. The results revealed that physical exercise was negatively associated with negative emotions ($r = -0.25$, $P < 0.001$), and positively correlated with resilience ($r = 0.47$, $P < 0.001$). Additionally, resilience negatively correlated with negative emotions ($r = -0.33$, $P < 0.001$). There was a high degree of correlation among all variables. These results supported further testing of the mediation and moderated mediation models.

Mediation analysis. The results in Table 1 showed that there was a significant correlation among physical exercise, resilience, and negative emotions, which provided a basis for testing the mediating role of resilience. Therefore, we employed the AMOS 23.0 and the maximum-likelihood method to construct the model for analyzing the relation of variables. As shown by the CFA results in Fig. 1: $\chi^2/df = 4.698$, GFI = 0.988, CFI = 0.993,

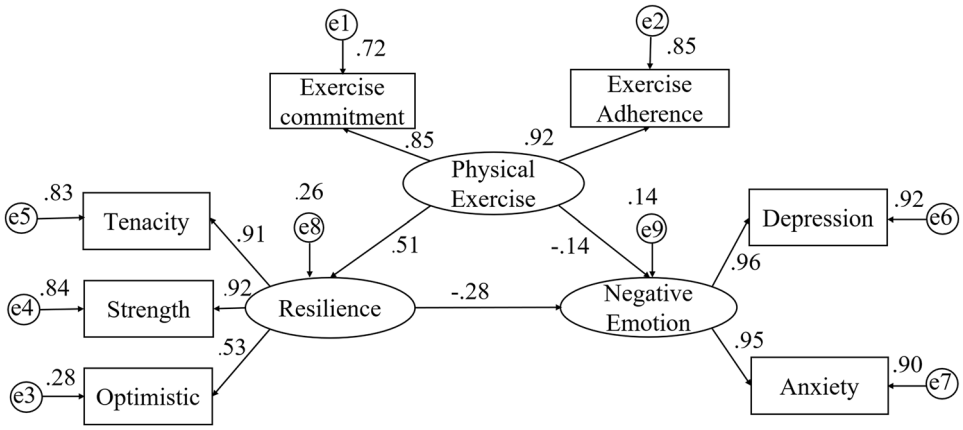

Figure 1. A structural equation model testing resilience factors—tenacity, strength, and optimistic—as mediators of the physical exercise and negative emotion.

Variables	Effect	Estimate	Bias-corrected 95% CI	
			Upper limit	Lower limit
Physical exercise → negative emotion	Total effect	−0.28	−0.34	−0.21
Physical exercise → negative emotion	Direct effect	−0.14	−0.21	−0.06
Physical exercise → negative emotion	Indirect effect	−0.14	−0.21	−0.10
Physical exercise → resilience	Direct effect	0.51	0.44	0.56
Resilience → negative emotion	Direct effect	−0.29	−0.36	−0.19

Table 2. Resilience moderates the effect of physical exercise on negative emotions.

AGFI = 0.970, NFI = 0.991, IFI = 0.993, RMSEA = 0.055, which indicated that the measurement model provided an acceptable fit for the data.

Mediation effect. The results presented in Fig. 1 indicated a significant indirect effect of resilience in mediating the relationship between physical exercise and negative emotions. Then, we used the bootstrap method to test the mediation effect of the structure model. The results of SEM analysis, as shown in Table 2, demonstrated that physical exercise had a direct and negative effect on negative emotions ($\beta = -0.14$, $t = -0.18$, $p < 0.01$), and the 95% confidence interval was from −0.32 to −0.19. Resilience was negatively related to negative emotion ($\beta = -0.25$, $t = -0.71$, $p < 0.01$), and the 95% confidence interval was from −0.33 to −0.16. Physical exercise had a significant and positive predictive effect on resilience ($\beta = 0.51$, $t = 0.23$, $p < 0.01$). Additionally, bootstrap confidence intervals were used to estimate the mediation effect. The results showed that the mediation effect is 0.14, the 95% confidence interval is from −0.19 to −0.10, and the confidence interval did not include 0. The total effect of physical exercise on negative emotions was 0.28. Therefore, resilience played a partial mediating role connecting physical exercise and negative emotions. In addition, the mediation effect accounted for 50.00% of the total effect.

Discussion

The correlation analysis indicated that physical exercise was negatively correlated with negative emotions among home-based college students during a public health emergency; that is, higher levels of physical exercise were associated with fewer negative emotions, which is consistent with findings from previous studies[64–66]. The structural equation model suggests that physical exercise is a negative predictor of negative emotions and has a significant direct effect, meaning that the occurrence of anxiety and depressive symptoms may have been influenced by low physical activity in home-based college students during the COVID-19 epidemic. The results provide additional support for the well-documented, cross-sectional link between physical exercise and negative emotions[5,67]. According to the hypothesis on the psychological impact of physical exercise, the most direct effect outcome of exercise is that it gives individuals a sense of pleasure and joy. The increase in positive emotions reduces the burden of negative ones[68]. Frequent exercise and participation in sports contribute to greater well-being and lower levels of anxiety and depressive symptoms in both sexes[69]. Physical exercise has significant anti-anxiety and anti-depressive effects, and is conducive to improving mental health[70,71]. Besides, moderate physical activity could amortise its negative effects on psychological health and lead to a more positive mental state[72]. In addition, physical exercise is a positive, effective means of health promotion, and an increase in exercise can improve the brain's emotional processing ability to relieve anxiety and depression[73].Thus, based on the abovementioned

mechanisms, physical exercise could be an intervention to treat anxiety and depression by improving a variety of physiological and psychological factors.

Our results show that resilience played a partially intermediary role in connecting physical exercise to negative emotions in college students, which is consistent with the findings of previous studies[74]. On the one hand, the structural equation outcomes revealed that physical exercise had a significant, positive predictive effect on college students' resilience, which supported the findings of Lines et al.[75] In terms of the relationship between physical exercise and resilience some researchers believe that physical exercise is a protective factor[76]. The internal factors that influence resilience, including cognitive, problem-solving, interpersonal and emotional skills, as well as increasing individuals' internal resources can generate greater resilience[77]. In particular, when one encounters troublesome circumstances or challenges, there will be an interaction between the individual and the environment. At this time, internal factors play a positive role in helping individuals to cope with difficulties in a positive manner. Resilience is not fixed and can potentially be strengthened by implementing certain interventions[78,79]. An experimental study of 1,546 first-year students found that physical exercise can effectively improve college students' resilience[80]. This may be because regular participation in physical exercise can successfully reduce physiological stress levels, harmonise emotions, and improve one's sense of self-control and state of mind, enhancing the level of resilience[81,82]. Additionally, physical exercise helps to cultivate students' positive psychological qualities such as self-confidence, extroversion, optimism, and emotional stability. Students can obtain a sense of pleasure and satisfaction—both spiritually and mentally—through physical exercise, leading to positive changes in psychological functions. Thus, physical exercise can be used to improve the level of resilience among home-based college students.

On the other hand, the structural equation results imply that being resilient is negatively linked with experiencing anxiety and depressive symptoms. This outcome is line with previous studies, illustrating that resilience has a buffering effect on the negative emotional consequences of adverse events[83,84]. According to the dynamic model of mental resilience, resilience is a skill that can be acquired; moreover, internal resources such as control, formed during the adolescents' developmental process, are crucial for the protective role of healthy growth[78]. As a vital component of mental health, resilience can help individuals to cope with negative emotions through optimistic attitudes that positively predict mental health[85]. The resilience model, proposed by Dray et al., indicates that people with high resilience are better able to face challenges, deal with them in more positive ways, and seek for support, and effectively solve problems[45]. Thus, individuals can better cope with negative emotions and overcome difficulties by using resilience. This positive psychological response mode is conducive to improving college students' sense of self-control and reducing levels of depression and anxiety[86,87]. Due to the protective effect of resilience, individuals can make full use of internal resources to adapt or recover, despite adverse conditions, and to eliminate negative emotions[80]. In one study, a resilience intervention strengthened the impact of physical exercise on anxiety and depression[88]. Based on these evidences, it is clear that resilience significantly moderates the relationship between physical exercise and depression, and anxiety. As shown by the above results, there is a strong correlation between physical exercise and negative emotions. These findings provide the best support for claims that routine physical exercise has protected against negative emotions during the COVID-19 epidemic. Hence, physical activity should be encouraged to reduce post-traumatic anxiety and depressive symptoms. This intervention is fairly easy to obtain online without requiring in-person contact, which is especially vital during the COVID-19 epidemic.

However, we faced several limitations. First, our study was a cross-sectional one. Although this allowed us to objectively reflect the relationship between different variables, we were unable to establish an exact causal relationship. Second, the sample lived in three provinces (Jilin Province, Liaoning Province, and Shandong Province) and was not collected as a representative sample. The participants only had bachelor's degree, which is not representative of college students in China. Third, the physical exercise questionnaire was not recognised, but modified by Chinese scholars. More specifically, it is only applicable to Chinese students. The use of larger, validated measurement scales could better determine how specific exercise types such as (exercise frequency, intensity, and time) affect anxiety and depression. Finally, there may still be some potential moderators that we have not considered.

Conclusions

We found physical exercise to be associated with less anxiety and depression during the COVID-19 epidemic. Additionally, resilience plays a mediating role in the relationship between physical exercise and negative emotions. Thus, physical exercise focused on building resilience might be a cost-effective strategy to reduce anxiety and depression during the COVID-19 epidemic Future studies should combine horizontal and vertical interventions to identify other potentially mediating variables to explore internal psychological mechanisms.

Received: 3 June 2021; Accepted: 20 December 2021
Published online: 31 December 2021

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Acknowledgements

The authors wish to thank the volunteer participants for their valuable time and contribution.

Author contributions

Conceptualization, X.N. L., H.S.Y; methodology, X.N. L.; investigation, X.N. L., N. Y.; data curation, X.N. L., N. Y.; software, X.N.L., H.S.Y.; formal analysis, X.N.L., and N.Y.; writing-original draft preparation, X.N. L., N. Y.; Writing-review and editing, X.N. L., H.S.Y.; All authors have read and agreed to the published version of the manuscript.

Funding

This research was funded by Social Science Planning Project of Shandong Province, grant number "GK202007035" and "the Fundamental Research Funds for the Central Universities, grant number "21CTYJ18".

Competing interests

The authors declare no competing interests.

Additional information

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Brain, Behavior, & Immunity - Health 20 (2022) 100420

Contents lists available at ScienceDirect

Brain, Behavior, & Immunity - Health

journal homepage: www.editorialmanager.com/bbih/default.aspx

Yoga and meditation, an essential tool to alleviate stress and enhance immunity to emerging infections: A perspective on the effect of COVID-19 pandemic on students

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ARTICLE INFO

Keywords:
Yoga
Meditation
Students
Stress
Anxiety
Depression
Wellbeing
Immunity

ABSTRACT

The COVID-19 pandemic caused by the Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) has negatively impacted the global healthcare and economic systems worldwide. The COVID-19 pandemic has also created an emotional and psychological pandemic among people of all ages irrespective of economic status and physical wellbeing. As a consequence of prolonged lockdowns, one of the most severely affected age groups globally is the young adults' group, especially students. Uncertainties in the academic calendar, restricted outdoor activities, and unusual daily routines during lockdowns led to higher incidences of stress, anxiety, and depression among students worldwide. In this review, we summarise the available evidence on the effect of lockdowns on students and discuss possible positive impacts of yoga and meditation on various psychological, emotional, and immunological parameters, which can significantly influence the general wellbeing and academic performance of students. Perspectives shared in the review will also bring awareness on how yoga and meditation could boost students' performance and assist them in maintaining physical and mental wellbeing during stressful conditions such as future epidemics and pandemics with novel infections. This information could help create better educational curriculums and healthy routines for students.

1. Introduction

On March 11, 2020, COVID-19, caused by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS CoV-2), was declared a pandemic by the World Health Organization (WHO). The Coronavirus disease, COVID-19, is primarily a respiratory illness and also shows the symptoms associated with the gastrointestinal tract (GI), hepatobiliary, cardiovascular, renal, and central nervous systems (Luo et al., 2020; Rothan et al., 2020; Vodnar et al., 2020; Wang et al., 2020). The most common symptoms of COVID-19 include fever, cough, fatigue, sputum production, headache, diarrhea, dyspnoea (difficulty in breathing), lymphopenia (reduced lymphocytes in the blood), and may include signs of pneumonia (C. Huang et al., 2020; Ren et al., 2020). A chest CT scan of COVID-19 patients with moderate to severe disease may show signs of pneumonia, acute respiratory distress syndrome, acute cardiac injury, and ground-glass opacities in the lungs (Pullen et al., 2020).

As an immediate and effective measure to stop the spread of the SARS CoV-2 infection and give enough time for the readiness of the hospitals to deal with the increased numbers of A&E attendances and hospitalizations, the governments of most of the countries imposed "lockdowns" (closures of services, businesses and schools, known as "lockdowns") at different stages of the pandemic and with varying levels of restrictions (Lancet, 2020). The imposition of rigorous home quarantine and social isolation ultimately resulted in significant adverse effects on the psycho-emotional wellbeing of people worldwide (Silva et al., 2021). According to the World Economic Forum, an average of 2.6 billion people worldwide were under social isolation and quarantine, leading to a stress-related disorder pandemic, emotional distress, and psychological consequences in the second half of 2020 (Ganesan et al., 2021). It was also documented that the recovered patients, their family members, and many others went through some degree of common mental disorders, such as depression and anxiety, which affected their quality of life (Grover et al., 2020; Salari et al., 2020; Xiong et al., 2020). According to the latest reports, the utmost elements that created stress, anxiety, and depression were the agitation of getting the SARS CoV-2 infection, loss of loved ones,

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https://doi.org/10.1016/j.bbih.2022.100420
Received 11 December 2021; Received in revised form 13 January 2022; Accepted 16 January 2022
Available online 19 January 2022

and financial problems (Al Mamun et al., 2021; Boyraz et al., 2020; Elbogen et al., 2021; Sahni et al., 2021) (Figure-1). Similarly, an electronic health record cohort study performed by the researchers from Oxford University in collaboration with TriNetX, USA, with data from 69 million individuals from which 62, 354 had a diagnosis of COVID-19 between January 2020 to August 2020, showed that survivors of COVID-19 are at higher risk of developing psychiatric sequelae such as depression, posttraumatic stress disorder (PTSD), obsessive-compulsive disorder (OCD) and psychotic symptoms (Maxime Taquet et al., 2021). Besides healthcare, public services, and other aspects of day-to-day life, the education system suffered a considerable setback. The uncertainties about the academic year, examinations, enhanced screen time due to educational resources and lecture delivery being online, restricted social interactions created a tremendous amount of emotional and psychological stress among students all over the globe (Aucejo et al., 2020; Limone et al., 2021). Thus, in addition to physical health, the COVID-19 pandemic has significantly affected the mental health of people of all ages worldwide (Fig. 1).

Several lines of evidence have shown that stress can also delay wound healing and compromise immunity through different physiological pathways (Pinto et al., 2016). Long-term stress-related chronic inflammations is also linked with higher risk for several diseases such as cardiovascular disease, cancers, diabetes, and autoimmune diseases (Dhabhar, 2014; Furman et al., 2019; Liu et al., 2017). Several reports have shown that the presence of underlying comorbidities such as cerebrovascular diseases, chronic lung diseases, cancer, diabetes, and hypertension could increase the incidence and severity of SARS COV-2 infection (Callender et al., 2020; Ejaz et al., 2020; Gupta et al., 2021; Honardoost et al., 2021). With current day lifestyle, incidences of diabetes, hypertension, and mental health-related diseases are increasing in young adults (Asif, 2014; Di Renzo et al., 2020; C. Zheng et al., 2020). Such disorders accompanied by stress and chronic inflammatory conditions could impact the general wellbeing and functioning of a healthy immune system to defend against emerging infections (Morens et al., 2004; Netea et al., 2020; Yazdanpanah et al., 2020). Thus, the current scenario could propel humans to equip themselves with ways to overcome the stressful effects of such pandemics and boost their physical and mental wellbeing.

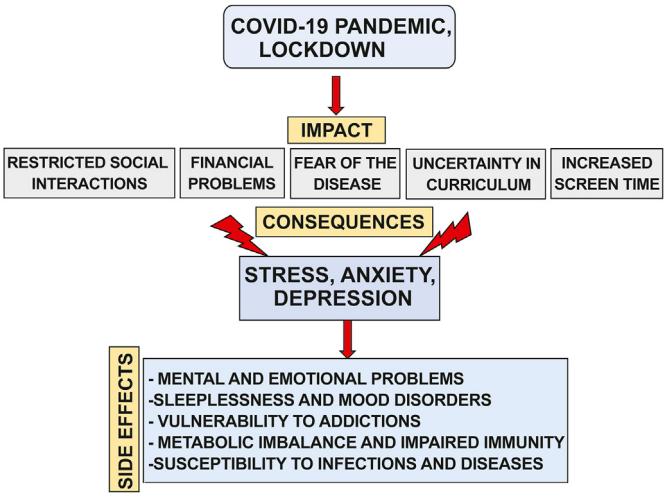

Fig. 1. Impacts, consequences, and side effects of the COVID-19 pandemic on students: This figure describes the impacts of the COVID-19 pandemic and associated lockdown on the students' daily life, such as restricted social interaction, fear of contracting SARS CoV-2 infection, uncertainty in academic curriculum, and increased screen time. Such changes during lockdown during COVID -19 pandemic have led to significant stress, anxiety, and depression, causing emotional, psychological, immunological, and metabolic imbalances.

1.1. Yoga and wellbeing

Yoga is considered a sacred practice that is effective in obtaining physical strength, mental balance, and spiritual growth. Yoga includes exercise and relaxation of the mind. Yoga comprises a variety of techniques and practices that include yogic positions (asanas), inhalations or breathing exercises (Pranayama), meditation, chanting of mantras, lifestyle changes, and practicing certain spiritual beliefs (Birdee et al., 2008). A commonly practiced form of yoga is Hatha Yoga that comprises asanas, postures, pranayama, and meditation (Riley, 2004). Yoga has been an essential part of Indian culture for thousands of years to alleviate stress and improve physical wellbeing. People performing meditation reportedly had relatively better mental health (Sahni et al., 2021). Recently, several yogic therapies have also been demonstrated to improve the recovery rate in patients with depression (Sathyanarayanan et al., 2019; Venkatesh et al., 2020). A study conducted by Elstad et al. with 202 healthy students in which 24 yoga interventions were given for 12 weeks showed a significant and long-term effect on reducing distress and improving sleep quality in participants (Elstad et al., 2020). In another study that was conducted between the year 2011–2016 by enrolling students from various yoga schools that practiced different yoga asana (yoga postures) techniques such as *Ananda, Ashtanga, Bikram, Iyengar, integral, Kundalini, Power,* and *Vinyasa*, showed that yoga interventions effectively decreased depression among these students (Bridges et al., 2017). In recent times, people have become more aware of the benefits of regular yogic practices (Vagga et al., 2020).

To date, evidence from extensive research on yoga and meditation have provided scientific data supporting yoga and meditation on stress and anxiety management (Breedvelt et al., 2019; Cramer et al., 2014; Manocha et al., 2011; Sarkar et al., 2021; Shohani et al., 2018; Smith et al., 2007). In addition to mental wellbeing, researchers have also endorsed the beneficial effects of regular yogic practices in improving metabolic and vascular functions of the human body (Erogul et al., 2014; Falsafi, 2016; Kim, 2016; Nemati, 2013; Oman et al., 2008; Ross et al., 2015). Besides the extensive beneficial effects of yoga in improving the quality of life and mental health, yoga and meditation have gained popularity for boosting immunity by improving circulation, removing toxins, modulating inflammatory mediators, and strengthening the immune system (Gopal et al., 2011; Sarkar et al., 2021; Venkatesh et al., 2020).

This review focuses on the effect of the COVID-19 pandemic and associated lockdown on the psychological and emotional wellbeing of students. We have also discussed the possible consequences of stress, anxiety, and depression on the immune system and made an effort to present evidence supporting the beneficial effects of yoga and meditation on the wellbeing of students who have faced challenging phases during the COVID-19 pandemic. This understanding could help prepare well for such future epidemics and pandemics that may simulate lockdowns and uncertainties in academic schedules for students.

1.2. Impact of COVID-19 pandemic on the stress, anxiety, and depression in students

According to the literature, the consequence of an adverse situation or very demanding circumstances is termed as stress, which is associated with anxious thoughts, physical, mental and emotional changes (Schneiderman et al., 2005; Trivedi et al., 2010; Yaribeygi et al., 2017). Around 322 million people, or 4.4% of the global population, were affected by depression in 2015 (Friedrich, 2017). Additionally, according to the Global Burden of Disease (GBD) 2010 study, Major Depressive Disorder (MDD) was considered as the primary cause for prolonged dysfunction (Ferrari et al., 2013). Specifically, a prolonged period of the imposed lockdown and the Government restrictions due to COVID-19 have negatively impacted the levels of stress, anxiety, and depression in all groups of people (Al Omari et al., 2020). According to several studies, sleeplessness, addictions with vulnerability for relapse, and

psychological symptoms in young adults occur due to excessive stress (Cuijpers et al., 2021; Dessauvagie et al., 2021; Sadeh et al., 2004; Sweileh et al., 2011). Major depressive disorder is a mood disorder that results in a persistent and long-term feeling of sadness and loss of interest. This disorder can affect how one can think, feel, and change behaviour, leading to various physical (e.g., reduced appetite, weight loss, weight gain, tiredness, lack of energy and sleep disturbances), emotional (e.g., feelings of sadness, tearfulness, emptiness or hopelessness, angry outbursts, irritability, and frustrations) and immunological (e.g., increased inflammation, rise in the levels of pro-inflammatory cytokines, glucocorticoids) effects (Bains N, 2021; Lee et al., 2019; Leonard, 2010; Vagga et al., 2020). Depression could affect the quality of life, especially for college students, because they experience the transition from adolescence to adulthood and may encounter different scenarios such as changes in social and family relationships, peer pressure for academic success, academic overload (Reyes-Rodríguez et al., 2013). Another study showed that the clinical depressive symptoms such as hopelessness, loss of pleasure and interest, negative self-thinking, fatigue, and concentration could be more prominent in college students than other groups of populations (Geisner et al., 2006). Teenage students may also face social depressive related behaviours such as internet overuse, smoking, frequent consumption of alcohol, presenting insomnia, and low self-esteem, which are associated with depression, anxiety, and stress (Ramón-Arbués et al., 2020).

As mentioned earlier, after the onset of the COVID-19 pandemic, governments of different countries imposed strict lockdown and social isolation for several months (Lancet, 2020). While the rising cases of SARS-CoV-2 infections and associated mortality aggravated physical and mental trauma, closure of educational institutions without any possibility of their reopening for in-person classes made students of all age groups, especially young adults of intermediate and higher educational institutions, more anxious about their curriculum and future. Many students pursuing specialized educational programs such as medicine, management, and engineering have lost track of the semester completion plans and delays in getting job offers after receiving their degrees (Aucejo et al., 2020). Various factors of the COVID-19 pandemic, such as its evolution, high transmissibility of novel mutations, challenges in vaccination worldwide, and the lack of immunity against the virus, further created a fearful condition for all, including young adults leading to the development of stress, anxiety, and depression (Orellana et al., 2020; Ornell et al., 2020; Rodríguez-Rey et al., 2020). In addition to the above factors, initiation of classes in online mode enhanced the stressful conditions in some families and students due to the non-availability of high-speed internet connections or digital devices and sometimes difficulty in understanding the course contents and the limited access to the online study materials (Alawamleh et al., 2020; Kapasia et al., 2020; Nambiar, 2020).

Screen time refers to the time spent performing online activities using different electronic devices ("Global digital overview," 2020). Initiation of academic and official activities via online mode increased the contact time with electronic devices such as laptops, smartphones, computers, and tablets and increased the screen time. Several reports suggest that radiations emitted by digital devices may negatively impact students' mental health (Limone et al., 2021). Additionally, virtual meetings and reduced social connections during COVID-19 lockdown, lowering students' wellbeing (Pandya et al., 2021; Rosen et al., 2014; Twenge et al., 2018). Thus, the conflicts between the parents and students also became one of the critical factors for increased stress and anxiety among students (Almroth et al., 2019; Behere et al., 2017; Spinelli et al., 2020).

1.3. *Effect of yoga and meditation on the factors affecting wellbeing and academic performance in students*

Following the Patanjali yoga sutra, yoga implements 'Chitta vritti nirodha,' which means managing or cooling the mind. In conjunction with enhancing physical strength and flexibility, it is also debated that yogic asanas help build attentiveness too (Cowen et al., 2005). In the following paragraphs, we further present the evidence available on the effect of yoga and meditation on various physical and mental wellness factors associated with students' academic performance (Figure-2).

1.3.1. *Role of yoga and meditation for a healthy life*

According to prior research, pranayama or yogic breathing techniques calms the nervous system and aids in maintaining blood pressure and stress responses (Goyal et al., 2014; Shetty et al., 2017). Physical relaxation, consciousness, and exultation are the effects of yogic practices such as Surya namaskar, which is an ancient yogic practice where twelve yoga postures are performed in sequence following a specific breathing pattern (Sun salutation routine) (Rocha et al., 2012). Different studies have ascertained that yoga can bring a productive conversion in mental and physical health by maintaining the adrenal-hypothalamic system, lowering corticosteroids, maintaining the sympathetic nervous system, and enhancing immunity (Arora et al., 2008; Büssing et al., 2012; Woodyard, 2011). Such observations were supported by the findings that yoga practices led to an increase in fasting blood sugar level, heart rate, cholesterol, CD4 T cell response, and LDL (Low-Density-Lipoprotein)

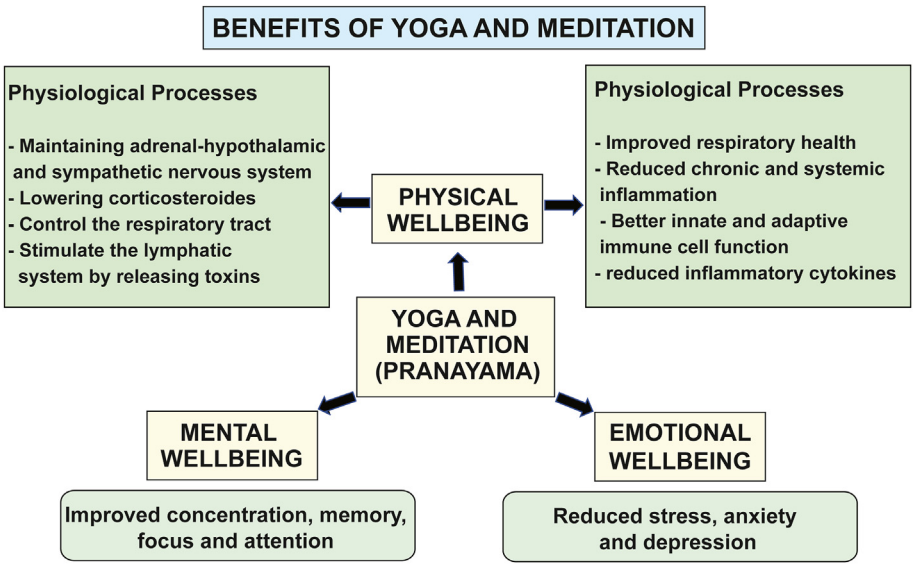

Fig. 2. Beneficial effects of yoga and meditation for students:
The schematic diagram shows the beneficial effects of regular yogic exercises, pranayama (breathing exercises), and other self-improvement routines in various parameters such as mental (e.g., attention, concentration, memory, alertness, sleep quality), emotional (e.g., reduced stress, anxiety and depression) and physical (e.g., strength, tome and flexibility of musculoskeletal system) wellbeing including physiological processes (e.g., metabolism) and immunological defence mechanisms (respiratory health, reduced inflammation, better innate and adaptive immune cell function) which have influence on academic performance and day today life of students.

irrespective of the age (Joseph et al., 2015; Kiecolt-Glaser et al., 2010; Pascoe et al., 2017). Regular yogic practice regulates the elimination of carbon dioxide and ultimately enhances the body's activeness by increasing peripheral oxygen saturation (Pal et al., 2015). Similarly, practicing yoga, meditation with pranayama are shown to reduce stress hormones and enhance the body's innate immune systems (Lim and Cheong, 2015). Previous studies have also shown a beneficial effect of pranayama in balancing the adrenal-pituitary-hypothalamic axis and inflammatory processes (Bower et al., 2016; Kaliman et al., 2014; Kiecolt-Glaser et al., 2010). Besides, pranayama techniques are also shown to control the respiratory tract, stimulate the lymphatic system, reduce inflammation, and influence virus-specific immune responses to vaccination (Morgan et al., 2014). Moreover, yoga is suggested as one of the non-pharmacological modes of stress management and wellbeing in anxious college students as it triggers neurohormonal mechanisms that bring about health benefits, reduces stress and anxiety, improves autonomic and higher neural centre functioning, and also improves the physical health of cancer patients (Sengupta, 2012).

Physical wellbeing is an essential part of a student's academic life and influences temperament and social performance (Preoteasa et al., 2016). A longer period of inactivity and confinement is known to affect the body's physical functions, such as the musculoskeletal system, whose optimum function is highly essential for young adults and students. Concerning physical wellbeing, it is known that less oxygen supply causes muscles stiffness that ultimately results in restricted body movements, and regular yogic practice helps in the functioning of the joints and tissue flexibility (Lau et al., 2015). Sitting on a bench for a more extended period in case of the students leads to poor blood circulation, which causes fluid retention and swelling within the body, which can be maintained by practicing various yoga postures such as, headstand, inverted poses, and child's pose (Chaya et al., 2008). So yoga could be considered the non-pharmacological way of maintaining physical and mental wellbeing and contributing to maintaining a healthy life and ultimately improving academic performance.

For school and college students, general wellbeing is also reflected in attention, concentration, and memory, which are an essential part of academic performance. Studies have suggested that relaxation is highly essential for good concentration, memory, and attention, which can be achieved by practicing yoga and meditation (Sheela Joice et al., 2018). It is well understood that the students' ability to focus, concentrate, and learn is directly related to academic performance and could be challenged under conditions such as the COVID-19 pandemic (El-Mir, 2019). Yoga and meditation practices are helpful in reducing depression, fear, and tension and is considered a holistic alternative and complementary therapy (Shohani et al., 2018) Importantly, it is shown that students' academic performance increases with the implementation of yoga by adjusting the stress level and helps increase neurological functions such as mental balance and visualization attention, especially in school age students (Kauts et al., 2009). Thus, a habit of practicing yoga and meditation and similar relation techniques can aid in enhancing their concentration, memory, and attention in challenging life events such as the COVID-19 pandemic.

A healthy sleep cycle is highly essential for students' performance (Okano et al., 2019). Lack of physical activity and poor nutrition during confinement periods such as lockdown and stressful conditions can affect the sleep cycle (Gualano et al., 2020). The amount and quality of sleep and circadian rhythm are known to affect the brain's functioning significantly and could alter immunological parameter Sergio (Garbarino et al., 2020). Studies show that regular practice of Surya namaskar is helpful in terms of improving alertness and reducing worry and negative emotions (Rocha et al., 2012). Yogic practices, meditation, and proper sleep contribute to enhancing daily functioning, emotional perception, attentiveness, and mental alertness (Ganpat et al., 2014; Godse et al., 2015; Sheela et al., 2013). Sex hormones influence the susceptibility to various infections, including their possible role in COVID-19 severity and outcomes (Haitao et al., 2020; Marzieh Saei Ghare Naz et al., 2021). Males are more susceptible to infection than females because of sex hormones (Draper et al., 2018; Klein, 2000). The menstrual cycle is one of the physiological rhythms of life that reflects the health of females. It could be associated with discomfort, pain, anxiety, and changes in the sleep cycle (i.e., peri-menstrual symptoms) and may affect the academic performance in females (Fernández-Martínez et al., 2020; Munro et al., 2021). Studies show that systematic yoga practice could have beneficial effects in alleviating such discomfort and symptoms associated with the menstrual cycle in females by stabilizing the neuro-endocrinal axis (Udupa et al., 2003). In conclusion, yoga and meditation could provide many beneficial effects that could help maintain students' physical and mental wellbeing and help with coping with stressful times such as pandemics and lockdowns.

1.3.2. Role of yoga in improving metabolism

The metabolic rate varies from person to person depending on various factors such as age, gender, and muscle to fat ratio, genetic makeup, physical activity, and hormonal balance (Park et al., 2016; Stefano Lazzer, 2012; Vishram et al., 2014). Metabolic rate is also associated with the control of various metabolic mediators (e.g., C reactive protein, IL-6, n-3 fatty acids, lactate), which can boost the body's immunity and promote wellbeing (Huang et al., 2016; Kominsky et al., 2010; Radzikowska et al., 2019; Swanson et al., 2012). The reduced outdoor activities and change in eating patterns experienced during the COVID-19 associated global lockdown became one reason for obesity among young adults (Robinson et al., 2021). Reports suggest that yoga can enhance metabolism and help burn the accumulated adipose tissue due to lifestyle (Na Nongkhai et al., 2021). Maintaining a balanced metabolic rate indicates healthy life, which is essential for the wellbeing and better performance of students (Rioux et al., 2019). Thus, yoga could be an essential tool to maintain good metabolism during the periods of prolonged inactivity, such as lockdowns.

The gut microbiome consists of thousands of organisms that help in food absorption, digestion, and energy production and ultimately enhance the immune system's functioning (Cronin et al., 2016; Mach et al., 2017). Psychological illnesses such as depression, anxiety, and cognitive disorders have been associated with gut microbiome dysbacteriosis (Foster et al., 2013; Nastasi et al., 2015). Thus, to maintain gut health, physical exercise and yoga could be a therapeutic factor as many friendly bacteria such as Lactobacillus and Bifidobacterium genera are known to respond to exercise (Dalton et al., 2019). The gut microbiome is also known to regulate the functions of the immune system. Importantly, microbiota and innate immunity are known to communicate bidirectionally; in other words, the immune systems of the body help in the maintenance of the host-microbes symbiosis. In turn, microbes help develop innate and adaptive immune systems responsible for protecting the body from various infections (Chu and Mazmanian, 2013; Zheng et al., 2020). Under stress-free conditions, a healthy microbiota is known to produce short-chain fatty acids that exert anti-inflammatory and antitumor effects in the absence of stress. Psychological stress is known to trigger the production of corticotropin-releasing hormone and catecholamine in various parts of the body, which may disturb the gut microbiota (Househam et al., 2017; Madison et al., 2019). During stress, an altered gut microbial population could affect the regulation of neurotransmitters mediated by the microbiome and gut barrier function (Carabotti et al., 2015). Reports show that meditation helps regulate the stress response, suppressing chronic inflammation states and maintaining a healthy gut-barrier function (Househam et al., 2017). Yoga and meditation could boost young people's immunity by indirectly affecting the gut microbiome. It could help in maintaining a healthy gut by regulating the stress responses that may trigger chronic inflammation (Househam et al., 2017). In addition, enhanced metabolism, which is one of the beneficial effects of practicing yoga and meditation, could help the students perform better as an associated factor.

1.3.3. Psycho-neuro-immunological effects of yoga and meditation in students

Stress can have significant effects on a variety of physiological systems, including the autonomic nervous system, the hypothalamic-pituitary-adrenal axis, and the immune system (Kemeny, 2003). Reports show that students undergo many short immunomodulating and possibly immunosuppressive stressful conditions during their study career (Kapasia et al., 2020). Two studies conducted on students have demonstrated that examination related stress could change the cytokine profile of the body from Th1 (e.g., IL2, IFNγ) towards Th2 (IL-4, IL-5, IL-6) response (Assaf et al., 2017; Dhabhar, 2014; Duck- Hee Kang, 2001). Thus, it is conceivable that prolonged academic uncertain conditions due to lockdowns could induce immunosuppressive responses in students and can alter their resistance to new infections. For example, examination periods are known to influence immune defences in students (Yasmin et al., 2020).

With the onset of the COVID-19 pandemic, substantial efforts were made to increase scientific research on boosting people's immunity with traditional and natural remedies (Khanna et al., 2021). To this end, yoga, meditation, and Ayurveda emerged as complementary immune boosters (Mishra et al., 2021). Yogic practices are known to regulate the functions of different organ systems of the body such as respiratory, circulatory, digestive, nervous, endocrine, and reproductive systems by altering physiological and psychological processes (Balaji et al., 2012; Sengupta, 2012). Reports show that yogic practices also modulate the functions of immune cells (Arora et al., 2008; Balaji et al., 2012; Sengupta, 2012). For example, in one of the studies, it was demonstrated that the practice of yoga could increase the natural killer cells that are highly important for the body's defence against viruses and tumor cells. This study also showed that yoga could reduce the inflammatory cytokines such as TNF-α and IL-6 (Agarwal et al., 2018; Vijayaraghava et al., 2015). In a meta-analysis of the results from several studies showed that combining pranayama and yogic postures could reduce inflammatory responses in chronic conditions (Djalilova et al., 2019). In the same line, a separate study showed that in rheumatoid arthritis patients practice of yoga significantly reduced the levels of pro-inflammatory cytokines (e.g., IL-6, IL-17, and TNF-α) and increased the levels of anti-inflammatory cytokine TGF-β (Gautam et al., 2020). Besides autoimmune diseases, yoga has therapeutic benefits on inhibiting the replication of hematopoiesis in HIV-1 infected patients (Bhargav H, 2010). The practice of yoga is also shown to prevent infection by increasing the salivary human β-defensin 2 (HBD-2) levels. HBD-2 is an antimicrobial peptide and helps destroy the lipid bilayers and hydrophobic core of microbes (Eda et al., 2013). Interestingly, one of the latest studies by Chandran et al. demonstrated that participation in an eight-day Inner Engineering meditation program resulted in differential expression of 220 genes in study subjects which are directly associated with immune response (Chandran et al., 2021). Additionally, the study showed that meditation could help in reducing oxidative stress, assist with detoxification and cell cycle regulation (Chandran et al., 2021). In conclusion, yoga and meditation could boost immunity in a natural way to maintain psychological wellbeing, which is an important factor in enhancing the overall performance of students.

2. Conclusions

From the presented evidence, it is conceivable that regular practice of yoga and meditation and have the potential to positively impact students' physiological, emotional, and immunological factors, affecting their wellbeing and academic performance. However still, there is a need for in-depth scientific studies exploring the relationship between yoga and students' mental, physical and psychological health. The COVID-19 pandemic has proven to be a wake-up call for humanity in many aspects.

COVID-19 pandemic has provided many lessons on possible issues students may encounter during such stressful times. Higher educational institutions have also strived to adopt innovative approaches such as digital learning platforms to streamline the educational system, facilitate learning and assist students in coping with stressful situations. Similarly, many institutions have also initiated virtual yoga and mindfulness meditation sessions to promote the mental health of their student and faculty. Hopefully, this review persuades the readership that performing a regular yoga routine has many benefits, including physical and mental wellbeing, and can help create a healthier younger generation with robust immune systems, essential to fight emerging infections such as COVID-19. Additionally, during prolonged lockdowns, several measures such as proper nutrition, adequate sleep routine, less exposure to social media and incorrect news, and support from family and institute authorities could help improve wellbeing and reduce anxiety in students. These lifestyle guidelines could be introduced in academic curriculum and traditionally taught alongside physical postures, adding to the holistic benefits that a yoga practice can bring to students.

Thus, adding regular yogic practices and other self-improvement routines to students' academic curriculum and daily practices in co-curricular activities or proficiency programs could help the younger generation take up the day-to-day challenges and stressful situations like lockdowns and pandemics and succeed in their personal and professional life.

Funding support

This work is funded by the Department of Science and Technology, Govt of India (Grant Number: DST/SATYAM/COVID-19/2020/386) to Pranita P. Sarangi and Shikha Jain.

Competing interests

The authors declare no competing interests.

Declaration of competing interest

The authors declare no competing interests.

Acknowledgments

The authors thank Prof. Barry T. Rouse, Distinguished Professor, University of Tennessee, Knoxville, USA, for proofreading the manuscript.

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Review

Yoga as an Integrative Therapy for Mental Health Concerns: An Overview of Current Research Evidence

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Abstract: Background: Because the prevalence of mental health concerns is high and access or full responsiveness to pharmacological or psychotherapeutic treatment for many individuals is low, there has been increased interest in yoga as a potential therapy for many mental health concerns. Approach: We synthesize and critique current research on the efficacy of yoga relative to pharmacological approaches for anxiety disorders, mood disorders, posttraumatic stress disorder, obsessive-compulsive disorder, and eating disorders. Results: Yoga has been tested mostly as a complementary treatment to standard psychiatric and psychotherapeutic approaches. Findings from efficacy trials largely support the notion that yoga can help reduce symptoms of many psychiatric conditions, including anxiety, depression, and PTSD symptoms, above and beyond the effects achieved by standard pharmacological treatments alone; however, most evidence is of poor to moderate quality. Plausible transdiagnostic bottom-up and top-down mechanisms of yoga's therapeutic effects have been advanced but remain untested. Conclusions: While results should be considered preliminary until more rigorous evidence is available, yoga appears to have the potential to provide many people suffering with psychiatric symptoms additional relief at relatively little cost. Yoga may be a viable complementary therapy to psychiatric and psychotherapeutic approaches for people with mental health challenges.

Keywords: yoga; anxiety disorders; depressive disorders; PTSD; eating disorders

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Citation: Park, C.L.; Slattery, J.M. Yoga as an Integrative Therapy for Mental Health Concerns: An Overview of Current Research Evidence. *Psychiatry Int.* **2021**, *2*, 386–401. https://doi.org/10.3390/psychiatryint2040030

Academic Editor: Paolo Girardi

Received: 15 September 2021
Accepted: 15 October 2021
Published: 20 October 2021

1. Introduction

Mental health is an increasingly urgent global public health concern. Untreated, mental illnesses account for a large share of global disease burden, estimated at 7 to 19% of the total [1]. Within 20 years, depression alone is expected to be the leading cause of global disease burden [2]. The costs in terms of suffering and lost potential to individuals, families, and society is immense. In spite of recent advances in technology, evidence-based treatments, and care delivery, many people suffering from mental illnesses remain untreated or receive only marginally effective treatments. Given that full alleviation of suffering from mental illness is uncommon, additional approaches are needed to complement these treatments, extend efficacy, and offer options acceptable to people who desire treatments other than or in addition to medication or psychotherapy.

One recently emerging approach to mental health is drawn from a very old Eastern tradition: Yoga. Yoga is a broad umbrella term for a variety of philosophical tenets and lifestyle practices, the most common of which in biomedical cultures is hatha yoga. Hatha yoga comprises physical postures, regulation of breathing, and meditation (see [3] for an overview).

While hatha yoga is often practiced as a form of physical exercise, it is now frequently studied as a treatment for a variety of mental and physical health conditions. The prevalence of yoga practice has increased significantly in recent years. In the US, for example, approximately 13.2% of adults report having practiced yoga, almost 163% more in 2012 than in 1998 [4]. Many individuals report practicing yoga to improve their mental health,

reduce stress, or bolster their mood [5]. Because many people already practice yoga to manage their mental health conditions and because many others may benefit, mental health professionals may want to be conversant with this expanding body of research and may consider integrating yoga into their treatment approaches.

In biomedicine, yoga is usually considered a complementary treatment; that is, a practice that can be integrated into a larger treatment plan that is based primarily on pharmacological treatment or psychotherapy. Earlier, yoga was sometimes considered part of "alternative" medicine, a broad body of treatments that attempt to provide alternatives to standard biomedicine. In the past few decades, many so-called alternative medical modalities have been subjected to scientific scrutiny to determine their value in treating a variety of health conditions. Those shown in clinical research to be of some value are often integrated into standard psychiatric and psychotherapeutic approaches to provide additional potential therapeutic benefit.

Because yoga is widely considered a way to promote mental health in the broader culture, clinical studies of yoga have proliferated in the past few decades, resulting in a large literature base. Many subsequent reviews and meta-analyses have been conducted in efforts to integrate this work (cf. [6–10]); however, making sense of these reviews and meta-analyses is complicated and difficult. The body of studies on which they draw is riddled with poor-quality clinical trials that fail to consider or eliminate bias. Further, definitions of "yoga" vary widely; thus, these published reviews of yoga have often included any intervention labeled as yoga by the authors, including Sudarshan Kriya yoga, which is almost entirely pranayama-based (breathwork), and Sahaj yoga, which is primarily seated meditation (cf. [7–9]). Most Westerners recognize yoga as including both of these aspects but also see asanas (yoga postures) as essential to yoga practice.

To increase our understanding of the efficacy of yoga for mental health conditions, we provide an overview of the broad body of empirical literature, focusing specifically on studies of asana-based yoga, which often also includes elements of meditation and breathwork. Extant published reviews and meta-analyses of yoga's efficacy for people with mental health diagnoses have generally not considered the other treatments in which patients or participants may be engaged (e.g., psychiatric medicine and psychotherapy). To better contextualize the efficacy of yoga with more mainstream treatments, we organized our overview according to whether the studies tested yoga as an alternative to psychopharmacological or other first-line treatments or as an integrative or complementary treatment used along with standard treatments. We reviewed studies on hatha yoga's efficacy for five of the most common categories of mental illness: anxiety disorders, depression, obsessive–compulsive disorder, PTSD, and eating disorders. Although we did not conduct a systematic review, we endeavored to include all published studies conducted with reasonable rigor that addressed the issue of efficacy with these five categories of disorders.

2. Methods

To identify studies for this overview, we relied on a set of recently-published meta-analytic reviews of each category of mental health condition [6–10]. We considered each of the studies cited within each review for inclusion and identified more recent studies through searches of PubMed, PsycINFO, and Google Scholar using as the search terms "yoga" and multiple variants of each of the diagnostic categories included here. Both authors examined each study to determine their eligibility for inclusion. The retained studies were those that had tested the efficacy of hatha yoga specifically, rather than only described its use, and that included information on other treatments provided and the nature of those treatments. We excluded studies that focused on pranayama- and meditation-only styles of yoga (e.g., Sudarshan Kriya yoga and Sahaj yoga) if they did not also include asanas as part of the yoga practice. Additionally, studies were not included if the articles weakly communicated designs or outcomes and prevented comparison or analysis of outcomes. These criteria meant we omitted some studies included in the previously cited meta-analyses.

In our overview, we distinguished between studies that consider yoga as a primary (alternative) or adjunctive (complementary or integrative treatment) treatment and have endeavored to describe the role of other first-line treatments when this information was reported.

3. Anxiety Disorders

Anxiety disorders are characterized by feelings of worry, anxiety, dread, or fear that are strong enough to interfere with a person's performance at work or school, in relationships, or in other important domains. They are associated with autonomic arousal, thoughts of impending danger, and avoidance or escape behavior [11]. Anxiety becomes problematic when it is out of proportion to the situation or developmental stage, persistent beyond the instigating stressor, and hinders functioning. Worldwide, prevalence estimates for anxiety disorders are around 7.3%, ranging from 4.8% to 10.9% [12]. Diagnosed anxiety disorders include generalized anxiety disorder, phobia, agoraphobia, panic disorder, social anxiety disorder, and separation anxiety disorder.

First-line treatments for high levels of anxiety and anxiety disorders include psychotherapeutic approaches, especially cognitive–behavioral therapy (CBT), and medication [13]. Patients who receive psychiatric medications often experience suboptimal anxiety reduction. For example, satisfactory responses to short-term selective serotonin reuptake inhibitors (SSRIs) and serotonin–norepinephrine reuptake inhibitors (SNRIs) for the treatment of generalized anxiety disorder (GAD) occur in approximately 60% of patients [14]. Approximately 30% of patients recover with standard pharmacology treatments, while another 30–40% are considered improved [15]. Relapse rates are very high and discontinuing medication greatly increases the odds of relapse [16].

Many people reporting high levels of anxiety do not seek medical treatment and reject psychotherapeutic or psychiatric interventions [17]. Concerns regarding potential side effects, high costs of treatment, potential addiction to medication, and dissatisfaction with pharmacological treatments contribute to low treatment adoption and adherence rates [18,19].

People suffering from anxiety disorders often choose to manage their anxiety on their own rather than by seeking medical treatment or engaging in psychotherapy or psychiatric interventions [20]. They often use self-help approaches such as support groups and physical exercise [20] and may also rely on alcohol or other psychoactive substances to alleviate their symptoms [21].

The appeal of yoga as an additional method to attempt to relieve anxiety has been growing in recent years. Indeed, reducing stress and anxiety is a primary reason people give for practicing yoga [5]. In the context of anxiety, yoga intervention research has occasionally considered yoga as an alternative to standard treatment but has almost always taken a complementary approach, offering yoga in addition to whatever treatment individuals were already receiving for their anxiety.

3.1. Yoga as an Alternative Approach for Anxiety Disorders

A few studies have directly compared yoga to pharmacotherapy. In an early study, 91 patients diagnosed as DSM-III "anxiety–neurotic" at a psychiatric outpatient clinic in India were randomized to receive yoga for 40 min/day five days/week for three months or given diazepam. Pre–post scores on an anxiety measures significantly improved for the yoga group and did not significantly change for the medication group [22].

Some studies have directly compared yoga with standard psychotherapeutic treatments while psychiatric medication management was administered across conditions. A recent study of 226 adult patients (mean age of 33, 70% female; 6% were on anxiolytics) with a primary DSM-5 GAD diagnosis were randomized to a 12-week trial of Kundalini yoga, CBT, or stress education [23]. The patients in the Kundalini yoga condition showed significant pre-to-post trial improvements in anxiety relative to the stress education group, although the CBT group improved even more. The authors concluded that Kundalini

yoga was efficacious for GAD, although the results support CBT as first-line treatment. A small study of 20 patients diagnosed with panic disorder were recruited from a Brazilian psychology clinic and randomized to receive either yoga or a combination of yoga and psychotherapy [24]. No information on medication was provided. Both interventions occurred weekly for 100 min and lasted 2 months. Significant reductions in anxiety levels associated with panic disorder, panic-related beliefs, and panic-related body sensations were observed in both treatment arms; however, the combined yoga and CBT group showed even further reductions in anxiety.

3.2. Yoga as a Complementary or Integrative Approach for Anxiety Disorders

In most studies of yoga as a treatment for anxiety, yoga is implemented as an adjunct to psychotherapy or medical treatment. A handful of these studies were conducted with people with diagnosed anxiety disorders. In one single-arm study, 55 adults in an acute inpatient psychiatric unit (with a variety of psychiatric diagnoses) participated in 1–2 yoga sessions in addition to treatment as usual (TAU) [25]. Patients who completed at least one session of yoga reported reductions in anxiety that lasted up to a full day; participants also reported using yoga and meditation as coping mechanisms at discharge. A recent study in India recruited 200 patients with anxiety-related disorders from a hospital psychiatry clinic [26]. Patients were randomized into a 3 month yoga or relaxation intervention; the yoga group demonstrated substantial reductions in anxiety relative to the relaxation group from baseline to end of intervention. Another study tested the efficacy of two different interventions and a non-interventional control group in mitigating the effects of depression or anxiety [27]. Ninety college students diagnosed with anxiety or depression (58.20% diagnosed with both; 31.34% anxiety only, 10.44% depression only; 56.6% were taking psychiatric medications) were randomized into an 8 week mindfulness meditation intervention group, an 8 week yoga group, or a non-interventional control group. Anxiety symptoms decreased significantly from baseline to end of intervention in both the mindfulness and yoga intervention groups relative to the control group.

Other studies focused on non-patient community samples who were recruited on the basis of reporting elevated levels of anxiety. For example, a clinical trial conducted in Australia included 101 people with at least mild anxiety or depression as reported on the DASS-21, a symptom measure [28]. Participants were randomized to receive 6 weeks of individualized yoga or be on a waitlist. Significant differences in anxiety and distress symptoms were noted from pre-to-post assessment in the yoga group, while anxiety and distress levels of those on the waitlist control did not change. A randomized preference trial was conducted with 500 community-dwelling older adults (mean age was 66 years, 87% women, 44% were on psychotropic medications), who scored high on a worry questionnaire [29]. Participants received 10 weekly sessions of CBT or 20 twice-weekly group yoga classes. Both groups experienced substantial reductions in worry and anxiety that did not differ between groups. Preference for yoga or CBT did not influence results.

Another randomized controlled trial was implemented in Australia with 131 community residents who reported experiencing mild to moderate levels of stress. Twenty-four percent of the sample was taking psychotropic medication [30]. Participants received 10 weekly sessions of relaxation or hatha yoga. Pre-to-post intervention scores on anxiety improved over time, but improvement did not differ by intervention.

Several studies have been conducted with medical patients with elevated anxiety. One randomized clinical trial of 38 breast cancer outpatients undergoing conventional treatment at a cancer center compared the anxiolytic effects of a yoga program to supportive therapy prior to their primary treatment (i.e., surgery) [31]. About 40% were taking anxiolytics. The results showed significant decreases in anxiety pre-to-post in the yoga group relative to supportive therapy. Another non-psychiatric medical-patient-focused study examined 250 people with osteoarthritis who had received transcutaneous electrical stimulation and ultrasound treatment [32]. They were randomly assigned to yoga or a TAU control

group for three months. Anxiety decreased in both groups but substantially more so in the yoga intervention.

Yoga was also studied in a healthy community sample with "normal" levels of anxiety. In this study, 34 healthy community participants with no noted psychiatric disorders were randomized to either 12 weeks of 3/week Iyengar yoga or walking. Those in the yoga group experienced greater reductions in anxiety relative to those in the walking group [33]. Participants were allowed to be on psychotropic medications although no information on medication use was reported. A study from India randomized women referred to a yoga clinic to either a yoga (twice weekly, 90 min duration, for two months) or a waitlist control group [34]. Both groups were evaluated at baseline and end of the two-month intervention. Women participating in yoga classes reported significant decreases in both state and trait anxiety, while women's anxiety levels in the control condition did not change.

3.3. Summary of Yoga's Anxiolytic Effects

In summary, yoga demonstrated substantial effects on anxiety in nearly all of the studies reviewed, which cover a broad range of samples, types of yoga, and study designs. Although some of the studies focused on diagnosed anxiety disorders, the majority were conducted with people who self-identified as having high levels of anxiety symptoms. The fact that in spite of this heterogeneity, yoga interventions were almost always efficacious suggests a robust effect.

Yoga's anxiolytic effects may be due to a number of different physiological, psychological, and behavioral mechanisms. Yoga may promote emotion regulation through integrating bottom-up physiological and top-down psychological processes that facilitate bidirectional communication between mind and body [35]. Yogic breathing and movement enhance autonomic nervous system (ANS) regulation. Through practicing yoga, individuals develop skills in remaining calm in times of challenge through deep breathing, mindful awareness, and attention. Yoga practices can stimulate the vagus nerve, helping to increase the balance of the ANS through the proportions of GABA and glutamate [36]. Also of importance, practicing yoga facilitates autonomic balance by increasing heart rate variability (HRV). Increased HRV is also associated with improved adaptation to changing environmental stimuli and physiological reactions to stress [37–39], while higher HRV promotes recovery following stressful situations [40]. Other potential top-down processes include attention control, emotional balance, coping abilities, and perspective and wisdom [35].

Although these studies are fairly consistent in demonstrating that yoga as an adjunct to standard first-line therapies may bring about additional relief from anxiety, caution must be taken in drawing firm conclusions. The studies reviewed were generally of fairly weak design, often using waitlist or TAU controls, which do not permit separating the effects of yoga from non-specific factors such as expectancies and attention. Further, the clinical trials reported here are prone to many types of biases that are pervasive in nearly all clinical trials [41]; thus, yoga may be considered a complementary option in treating a range of anxiety disorders given its potential effectiveness and minimal disadvantages, although stronger clinical trials are needed to build a firmer evidence base.

4. Major Depressive Disorder and Depressive Symptoms

Major depressive disorder (MDD) is characterized by changes in mood (depressed mood), motivation (loss of interest or pleasure in daily activities), cognition (inappropriate guilt, diminished concentration, and recurrent thoughts of death or death-furthering thoughts and behaviors), and physical symptoms (increases or decreases in eating, sleeping, activity, or energy), which significantly affect a person's ability to function [11]. In the US, the 12 month prevalence for MDD is 7%; women are more likely to be diagnosed with MDD than men, and young people (18–29 years) are three times as likely to be diagnosed as people who are 60 or older [11].

Recommendations for treating MDD often include antidepressants and cognitive and interpersonal therapies. Antidepressants have a somewhat more rapid effect for people

with moderate to severe MDD and is equivalent in efficacy to cognitive therapy by 16 weeks; people receiving cognitive therapy are less likely to relapse following treatment [42]. Several non-pharmacological treatments have also been shown to be efficacious, including aerobic exercise [43], behavioral activation [44], and mindfulness-based interventions [45]. Yoga may also be an effective treatment for MDD (cf. [7]).

4.1. Yoga as a Complementary or Integrative Approach for MDD and Depressive Symptoms

Studies of yoga as an integrative and complementary treatment compare participants receiving treatment as usual (TAU) plus yoga to TAU alone. In this case, participants may receive an antidepressant, cognitive therapy, or other treatments. For example, one study randomly assigned participants in a psychiatric hospital diagnosed with an affective disorder (42.5% with MDD) to either TAU or TAU plus a 30-day trial of asanas, breathwork, and meditation [46]. Members of the yoga group reported a significantly greater decrease in depression and anxiety scores and significantly greater clinical improvement relative to the control group over the trial. Another clinical trial assigned people with MDD to one of three groups: an 8-week Bikram group, aerobic exercise, or a waitlist control [47]. Remission rates in the yoga and aerobic exercise groups were similar at 61.1% and 60.0%, respectively, of the levels at the start of treatment and were significantly higher than waitlist controls (6.7%). Reductions in depressive symptoms in both active groups were mediated by changes in rumination. About 20% of their full sample was on medication and about 20% were receiving psychotherapy.

On the other hand, a study compared an inpatient population receiving one of two antidepressants or an antidepressant plus a 5 week course of weekly hatha yoga in a randomized trial [48]. Although both groups (yoga plus TAU vs. TAU) reported a significant decrease in symptoms over time, the yoga plus TAU group did not report a significantly greater decrease in symptoms. Similarly, comparable decreases in depressive symptoms were reported in a study of women with diagnosed MDD or dysthymia who were randomly assigned to either an eight week weekly hatha yoga group with home practice or an attention control group [49]. Nearly 70% of participants reported being in psychotherapy. Almost two-thirds reported taking an antidepressant; somewhat less than 40% were taking an anxiolytic. Those in the yoga plus TAU group reported significantly lower rumination scores at the end of the trial than did participants in the attention-control plus TAU group.

Some intervention studies did not explicitly compare yoga to other treatments, but rather only compared doses of yoga [50]. For example, one trial assigned people diagnosed with MDD to receive either a high or low dose of home and studio Iyengar yoga (90 min class, three vs. two times per week for 12 weeks); 87% of the high dose group and 73% of the low dose group responded with more than a 50% decrease in scores on the Beck Depression Inventory-II (BDI-II), while both groups experienced remission at the same rate (BDI-II scores less than 14 at week 12: 93% of high dose group, 87% of low dose). In another study from the same research group, participants diagnosed with MDD were randomly assigned to either a low or high dose of home and studio Iyengar yoga, as above [51]. Eight of the nine participants who had been suicidal at the start of the study no longer reported suicidality at the end of the intervention. Although their sample size was small, the reported change did not appear to be dose-dependent. Note that the "low dose" of yoga described in these studies was more intense and longer in duration than that described in most other studies reported in the present review.

Other studies have directly compared participants with MDD receiving a trial of yoga to participants receiving other treatments. For example, adults with untreated MDD were randomly assigned to either an eight-week, twice-weekly hatha yoga class or an attention-control education group [52]. Yoga participants reported significantly greater changes in depressive symptoms and were more likely to experience remission from MDD during this period; however, they did not report changes in self-esteem or self-efficacy. Another study randomly assigned women with a diagnosis of MDD to either a 12-week mindfulness-based yoga intervention (home-based yoga asana, breathwork, and meditation practice with

telephone-delivered mindfulness education sessions) or a walking condition (home-based walking sessions and telephone-delivered health education sessions) [53]. Both groups reported similar and significant decreases in depressive symptoms over the course of the study, although the yoga group reported a significant decrease in rumination symptoms relative to the walking group. Another study randomly assigned women with diagnoses of MMD or dysthymia to either a yoga intervention or a health education group [54]. Both groups met weekly for 8 weeks for 75 min/week. The yoga group reported significant decreases in symptoms of depression and rumination relative to the health education group, and these decreases were maintained over a year; however, the one year follow-up results are difficult to interpret due to high attrition from the study (only 7 of 15 members of the yoga group and 2 of 12 of the health education group completed the follow-up assessment).

Yoga has also been tested with women diagnosed with MDD during pregnancy. This is an especially important intervention target, as many pregnant women prefer non-pharmacological treatments for their depressive symptoms. In one group, 92 women diagnosed with prenatal depression were randomly assigned to a hatha yoga group designed for women during their second and third trimester (20 min per week for 12 weeks) or a leaderless social support group [55]. The yoga did not include either breathwork or meditation. At the end of the trial, both groups reported significantly less depression, anxiety, and anger and improved relationships, and the effects were similar across the two groups. Changes in depression and anxiety were maintained at their follow-up postpartum. In another study, 46 pregnant women with elevated anxiety or depression were randomly assigned to eight weeks of prenatal yoga (8 weeks of 75 min sessions weekly) or TAU, which was accessed outside of the study [56]. Yoga was perceived as safe, feasible, and acceptable. Depression symptoms in the yoga group did not differ significantly from those reported by the TAU group, although the yoga group experienced significantly greater decreases in negative effects. Some members of the TAU and yoga groups used an antidepressant or received psychotherapy during the study period and four members of the TAU group performed yoga on their own.

4.2. Summary of Yoga for MDD and Depressive Symptoms

Multiple studies suggest that yoga interventions reduce the psychological and physical symptoms of depression in populations with clinical levels of depression and in those with subclinical symptoms (cf. [7,57–59]). Participants with depression find yoga interventions acceptable and beneficial (cf. [49,54,56]). In their meta-analysis, Haller et al. [57] concluded that yoga's effect on treating MDD was of a "large size" relative to TAU and "medium size" relative to standard interventions. This conclusion was consistent with that of a review by Cramer, Anheyer, Lauche, and Dobos [7]. Our review includes more articles than did the review by Cramer et al. [7], but also concludes that yoga is a promising intervention for MDD. We found that, relative to an active control, two of the four study groups performed significantly better than the control group [52,54]. When compared with active controls (e.g., walking or social support), they performed as well [53,55,56]. Both studies that looked at changes in rumination reported significant decreases in symptoms [53,54]. Studies of complementary interventions (interventions plus TAU) were more mixed in outcomes. Some supported the use of yoga as a treatment for MDD [46,47]; others did not see any additional advantage compared to TAU or an attention control [48,49].

Nonetheless, similarly to Haller and colleagues [57], we conclude that the data in these studies were often of very low quality, as there were often very low doses of yoga, no active control groups, considerable dropouts from the study, insufficient blinding of participants and researchers, and other biasing factors.

5. Obsessive–Compulsive Disorder

Obsessive–compulsive disorder (OCD), although not technically classified as an anxiety disorder, can be a life-long disorder often featuring high levels of anxiety and psychosocial impairment. SSRIs are the primary pharmacological approach, but approximately

50% of patients do not respond to this treatment. When combined with the standard behavioral therapy for OCD, exposure and prevention, about 30% of OCD patients remain non-responders [60].

We found just one study that examined yoga and OCD. A randomized clinical trial compared Kundalini yoga to a relaxation response intervention in 48 patients who met criteria for OCD; 52% were taking psychiatric medication [61]. Both groups improved in OCD symptoms, although the yoga group demonstrated greater improvements than did the relaxation response group, suggesting that Kundalini yoga may be considered an effective add-on for OCD patients unresponsive to more traditionally used treatments.

6. Posttraumatic Stress Disorder

Many people experience posttraumatic stress symptoms after experiencing or witnessing a traumatic event such as a natural disaster, a serious accident, a terrorist act, combat, or rape, or after being threatened with death, sexual violence, or serious injury [62]. These symptoms include intrusive thoughts of the trauma, avoidance, hyperarousal, and disturbances in cognition and mood [11]. When symptoms are severe and last at least one month, a diagnosis of posttraumatic stress disorder (PTSD) is applied. The annual prevalence of PTSD in the US is 3.5% and the lifetime prevalence is 9% [62]. Women are twice as likely as men to be diagnosed with PTSD [63].

Psychiatric treatment of PTSD typically consists of antidepressants such as SSRIs and SNRIs, which are used either alone or in combination with psychotherapy or other treatments. Recent meta-analyses reported small differences in outcomes between most pharmacological treatments for PTSD and placebos; nonetheless, medication may be helpful in controlling symptoms of PTSD, which may in turn help those with PTSD to engage in psychotherapy more effectively [64,65].

Psychotherapy, especially trauma-specific therapies such as prolonged exposure therapy or cognitive processing therapy, appear to be superior to medication as first-line treatments for PTSD [66]. These therapies typically focus on extinguishing conditioned fear responses, requiring patients to manage intense emotions while focusing on conditioned stimuli, such as sensations from the environment or one's memories [67]. Rates of premature termination from psychotherapeutic treatments for PTSD can be high. These high rates of attrition have been attributed to difficulties that many patients experience in tolerating these treatments [67].

Given these treatment difficulties, complementary therapy approaches for individuals with diagnosed PTSD or high levels of posttraumatic stress symptoms have received increasing interest by both mental healthcare providers and patients themselves. In particular, mind–body approaches may decrease trauma-related symptoms and improve emotion regulation [35], meaning they could help patients tolerate psychotherapy. Only a small number of studies have yet examined the efficacy of yoga for treating PTSD; we were unable to identify any articles directly comparing yoga to psychopharmacological approaches. All of the reviewed studies either allowed participants to continue with their other treatments as usual or did not mention other treatments at all in their published articles.

6.1. Yoga as a Complementary or Integrative Therapy for PTSD

In one of the earliest studies of yoga for PTSD, 64 women diagnosed with chronic, treatment-resistant PTSD were randomly assigned to either a trauma-informed yoga or supportive women's health education group. Each intervention took place for one-hour weekly over 10 weeks [68]. Study participants were required to be engaged in ongoing supportive therapy and continue current pharmacologic treatment. Women in both conditions showed decreases in PTSD symptoms by the end of the intervention, although the decreases in the yoga group were much larger.

Several yoga clinical trials have been conducted specifically with veterans with PTSD. A quasi-experimental pilot study examined veterans diagnosed with PTSD who completed a yoga intervention in gender-specific groups [69]. Improvements between baseline and

postintervention were statistically significant for PTSD symptoms as well as for depression, sleep, quality of life, and subjective neurocognitive complaints.

Another single-arm pilot yoga intervention designed for veterans with diagnosed comorbid chronic pain and PTSD was conducted at a large urban Veterans Affairs Medical Center [70]. The sample was primarily African American (69%) and male (61%), with a mean age of 51.41 years. The results indicated reductions in overall PTSD symptoms. Veterans reported significant improvements in their ability to participate in social activities and significant reductions in kinesiophobia, an especially helpful improvement for treating pain.

A recent study randomly assigned participants (91.4% veterans; 66% male; 61.7% White; 75.1% currently on psychiatric medication) who met diagnostic criteria for PTSD to attend one of two weekly interventions, yoga or a wellness lifestyle program, for 16 weeks [71]. Participants in both groups showed substantial decreases in PTSD severity over the course of treatment, although those in the yoga group showed significantly greater reductions in PTSD severity at treatment end than did those in the lifestyle program. Group differences persisted at 7 month follow-up but were no longer statistically significantly different.

Several studies have focused on community residents self-reporting high levels of PTSD symptoms. One clinical trial recruited people from the community who had PTSD symptoms, with eligibility based on reporting clinically significant levels [72]. Approximately 60% of the sample reported having been diagnosed with PTSD and 47% reported taking psychiatric medication. Participants were randomly assigned to eight weeks of Kundalini yoga or a waitlist. Participants in both groups demonstrated decreases in PTSD symptoms, although those in the yoga group reported a significantly greater decline. Participants in the yoga group also showed greater improvements in measures of sleep, positive affect, perceived stress, anxiety, stress, and resilience relative to those on the waitlist.

A community sample of 38 women (52% White, mean age of 44, 25% veterans) with self-reported full or subthreshold PTSD symptoms was recruited and randomized to a 12-week Kripalu yoga intervention or a waitlist [73]. Yoga participants reported fewer reexperiencing and hyperarousal symptoms by the end of the intervention. The waitlist control group, however, showed similar decreases in reexperiencing and anxiety symptoms, which may be a result of the positive effect of self-monitoring on PTSD and associated symptoms or may indicate regression to the mean.

Finally, a clinical trial in Colombia randomized ex-combatants from illegal armed groups who had been diagnosed with PTSD (73% male, 9% reported prior treatment) to either sixteen weeks of twice-weekly yoga or a waitlist control [74]. Both groups decreased in their levels of PTSD symptomatology over the sixteen weeks, although the yoga group reported a 19% greater reduction in symptoms.

6.2. Summary of Yoga for PTSD

Although preliminary, these studies collectively provide promising support for the use of yoga as an adjunct to pharmacological or psychotherapeutic approaches to treating PTSD. The effects are substantial and are in addition to any effects observed for other treatments participants may have been receiving.

Adding yoga practice to standard treatments for PTSD is based on a solid theoretical rationale. Although the specific mechanisms by which yoga improves outcomes for people with PTSD have yet to be empirically established, several theories have been put forward. Yoga, with its combination of controlled breathing, relaxation, meditation, and movement, can shift autonomic balance towards the parasympathetic branch of the autonomic nervous system, thereby reducing the hyperactivation of the amygdala and elevated cortisol levels that often accompany PTSD [68]. Yoga can alleviate PTSD via psychological pathways as well. As noted above, yoga can promote better emotion regulation, helping individuals tolerate and persist in psychotherapy [35], and may increase mindfulness, which helps reduce the avoidance that is characteristic of PTSD [75].

7. Eating Disorders

Eating disorders are categorized into three main types: anorexia nervosa, bulimia nervosa, and binge eating disorder. The 12 month prevalence rates of anorexia nervosa and bulimia nervosa are, respectively, 0.4% and 1–1.5% of the population, with 10 times as many females affected as males for both disorders [11]. For binge eating disorder, gender ratios are much less skewed, with 12 month prevalence rates of 1.6% for women and 0.8% for men [11]. The reported relapse rates for anorexia nervosa range between 9% and 52%, with most studies reporting rates greater than 25% [76]. Although 45% of people with bulimia nervosa were reported to be in remission and 27% improved at follow-up, 23% had a chronic course [77]. The mortality rates are relatively high for anorexia nervosa (4.0%) and bulimia nervosa (3.9%) and are further elevated by high rates of suicide [78]. Comorbidity with anxiety disorders and depression is common [79].

Yoga is frequently used in a multimodal treatment for people with eating disorders [80]. Yoga can address the comorbid depression and anxiety associated with eating disorders, as well as body dissatisfaction and negative affect [81,82]. It also, in theory, addresses a weakness of other cognitive therapies, as it focuses less on the cognitive aspects of the disorder (e.g., judging) and more on accepting and being present in the body [83].

7.1. Yoga as Prevention of Eating Disorders

Young adults in a population-based survey who engaged in yoga and Pilates were not at lower risk of engaging in disordered eating than those who did not [84]. Young women who reported participating in yoga or Pilates were less likely to report body dissatisfaction than those who did not, but they did not differ significantly in their weight control methods and binge eating. On the other hand, young men were more likely to use extreme strategies for controlling their weight and to binge eat.

Some studies examined changes in eating disorder symptoms and body satisfaction in general community samples, focusing on preventing or reducing symptoms of eating disorders. For example, in a naturalistic design, fifth grade girls self-selected either a yoga intervention (N = 91, 14 weeks of 90 min yoga plus prevention curriculum) or a waitlist control (N = 41) [83]. Over the course of the program, girls in the yoga intervention group significantly decreased in their drive for thinness and body dissatisfaction and increased their self-care at the post-test when compared to girls in the control group. This study partially replicated an earlier study in a similar but somewhat shorter intervention without a control group [85]. That study reported decreased body dissatisfaction, decreased tendencies to think about and engage in uncontrolled eating, and improved social self-concept.

In another study, college students (N = 99, 77.8% female) completed a yoga class that met for 50 min, three times per week, for eight weeks [86]. Relative to the beginning of the course, body dissatisfaction and eating disorder pathology were significantly lower at the end of the course, while body appreciation and self-compassion increased. Men reported fewer concerns about being overweight and more improvements in body satisfaction as a result of the course than did women. Finally, 113 women were randomly assigned to a yoga intervention, a cognitive dissonance intervention, or a control group; 93 women completed the post-intervention assessment [87]. Information about psychotherapy or medication use was not provided. Both interventions met weekly for 45 min/week over six weeks. Pre-to-post intervention, women in the cognitive dissonance group demonstrated significant decreases in disordered eating, drive for thinness, body dissatisfaction, and alexithymia. No significant differences over time were reported for the yoga or waitlist group. No changes in anxiety or depression scores were reported for any group.

Other studies focused on at-risk adult populations in the community. Ninety overweight or obese participants from a community sample with a binge eating problem were randomly assigned to a weekly 60 min hatha yoga session for 12 weeks or a waitlist control [88]. The yoga group's binge eating scores and physical activity significantly decreased, while the waitlist controls showed no changes. These differences were maintained at a

three month follow-up. Five women with a history of both eating disorders and doing yoga completed a six day Forrest yoga workshop (yoga, healthy cooking, and reflection) with follow-ups one month after the workshop [89]. Over the course of the study, the participants' ability to recognize and respond to emotional states and affective problems improved. They also reported decreases in eating disorder symptoms and psychological maladjustment between baseline and postintervention, effects that were maintained at the one month follow-up. Finally, a group of adult women (N = 52, 25–44 years old) who were classified as restrained eaters with reported elevated stress were randomly assigned to either a Bikram yoga intervention (two 90-min classes weekly for eight weeks) or a waitlist control [90]. No participants were also receiving concurrent mental health treatment of any kind. Yoga participants reported greater decreases in the frequency with which they were binge eating and less eating to cope with negative emotions.

7.2. Yoga as a Complementary or Integrative Therapy for Eating Disorders and Disordered Eating

In a single-arm study, 20 adolescents with mixed eating disorder diagnoses (75% diagnosed with "other specified feeding or eating disorder") enrolled in a 12 week trial of hatha yoga (between 60 and 90 min per week), although only 70% completed the baseline assessment [91]. Of the total enrolled, 45% had prior experience with yoga; 55% completed at least seven of the 12 sessions and the final assessment at 12 weeks. No information on the nature of other treatments received was reported. Participants reported no changes in restraint and eating concerns but significant decreases in weight concern, shape concern, anxiety, and depression.

Norwegian adults who were solicited from sites with access to people with eating disorders were randomly assigned to either a hatha yoga group (twice weekly for 90 min) or a waitlist control [92]. Twenty-one completed assessments at the post-test, with 12 of 18 and 9 of 12 participants, respectively. Six were also receiving concurrent psychotherapy—four in the yoga group, two in the control group. No information about medication was reported. Scores on the global, restriction, eating concern, and weight concern scales of the Eating Disorders Examination decreased across time for the yoga group but not the waitlist control group. No changes in shape concern were observed. Changes were maintained at six month follow-ups. In another trial, adults meeting criteria for either bulimia nervosa or binge eating disorder were randomly assigned to either a Kripalu yoga (90 min weekly for 8 weeks; N = 26 completers) or a waitlist control group (N = 27 completers) [93]. Many had a history of prior psychotherapy (79.2%) and current medication (30.19%). Relative to waitlist controls, participants in the yoga group showed greater decreases in binge eating frequency, emotional regulation difficulties, and self-criticism and improved self-compassion and mindfulness skills over the course of the study.

Adolescents receiving outpatient treatment for an eating disorder were randomly assigned to either a TAU waitlist or an eight-week trial of individual yoga (twice weekly for an hour) plus TAU [81]. Participants were female (92%), diagnosed with anorexia nervosa (55%), and had a history of hospitalization (45%) and overexercising (48%). At the end of treatment, adolescents in the yoga group reported fewer symptoms of eating disorders, which was maintained at a one month follow-up. Symptoms of depression and anxiety declined across time for both groups, which were not significantly different from each other. Food preoccupation declined between the start and end of each yoga session.

Thirty-eight participants in a residential eating disorders program (97.3% female, 58% diagnosed with anorexia nervosa) were randomly assigned either to an hour-long hatha yoga class for five days immediately before dinner or a control group completing regularly scheduled residential activities during the same period [82]. Pre-meal but not post-meal negative affect declined among participants in the yoga group.

7.3. Summary of Yoga for Eating Disorders and Disordered Eating

Yoga appears to be a promising adjunct for treating people with eating disorders and may be an efficacious prevention strategy in reducing risk factors and symptoms when

used in the community (e.g., [83,86,88]). Although the studies reviewed generally drew positive conclusions about yoga's efficacy with these populations and make sense from a theoretical standpoint, the research evidence is weak, as many studies lacked a control group and studies that did employ a control group often used waitlist controls rather than active control groups. In a meta-analysis, however, effect sizes for global eating disorder psychopathology and body image concerns were small but significant, and for binge eating and bulimia were moderate to large [6]. Effect sizes for dietary restraint and eating concerns were not significant.

8. Conclusions

Any general conclusions drawn from our review must be tempered by acknowledging the lack of rigor of this body of research, and we discuss in some detail these limitations below; however, the extant studies have fairly consistently yielded findings suggesting that yoga may be a helpful addition to first-line therapies for people diagnosed with anxiety, depression, and other psychiatric disorders. Yoga may be an appealing option for many people who are hesitant about psychiatric medications or psychotherapy. Yoga is widely available and can be made affordable [6]. Further, although occasional injuries were described in the research reported here, yoga has few negative side effects, which are mostly musculoskeletal issues such as strains and sprains [3]; nonetheless, some studies of people with eating disorders reported problems with social comparisons or negative self-talk [6].

Many plausible mechanisms by which yoga may affect symptoms have been identified, although their function as the link between yoga practice and symptom reduction remains to be tested. Importantly, many of these mechanisms are transdiagnostic. For example, stress is known to exacerbate virtually every mental health symptom [94] and yoga's stress-reducing properties have been well-documented [3]. Yoga helps to shift autonomic balance towards the parasympathetic nervous system, which provides a cascade of benefits (increased frequency of heart rate variability, decreased GABA), manifesting as reductions in many types of symptoms [3,9,33,36]. Stress reduction through yoga also provides myriad psychological benefits that may reduce mental health symptoms, including increased emotion regulation capability, improved health behaviors, better social connections and support, and deeper spirituality [95].

The current review was based on studies identified in previous systematic reviews along with additional literature searches, but does not constitute a full systematic review of yoga for each disorder. In addition, the review is based on a body of literature that is generally not strong; however, the current limitations of this body of literature provide ample direction for more rigorous research in the future. Many of the reviewed studies relied on treatment as usual or waitlist controls, which did not account for non-specific factors such as expectancies and attention. Future well-designed clinical trials should randomize participants into conditions of yoga and comparators, so that the added value of yoga can be determined. Many of the studies we reviewed did not even report whether participants were also receiving medication or psychotherapy let alone control for them in analyses. We know little about the therapeutic "dose" of yoga, and most of the trials of yoga reported here were very short; yoga's beneficial effects likely accumulate over months and years.

Hatha yoga is a wide umbrella of many distinct types of yoga that vary on many dimensions. Studies should carefully select and tailor the yoga intervention to the targeted symptoms, perhaps considering the specific mechanisms targeted. For example, yoga that emphasizes breathwork and linking breath to movement may be particularly helpful in improving vagal tone, while more gentle or restorative types of yoga may target the relaxation response. More vigorous yoga may help patients to improve their cardiovascular system and muscular strength, which may improve emotion regulation abilities [96]. To date, however, different yoga styles do not appear to differ in their rates of positive outcomes [4].

In summary, yoga appears to be a viable complementary intervention approach for a range of mental health challenges. The research evidence in support of its beneficial effects is not yet strong but is becoming more robust over the years as researchers implement more rigorous trials. It is appealing to many people and of low risk and low cost. Further, there are many different types of yoga, meaning that people have options regarding different styles and intensities and may be able to find the best fit for developing a yoga lifestyle that helps them achieve and maintain better mental health.

Author Contributions: Conceptualization, writing of both the original draft and reviewing and editing, C.L.P. and J.M.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest, financial or otherwise.

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Military Emotional Wellness

April 29, 2022, 11:11 a.m.

Emotional wellness can be a difficult concept to gauge — it seems all facets of health connect in some way to your emotions, whether you feel joyful at seeing your favorite sports team win, worried about your deployment, angry at losing a loved one, or any of the myriad emotional responses everyday life can trigger. Service members are often under tremendous pressure to keep their emotions under wraps. Those who do hold in toxic emotions are far more likely to cause themselves and others unintended harm.

What does “emotional wellness” mean?

1. Emotional wellness is emotional self-awareness and acceptance of your emotional reactions:

   Self-awareness means knowing yourself and your environment, so your emotional reactions match the circumstances that trigger them. It’s normal to feel agitated by a colleague’s annoying gum chewing habit, and getting angry to the point of wanting to harm your colleague may be a sign your emotional responses are out of your control.

   Acceptance means letting yourself experience your emotions without ignoring them or feeling guilt or shame. Often, service members wishing to save face in front of their peers

may believe repressing emotions is the right way to handle grief, anger or embarrassment. Not so!

2. Emotional wellness means having the ability to bounce back when emotions take a negative turn and effectively cope with stress:

   Bouncing back from negative emotions, like sadness, grief, fear and other classifications of emotional pain, doesn't mean recovery happens overnight. Emotionally resilient individuals are active participants in their own recovery, thinking positively and seeking help as time heals their emotional wounds.

   Coping with stress effectively can be a challenge for service members, but it can also be a learned skill in maintaining emotional equanimity during stressful situations. Making conscious decisions to meditate, exercise, turn to friends and family for support, develop effective problem-solving skills, or keep a journal are effective stress management strategies.

3. Emotional wellness means making positive choices and fostering positive relationships:

   Making positive choices is one of the simplest expressions of emotional wellness. Individuals who make positive choices act in accordance with their well-being, resisting the extra drink at the bar at the end of a stressful day, talking to their spouse about troubling thoughts, or just choosing to pursue optimism instead of pessimism.

   Positive relationships signify an emotionally-well individual because having good friends and family means cultivating mutual care and understanding with others, creating a support network, and avoiding those who may send you down a negative path. Remember: a true buddy will build you up — not knock you down.

Know Signs of Emotional Distress

If you or someone you know exhibits any of the signs of emotional distress below, contact your Director of Psychological Health today.

- Inability to eat, sleep or concentrate
- Negative outlook or depression
- Thoughts or attempts at self-harm
- Irritability, inability to control anger
- Impulsive behavior
- Feelings of helplessness or hopelessness
- Fearfulness, nervousness or anxiety
- Hypersensitivity to perceived threats, unexplained suspicion or fear
- Feeling emotionally numb or detached
- Inexplicable sadness
- Flashbacks to a traumatic event
- Confusion or disorientation

- Resistance to engaging in everyday activities
- Extreme mood swings
- Loss of work ethic or social functionality
- Poor self-care

Tips to Improve your Emotional Health

1. **Get to know yourself**. Ask yourself questions like "Do I have close relationships with people who have a positive influence in my life?" "How have I handled conflicts in my life?" "Am I able to accept responsibility for my actions?" "Is stress affecting my attitude, my relationships or my health?" Answer honestly.
2. **Keep a journal**. Journaling helps cultivate mindfulness by letting you be the spectator (or "narrator") of your life. Write down any thoughts, feelings, reflections that come to mind and read over what you wrote. Like someone on the outside looking in, you can arrive at information about yourself you never knew before.
3. **Practice optimism**. Smile more. Laugh more. Reach out to others or try to put a positive spin on a stressful situation. Even if your heart isn't in it at first, practicing the act of optimism will eventually become a habit and change the way you feel.
4. **Learn to manage stress**. Time management strategies that help declutter your mind (or at least your desk) can offer relief when you have a stressful schedule. Relaxation techniques including deep breathing, yoga poses, progressive muscle relaxation and positive visualization are other proven methods for reducing stress. Listen to Chill Drills by Military OneSource. This free audio app was developed to help service members and their families relax and manage stress. Once you download Chill Drills onto your device, you won't need an internet connection to practice the relaxation exercises. Remember, scheduling time for yourself can be as important as scheduling anything else on your to-do list. And when possible, remember to rest.
5. **Seek support from a trusted professional**. Counselors, chaplains, therapists, and your Director of Psychological Health are all available to you when you need a confidante or military support. They are experienced professionals who are there to serve your immediate emotional needs, as well as work collaboratively with you to develop emotional habits that work better for your needs.

Why Do Navy SEALs Use Box Breathing?

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Medically Reviewed on 11/18/2021

Privacy & Trust Info

U.S. Navy SEALs use a breathing technique known as box breathing in high-stress situations to aid in stress management and overall wellness.

To relieve stress, Navy SEALs use a technique known as box breathing.

Navy SEALs are frequently placed in high-stress situations. Box breathing is a valuable mindfulness technique that can aid in stress management and overall wellness.

- Box breathing is just one of the techniques used by Navy SEALs to stay calm.
- The name comes from the fact that you divide your breathing into four steps as if you were breathing along the four edges of a box.

4 steps of box breathing

The 4 steps of box breathing include:

1. **Step 1:**
    - Inhale slowly through your nose while mentally counting to four.
    - Concentrate on filling your lungs and abdomen with air.
    - Let your body feel how air is filling your lungs.
2. **Step 2:**
    - Take a deep breath.
    - Hold your breath and mentally count to four again.
3. **Step 3:**
    - Exhale slowly through your mouth while mentally counting to four.
    - Concentrate on getting all the air out of your lungs at once.
4. **Step 4:**
    - Take a deep breath.
    - Hold your breath and mentally count to four again.

Return to step 1 and repeat the process until you can feel yourself becoming calmer and more relaxed.

Box breathing is something that Navy SEALs do for about five minutes.

The US Navy SEALs have recently adopted a technique known as tactical breathing to assist soldiers in dealing with high-stress situations during combat and battle.

How does box breathing relieve stress?

Although slow breathing techniques are effective in the long term for stress reduction and heart rate reduction, methods such as box breathing work wonder in high-stress situations by calming your autonomic nervous system.

- Many autonomous bodily functions such as blood pressure, body temperature, and heart rate are regulated by this system.
- It is made up of two parts, namely, the sympathetic system, which stimulates bodily activity (fight or flight), and the parasympathetic system, which relaxes your body (rest and digest).
- When you hold your breath, CO_2 levels in your blood increase, which increases the cardioinhibitory response (lowering your heart rate).
- This activates the parasympathetic nervous system, resulting in a calming and relaxing effect, or, to put it another way, breathe slowly and relieve stress.

4 benefits of box breathing

Box breathing is an effective method for overcoming stress and improving your body's future response to stress and anxiety.

Here are 4 health benefits of box breathing:

1. **Improves mental well-being:**
    - Consider learning the box breathing technique if you've ever considered meditating to reduce stress and improve your mental health.
    - Breathing is inextricably linked to cognitive activity such as thinking and reasoning.
    - According to some studies, taking slow, mindful breaths helps reduce stress and feelings of depression.
2. **Heightens cognitive performance:**
    - Box breathing clears the mind, allowing for greater focus and concentration.
    - Deep, rhythmic breathing exercises help people with attention deficit hyperactivity disorder manage impulsive behavior.
    - Taking slow, controlled breaths helps balance our nervous system, which allows us to clear our minds and increase our attentiveness.
3. **Enhances the body's future reactions to stress:**
    - Resetting your breath with box breathing will benefit both your mind and body in the long run.
    - Researchers discovered that regular deep breathing exercises can activate the genes associated with your body's energy and insulin levels while decreasing those associated with inflammation and stress.
4. **Helps deactivate the fight-or-flight response:**
    - The sympathetic and parasympathetic nervous systems are two subsystems of the autonomic nervous system.
    - When the sympathetic nervous system is activated, the body goes into "fight, flight, or freeze" mode, preparing itself to "fight" for survival by releasing cortisol (a stress hormone) (dilation of the pupils and muting pain perception).
    - A panic attack occurs when the body enters this mode without being triggered.
    - Deep breathing causes the body to enter the parasympathetic or "rest and digest" mode, which helps calm it down in stressful situations.

To practice box breathing

- Set a timer for five minutes.
- Sit with a straight spine on the floor or in a chair with your feet flat.
- Close your eyes and inhale for a count of four.
- Hold your breath for a count of four.
- Exhale for a count of four.
- Hold for a count of four.
- Repeat until the alarm sounds.

What is tactical breathing?

When under duress, Navy SEALs use two breathing techniques to induce a more relaxed state in the body, and anyone can use them to control stress. They use tactical breathing, in addition to box breathing.

Tactical breathing is a technique used when you feel the trigger of the fight-or-flight response.

- To do this, place your right hand on your stomach and exhale heavily.
- Then, slowly draw your breath upward from your abdomen to your upper chest by inhaling through your nostrils.
- Exhale slowly, beginning at your chest and working your way down to the air in your abdomen.
- Consider your navel to be in contact with your spine while breathing.
- Once you're comfortable with a full, deep breath, do it again, but this time exhale twice as long as you inhale.
- Breathe to the count of four, pause briefly, and exhale to the count of eight.
- Repeat at least three times.

Box breathing and tactical breathing are based on pranayama, an Ayurvedic form of breathwork that originated in India and is practiced in yoga. It has extremely ancient roots, with various techniques for calming, bringing in energy, refining focus, and relaxing the nervous system. However, it was recently popularized and brought mainstream by the military.

International Journal of
Environmental Research and Public Health

MDPI

Article

Effects of Classical Breathing Exercises on Posture, Spinal and Chest Mobility among Female University Students Compared to Currently Popular Training Programs

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Abstract: Worldwide, university students' physical health and posture are declining due to a sedentary lifestyle. The aim of our study was to evaluate the effectiveness of physiotherapeutic breathing exercises on posture and spinal mobility among healthy female university students compared to other training methods. Sixty-one female students of the University of Debrecen were assigned to breathing exercise (BE; n = 15), yoga (Y; n = 16), Pilates (P; n = 15) programmes and interval-training (IT; n = 15). Each training session lasted one hour, performed twice a week for 7 weeks. Students were assessed using standardized clinical tests. All programmes resulted in significant improvement in chest expansion. Results of Schober's test showed substantial improvement using BE ($p < 0.05$), Y, P ($p \leq 0.01$) programmes. Significant changes in occiput-to-wall distance (Y, P $p \leq 0.01$) (BE $p \leq 0.001$) were observed in three groups except the IT group. Fingertip-to-floor test (Y, P $p < 0.05$) results showed significant changes in two groups. The most outstanding effects on lateral flexion were achieved using BE (right, left $p \leq 0.001$) programme. A comparison with results achieved using yoga and Pilates revealed that the physiotherapeutic breathing exercise programme is an equally effective method to significantly improve spinal mobility and correct postural problems in healthy young women.

Keywords: breathing exercises; spinal and chest mobility; posture; female university students

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Citation: Csepregi, É.; Gyurcsik, Z.; Veres-Balajti, I.; Nagy, A.C.; Szekanecz, Z.; Szántó, S. Effects of Classical Breathing Exercises on Posture, Spinal and Chest Mobility among Female University Students Compared to Currently Popular Training Programs. *Int. J. Environ. Res. Public Health* **2022**, *19*, 3728. https://doi.org/10.3390/ijerph19063728

Academic Editors: Britton W. Brewer and Carmen Amezcua Prieto

Received: 6 February 2022
Accepted: 18 March 2022
Published: 21 March 2022

1. Introduction

A sedentary lifestyle is causing university students' physical health to decline worldwide [1]. The World Health Organization's (WHO) recommendation (2020) for healthy adults between 18–64 years of age is at least 2.5–5 h of moderate-intensity aerobic type physical activity or at least 75 min to 2.5 h of vigorous-intensity aerobic type physical activity weekly to prevent the consequences of sedentary behaviour [1]. According to WHO's definition, sedentary behaviour means any waking behaviour characterized by an energy expenditure of 1.5 METs or lower while sitting or lying (e.g., office work, driving, watching TV in leisure time, occupational or total time) and screen time means time spent watching screen-based entertainment in sitting or lying position [1].

A sedentary lifestyle is common in the general population of developed countries and even more so among university students. Based on a meta-analysis published by Castro et al. [2], university students spend 7.29 h per day sitting, based on self-reported data. The results suggest that higher levels of sedentary time are observed among university

students compared to young adults in general, and this ratio has increased over the last 10-year period [2]. Similarly, Lee E. et al. [3] found that among Korean university students the mean sitting time was 7.96 h per day, and it was also shown that their stress, anxiety and depression significantly worsened if sitting hours increased [3]. According to a study by Nikitara K. et al. [4], based on Eurobarometer 2017 data, approximately one-third (36.2%) of adults under 65 were physically inactive in 28 countries in Europe. Subjects with increased sedentary behaviour had higher risks for obesity, cardiovascular disease, diabetes, cancer, hypertension, osteoporosis and osteoarthritis, compared to those who sit less [4]. Moreover, sedentary behaviour prevalence in European adolescents has not changed for 15 years. Data from the Sport and Physical Activity EU Special Eurobarometer reveal that the prevalence of a sedentary lifestyle between 2005 and 2017 remains similar (74.2 to 76.8%; $p > 0.05$). A duration of 4 h and 30 min of sitting time was determined as sedentary behaviour [5].

Some of the consequences of sedentary behaviour are postural disturbances [6]. Functional imbalance in muscles chains, limited chest expansion and joint range of motion can be experienced due to long-term sitting periods and a sedentary lifestyle [6,7]. The physiological curves of the spine, tilting of the pelvis and joint axes could be influenced by sedentary behaviour [8,9]. The developed muscle imbalance, called upper and lower crossed syndrome, can determine the whole posture of the body, increasing and maintaining tight and weaken muscle conditions [9,10]. The abnormal curves can inhibit stabilization of the core muscle system, significantly reducing mobility of the chest, leading to decreased deep breathing [9,10]. The muscle imbalance can be a higher risk for functional musculoskeletal complaints, pain and indirectly lower cardiorespiratory exercise tolerance among young adults [4,7].

Targeted exercises might influence these postural muscle changes [8]. According to the literature, men and women may respond to loading similarly because the cellular mechanism that regulates the physiological and biomechanical answers to exercises are the same, but there are some specific aspects in female participants, e.g., the menses cycle, which can influence their performance. According to a study by Bakar et al. [11], although untrained men and women may respond similarly to weight training, there are significant differences in baseline conditions—flexibility and strength—between genders [11,12].

Functional postural disturbances could be corrected by target exercises [8]. Improved flexibility can increase movement efficiency and may decrease the risk for musculoskeletal injuries [10]. Improved chest expansion by the controlled stretching and strengthening breathing exercises may play a role in preventing respiratory problems and achieving a higher level of cardiorespiratory load ability [12,13].

Several studies have suggested that, due to relaxation techniques, slow and controlled movements combined with deep breathing, yoga and Pilates are effective in the treatment of sedentary behaviour-induced musculoskeletal complaints, stress level and anxiety [14]. Pilates is a complex motion which contains the anatomical knowledge of "West" and the movement culture of "East". The Pilates method, designed by Joseph H. Pilates, has 6 principles: strengthening and stabilising the centre of the human body, improving the breathing techniques, concentration, mind control, flowing the exercises into each other, and a slow and correct exercise performance [15,16]. Yoga is not solely a physical activity; it is a special philosophy of life containing traditional elements of Hinduism such as moral and ethical precepts [17]. It is a combination of physical, mental, and spiritual practices or disciplines from ancient India [18,19].

Several studies have examined the reliability and validity of the clinical tests which were used in our study, such as Schober' test [20,21], occiput-to-wall distance (OWD) test [22], fingertip-to-floor test [23,24], spinal side bending (lateral flexion) test [25,26] and measurement of chest mobility [27]. These studies suggested that these tests are able to provide reliable information about spinal and chest mobility. The benefits of these physical tests are that all of them can be used in all circumstances, can lead to results quickly, can be carried out easily, and are simple and cheap. The studies also indicated that the

results of these tests show a close correlation with results provided by medical devices, and assessments can be performed with minimal infrastructure and human resources [28,29].

Breathing exercises supervised by physiotherapists as an effective method of respiratory physiotherapy have high priority in the rehabilitation of pulmonary diseases and in the improvement of low loadability and limited mobility [30,31]. Nevertheless, there is not enough information available about the effectiveness of physiotherapeutic breathing techniques in the primary prevention of sedentary lifestyle-induced musculoskeletal and associated complaints.

The primary aim of this study was to evaluate the effectiveness of physiotherapeutic breathing exercises (BE) with regard to posture, range of motion of intervertebral joints and muscle flexibility in female university students compared to the effects of the reliable and popular yoga, Pilates and aerobic interval training as special motion programmes. Our secondary aim was to examine whether dynamic type aerobic exercises can compensate as effectively for sedentary behaviour-induced muscle imbalance and decreased flexibility as assessed by three slow motion programmes. Finally, we aimed to examine whether the ratio of sedentary behaviour in physiotherapy students is similar to relevant literature data.

We hypothesized that BE can deliver similar improvements in terms of postural deviations and muscle flexibility as the assessed yoga, Pilates and aerobic interval training programmes. On the other hand, in our opinion, therapeutic exercises carried out in a dynamic form are not so effective in improving flexibility. Finally, we also hypothesized that the ratio of sedentary lifestyle among university students in physiotherapy is less than among university students around the world in general.

2. Materials and Methods

2.1. Participants

In the present study, we examined full-time undergraduate female students at the Department of Physiotherapy, Faculty of Public Health, University of Debrecen (UD), who voluntarily participated after an online invitation and were randomly assigned to one of four short-term training programmes, the breathing exercise (BE) programme and three other programmes, yoga (Y), Pilates (P) and dynamic aerobic interval training (IT).

The participating students could not have any diagnosed spinal or other musculoskeletal problems, internal organ or cardio-respiratory diseases, including asthma. These exclusion criteria were assessed based on self-reporting before the intervention. Further exclusion criteria were any symptoms that might have influenced the results of the study, such as body mass index over 29.9 kg/m^2, abnormal fat mass around the area of thoracic and lumbar spine, pain or inflammation of joints and unstable standing capability due to pain. Participants could not participate in any of the training programmes known to and/or practised by them previously. Students with knowledge of breathing physiotherapeutic techniques could not participate in the targeted BE programme.

In order to exclude the influence of other training methods, the students were not allowed to take part in any other type of training during the assessed period. More than one absence resulted in that participant not being permitted to continue the programme. The students had to be willing, available and able to perform the assessments and tests at the specified time. Failure to participate in follow-up (participant did not complete a sufficient number of intervention training sessions or did not return for post-intervention testing) and lack of signature on informed consent resulted in exclusion from the study.

Providing elective subject credits was applied as motivation for participants in order to avoid absences, dropping out and achieve active conscientious participation of the students. In each group, a small number of participants were chosen because this is how motion programmes can be effectively executed. The chosen motion programmes required strict control by the instructors. The different techniques, positions and motions had to be corrected continuously in order to achieve the aimed development. We found that a physiotherapist and/or coach can work effectively with a maximum of 20 participants during training. All of the applied clinical tests were similar physical examination tests in

our study, and according to Wiyanad A. et al. [22], the sample size calculation indicated that the study required at least 14 participants in case of OWD test for a reliability study. According to the study of Perret C. et al. [24], because the fingertip-to-floor test has excellent validity, reliability, and responsiveness, it can be used in clinical practice and therapeutic trials. The author suggested that despite the small sample size (ten patients), this simple clinical measure is very closely related to X-ray measures. A priori sample size calculation was performed based on these relevant studies [22,24].

All of the physiotherapist students of all academic years of the Department of Physiotherapy (n = 280) were invited, each being sent an online invitation, and they could apply for the programme voluntarily. It was examined whether the inclusion criteria were fulfilled, and there were no exclusion criteria. The previously designed number of students in each programme was 20, but it was decreased in each group according to inclusion and exclusion criteria. Those students who were not eligible could not participate in the different motion programmes. The eligible students could be randomly selected in any further motion programmes which were neither known to nor practised by them previously. The motion programs were colour coded and the students were number coded. Numbers and colours were selected by a draw.

A total of 61 females (aged 20–22 years) participated in this study (Figure 1). The BE (n = 15) mean age 20.1 ± 0.99, Y (n = 16) mean age 20.4 ± 1.40 and P (n = 15) mean age 20.3 ± 1.20 groups had similar anthropometric mean values, there were no significant differences between them except for the IT group (n = 15) mean age 21.2 ± 1.21, which differed from the other groups in body mass index and body fat rate (Table 1).

Table 1. Anthropometric data of university students who participated in four different training programmes (mean ± SD).

Groups	Breathing Exercises (BE)	Yoga (Y)	Pilates (P)	Interval Training (IT)
Age (year)	20.1 ± 0.99	20.4 ± 1.40	20.3 ± 1.20	21.2± 1.21
Number of participants (female:male)	15:0	16:0	15:0	15:0
Body Mass Index (kg/m^2)	20.97 ± 2.51	21.35 ± 3.42	20.89 ± 2.29	24.49 ± 2.64
Body fat (%)	30.15 ± 5.05	29.66 ± 7.50	28.29 ± 5.93	34.31 ± 4.82

The four programmes were conducted simultaneously but on different days of the week. All assessments were carried out at the same time of day, before and after the training period. Body fat and BMI were calculated only before the intervention using the OMRON Body Fat Monitor BF306 type handle device. The individual data such as height, weight, gender and age of participant were set by the examiner in the device. The BMI and body fat were assessed in standing position keeping the device by the participant at shoulder level in front of the body during the calculation.

The number of sitting hours and the ratio of physical activity were calculated based on self-reporting, as in the literature [2], only before the intervention. The self-reported data collection was used by oral questioning in our study. The ratio of physical inactivity was determined based on those students who had not performed any sport activity at all in their spare time in the previous one-year period.

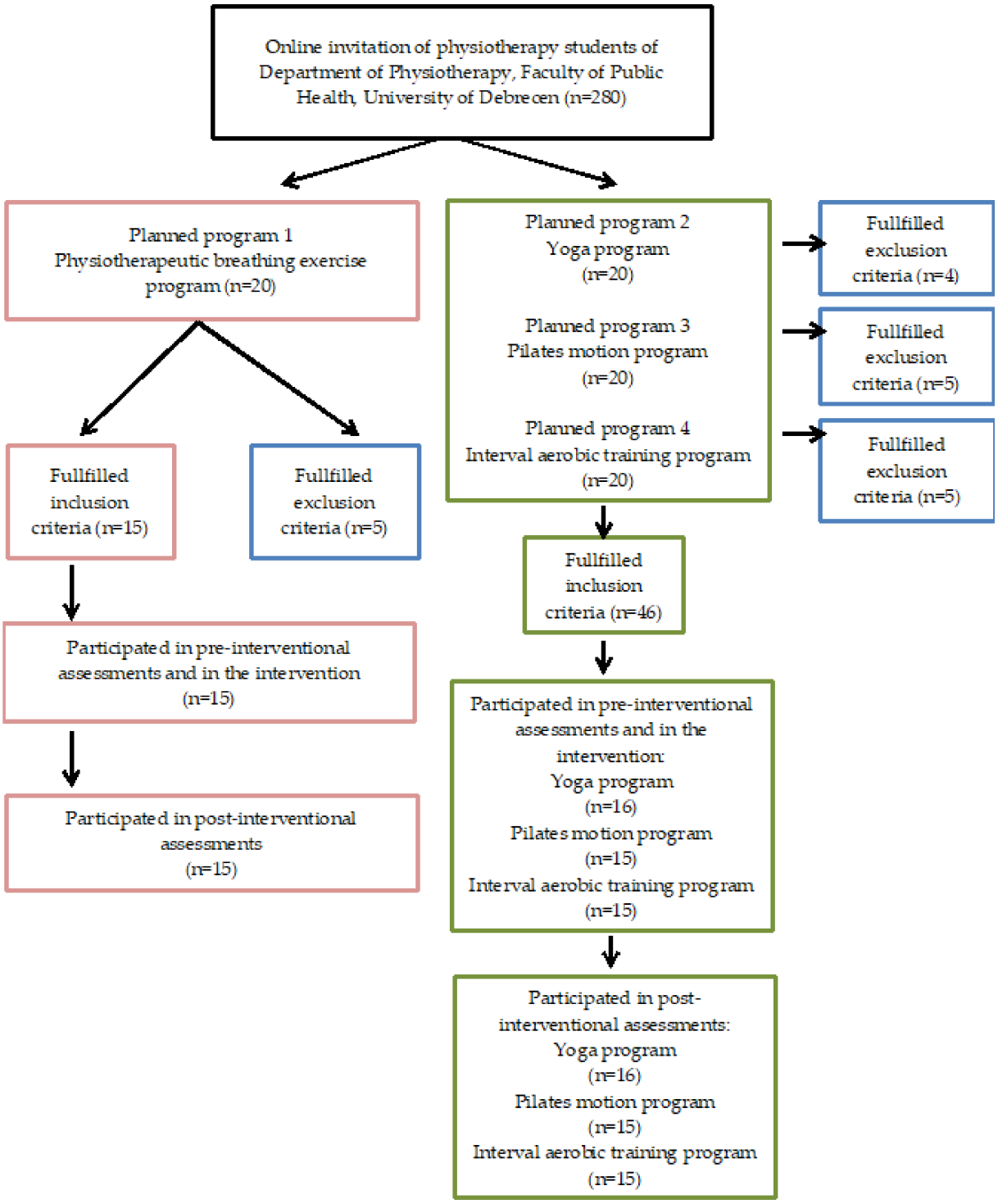

Figure 1. Flow diagram of subject selection process of the study.

2.2. Outcome Measures by Standardized Clinical Tests

The applied clinical tests aimed at providing information about posture, spinal and chest mobility before and after the training period. All tests were measured by the same experienced physiotherapist (first author), assisted by two further physiotherapists in controlling the measurements in order to avoid measurement errors.

2.2.1. Assessment of Chest Expansion

The participants were asked to be in standing position with their arms along their body. The participants being examined were asked to stand in a stable position while the circumference of their chest was measured at the level of the axilla as lower chest expansion shows a higher measurement error than the upper [27]. The tape was slowly encircled around the chest and the position was continuously under control during measuring to avoid measurement error. The participant was asked to inhale slowly through the nose and to expand the lungs as much as they could. In the second phase, they were asked to exhale the air completely through the mouth. The participant had to stay in apnoea for 2–3 s to allow for measurements by the examiner. The measurement was taken at the maximum point of exhalation and inhalation. The difference between the two rates was calculated. The assessment was repeated one more time and the better rate was used. The greater the mobility of the chest, the greater the difference. The average value of chest expansion for a healthy adult is over 3 cm [10,32].

2.2.2. Schober's Test

This test provides information about the range of motion of flexion of the lumbar spine. The participants were asked to stand in an upright position. After the palpation of posterior superior iliac spine on both sides, the level of spinous process of the S2 vertebra was marked and with a measuring tape a 10 cm distance upward was measured and also marked. In order to avoid measurement error, the participants were asked to bend forward slowly as far as they could with straight lower limbs without tilting their pelvis. The distance between the two marked points was measured again. We can obtain an estimate of lumbar spine flexion by calculating the difference between the rates of the two measurements. Normally the distance is 15–17 cm so lumbar flexion is 5–7 cm. If the rate is lower than normal, this can be a consequence of the decreased flexibility of the paravertebral muscles and limited range of motion of the intervertebral joints in the lumbar region [32,33].

2.2.3. Occiput-to-Wall Distance Test (OWD)

This test provides information about the posture of the participants by measuring the position of the head and neck to the trunk, a simple tool for screening and monitoring to determine the presence of thoracic hyperkyphosis [22]. The results are influenced by the rate of spinal curvatures in sagittal plane; thus, OWD is also affected by the rate of thoracic kyphosis and lumbar lordosis.

In an optimal situation the occiput touches the wall while the participants stand with their head in a neutral position. If it does not touch the wall, the distance between the wall and the occiput is measured. In order to avoid measurement error, the participants were under strict control while standing with their back against a vertical surface (wall), their heels and buttocks touching the wall in their normal standing position. The participants were standing with their head facing forward and their knees extended as much as possible. The distance between the occiput and the wall was measured by a tape. The measurement was repeated three times with a period of necessary resting. The best of the three measurements was used for the data analysis. A distance below 4–5 cm between the occiput and the wall is normal. Pre-positioned posture is defined as an OWD > 5.0 cm. If the distance is larger than normal, it can be a consequence of increased thoracic kyphosis or a head thrust forward which is due to increased lumbar lordosis. Decreased distance represents improvement of this parameter [34].

2.2.4. Fingertip-to-Floor Test

This test can be used to measure flexibility of the hamstring muscle group and mobility of the thoracic and lumbar spine. Participants were asked to bend forward as far as they could with their stretched and closed knees, and to try to touch the floor slowly under strict control to avoid measurement error. Optimally the participants were able to touch the floor with their middle fingers. If they could not, the distance between the tip of the

middle finger and the floor was assessed. Decreased distance means improvement of this parameter [32,33].

2.2.5. Trunk Side Bending (Lateral-Flexion) Test

The rate of trunk side bending, the harmony of motion and symmetry between both sides are measured using this test. For the assessment of trunk lateral flexion, the participants were asked to stand with their backs against a vertical surface (wall), heels and buttocks touching the wall. They were asked to slide down their hands along their thighs during bending to the left and then to the right side. In order to avoid measurement error, they were under strict control during measurement when they were asked to perform large trunk lateral flexion slowly but as much as they could to the right and then to the other side without rotating their trunk forward and elevating their heels from the floor on the opposite side during trunk lateral flexion and they had to keep their shoulders against the wall.

The distance between the tip of the middle finger and the floor was measured in lateral flexed position. There is no normal value. Decreased distance means improvement of this parameter. The test was taken on both sides. The difference between the rate of right and left side lateral flexion was also analysed. If it is larger than 2 cm, it may be due to functional deviations (e.g., quadratus lumborum muscle imbalance) or structural deformities (e.g., scoliosis) in the background [32,33].

2.2.6. Heart Rate Monitoring—Pulse Control

It was necessary to carry out pulse control only during the IT fitness training in order to keep the participants' heart rate in their own zone during the training. It was necessary to keep the pulse under control because the participants' endurance level was also improved due to the IT programme, but the results of improvement of endurance were not presented in this study. Load intensity can be determined individually and previously using modified Karvonen formula ((220 − age) − resting pulse) × targeted intensity (between 60–80%) + resting pulse) and can be controlled during the training through pulse control. Adequate "own-zone" loading (a safe individual exercise zone) and individually planned target heart rate training zone may be achieved due to the above methods. The rate of general thresholds can be changed individually. The participants measured their own pulse. The participants had previously been taught to carry out the measurement appropriately and the process was repeated and controlled before each training to avoid measurement errors, but this process is not as reliable as assessment by pulse watch. We should know that real heart frequency is slightly greater because the measured rate can be decreased during the 15 s assessment. We conducted a test to examine the reliability of HR monitoring estimated by students. The students performed 3 sets of submaximal exercises (burpees) at approximately 60%, 70% and 80% of HR max after a short warm up. The actual HR was checked only by the investigator (first author) using a Polar H10 chest-belt. Students counted their pulse for 15 s immediately after exercising at each intensity. The investigator registered the exact HR at the beginning and at the end of the 15 s period and calculated the estimated HR by multiplying the student's result by 4. Based on these data, intraclass correlation coefficient (ICC) was determined: the ICC(2,1) 0.8372 95%CI [0.7170–0.9082] indicated good reliability. According to this result the participants were instructed to measure their radial artery pulse for 15 s and multiply the result by 4. The participants had been informed about the subjective symptoms of overloading too, so that they could recognise in time [12].

2.3. Applied Training Programmes

2.3.1. Breathing Exercise (BE) Programme

A breathing exercise programme is a physiotherapeutic motion therapy in which respiratory muscle training, relaxation techniques, breathing techniques, e.g., deep breathing,

hand controlled abdominal/diaphragmatic breathing, aimed stretching and strengthening exercises are combined with each other [30,31].

The 5–10 min warm-up contained relaxation techniques, a muscle pump mechanism to improve venal and arterial circulation from distal to proximal, elongation with deep inhalation combined with relaxed exhalation and sough in order to reduce stress levels in the supine position.

The 35–40 min training phase contained special targeted exercises for stretching and strengthening the skeletal muscles of the trunk and extremities, as well as respiratory muscles in order to improve chest mobility, muscle strength and flexibility during trunk flexion, extension, lateral flexion and rotation. Deep breathing, controlled diaphragmatic breathing, slow relaxed exhalation with pursed lips technique, direct apnoea exercises for 2 or 3 s and segmental breathing techniques with hand control on chest and/or abdomen were used. Segmental breathing technique was used for the ventilation of the basic part of lung tissue with hand control. Active cyclic breathing technique was applied as a combination of the learned techniques: all phases of respiration were guided (deep inhalation, keeping the air in for 2 or 3 s, slow exhalation with pursed lips and having a deep sough at the end). Participants inhaled through their noses and exhaled through their mouths during breathing exercises. Exercises were performed slowly in different but predominantly lying or deep crawling positions. Vertical positions such as sitting or standing were only applied in 5–10% of the exercises. Supine position was used in approximately 50% of the exercises, in which stretching exercises during trunk lateral flexion and rotation were combined with respiration. Targeted strengthening for abdominal muscles was dictated in this position in order to support exhalation and strengthen inhalation. Physiotherapeutic bridge position was dictated from supine in order to strengthen the gluteus maximus muscle and stretch hip flexors especially the iliopsoas muscle by improving hip extension. Elevation of the lower limbs to our chest and knees to forehead during trunk and hip total flexion could stretch muscles on the lumbar spine especially erector spinae and quadratus lumborum fibres. The next side lying position was applied to strengthen hip abductors as synergist muscles of trunk lateral flexors. This position was used to support chest expansion and mobility during trunk rotation and lateral flexion also by stabilised pelvis and lower limbs. Prone position was used especially to ventilate the posterior basic parts of lung tissue, to stretch pectorals and strengthen the middle and lower fibres of the trapezius muscle. We could use this position to strengthen gluteus maximus directly as the synergist muscles of trunk extensors. The next positions were all fours and deep crawling positions in which full trunk expansion could be developed while stretching pectorals and lumbar extensors and strengthening thoracic extensors in order to achieve muscle balance in the shoulder girdle. Trunk rotation could be performed by using the upper limbs against stabilised pelvis and lower limbs. Anterior plank position was applied from all fours in order to isometric strengthen the core muscles.

Breathing exercises combined with relaxation and static stretching exercises were used during the 5–10 min of cool-down phase too in order to avoid muscle soreness and achieve calm condition in sitting position. Sitting or standing positions were used only at the end of the training for stretching during bending to toes with straight knees and improvement chest mobility during guided respiration combined with trunk lateral flexion and rotation.

The different positions could support ventilation of different parts of lung tissue and the effect of gravity on skeletal muscles was changed in various positions, which can influence the effects of the exercises. Quiet relaxing music was played during the exercises. The aims of the breathing exercises were to ventilate all parts of the lung tissue and consequently improve gas exchange by influencing thoracic-abdominal pressure due to abdominal breathing techniques and to stretch and strengthen the respiratory muscles [35,36].

Stretching exercises were used to teach participants to identify the feelings associated with tensed muscle and fully relaxed muscle and total resting condition. The physiotherapist focused on improving all types of trunk motions while the pelvis was stabilized in

order to have clearly separated movements and more efficient activation of the targeted muscles. The exercises were not demonstrated but all motions were dictated in detail by the physiotherapist and the incorrectly performed movements were corrected throughout the programme. The exercises were under strict continuous control by the physiotherapist by dictation and hand control if necessary, during the whole session. The programme was aimed at achieving a more effective breathing technique and improving spinal and chest expansion using the above special breathing techniques and dictation of all phases of inhalation and exhalation too. Easier exercises were dictated 3 or 4 times at the beginning. More difficult exercises were provided, and the repetition number was increased when the participants were stronger in order to achieve progressive improvement. The breathing exercise programme was supervised by an experienced physiotherapist.

2.3.2. Yoga (Y) Programme

Yoga involves special positions (poses) to strengthen the muscles and to maintain well-being; it is also a spiritual philosophy, with the guidance of the master, repetitions of mantras, the regulation of respiration, and meditation by relaxation making it a self-analysing way of life focused on perfecting one's self physically, mentally and spiritually [37]. The 5–10 min long warm-up was started in every session with relaxation techniques combined with elongation and deep respiration. This phase plays an important role in reducing muscle tone as well as achieving total physical and mental relaxation. The instructor placed greatest emphasis on strengthening and stretching the trunk muscles in order to improve the mobility of the spine in the 40–50 min of the training part. The exercises followed each other in accordance with the principle of gradation of difficulty and concentration. The exercises were demonstrated and corrected by the instructor during the exercises. The participants had to perform the movements in conjunction with breathing. The instructor introduced the students to different yoga positions in each session, thus making the lessons more difficult. The 5–10 minutes' cool-down phase contained relaxation in order to achieve calm condition in supine or sitting positions.

Yoga poses were performed slowly in 50% of cases in supine, prone and all fours and approximately in 50% in vertical positions during training. The achievement of the poses was guided step by step by the instructor and easier and more difficult alternatives were provided for participants. All phases of respiration were not dictated, in contrast to the BE programme. The participants were instructed to concentrate on their respiration in their own rhythm while keeping the achieved poses. The yoga training contained predominantly exercises for the mobilisation of the trunk and pelvis muscles in order to improve chest mobility, muscle strength and flexibility. Exercises to improve balance skill were also used by decreased supporting surface during the Y programme approximately in 5–10% in contrast with the BE programme. New and more difficult poses were dictated if the participants were stronger in order to achieve progressive improvement. The yoga programme was supervised by an experienced yoga instructor.

2.3.3. Pilates (P) Programme

Stretching and strengthening the trunk and pelvis muscles combined with respiration were in the focus during Pilates exercises. The 10–15 min warm-up contained relaxation techniques combined with stretching and deep inhalation on each session. This phase played an important role in reducing muscle tone and achieving a calm condition of participants.

The 30–40 min of the training part focused on aimed strengthening and stretching of trunk and hip muscles due to predominantly trunk flexion and extension and rotation in order to improve the mobility of the spine. The special Pilates exercises followed each other in accordance with the principle of gradation of difficulty and concentration [38]. The exercises were demonstrated and the incorrectly performed movements were corrected by the instructor during the exercises of the Pilates programme. The participants learned to perform the demonstrated movements in conjunction with breathing. The 10–15 min

cool-down phase contained relaxation combined with static stretching and a deep breathing technique in order to avoid muscle soreness and achieve a calm condition.

During the performance of the exercises the basic principles of the Pilates method were in the focus. Concentrating on inhalation and exhalation was combined with relaxation and targeted strengthening or stretching exercises but special breathing techniques such as active cyclic breathing technique or sniff breathing and pursed lips exhalation techniques, etc. were not applied. Overall, 60% of the exercises were performed slowly in supine, prone and all fours and approximately 40% in sitting or standing positions during training. To achieve progressive improvement, new and more difficult exercises were dictated when the participants were stronger. The Pilates programme was supervised by an experienced Pilates instructor.

2.3.4. Interval Training (IT) Program—Dynamic Aerobic Endurance Training

Interval training is dynamic special aerobic endurance training in which low- and high-intensity periods vary in a previously determined ratio [12]. In order to improve muscle oxidative and endurance capacity interval training (IT) is an established exercise method used in the rehabilitation of patients with chronic problems, in the primary prevention of a healthy population and also in the preparation of athletes [39].

The 10 min warm up contained dynamic stretching and aerobic type exercises in standing position in order to achieve required heart and respiratory frequency as preparation for the intensity of the work-out phase. The 35–40 min of the work-out phase was structured by low- and high-intensity periods varying in the ratio of 3:1 (6:2 min). The intensity was 65–70% of heart rate (HR) max during the active resting period in standing position and 75–80% of HR max during the high-intensity period, which was measured by the technique of pulse control. The rhythm of the music was between 133 and 136 bpm during this fitness training programme in order to keep intensity under control. In the active resting period, low-impact, low-intensity aerobic exercises were performed to improve the cardiovascular system using easy choreography in standing position. Low-impact but high-intensity exercises were carried out to improve strength—endurance in the high-intensity period. The resting period was performed together in one group while the high-intensity exercises were performed in small groups on stages. The exercises were demonstrated and the incorrectly performed movements were corrected orally by the instructor during the exercises. Similar kinds of aimed strengthening exercises were performed for the muscles of the anterior, posterior, lateral and spiral muscle chains of the shoulder girdle, trunk and pelvis girdle in the same lying and crawling positions as the ones used during the BE programme, but especially dynamically in the high-intensity periods. The 10–15 min cool-down phase contained relaxation techniques combined with static stretching and deep inhalation on every occasion in order to reduce muscle tone, avoid muscle soreness and achieve a calm condition of the participants in standing position. Approximately 30% of the exercises were performed dynamically in supine, prone and crawling positions and approximately 70% in standing position without guided respiration and dictated breathing techniques during training. More difficult exercises were dictated and the ratio between the low- and high-intensity periods was changed (2:1; 1:1) if the participants were stronger, in order to achieve progressive improvement. The IT programme was supervised by an experienced fitness instructor.

The four training programmes were performed twice a week, one hour per occasion, for 7 weeks. No other programme was provided for them that would use breath control, in order to exclude its influence.

2.4. Statistical Analysis

The baseline measurements' data are presented as mean ± SD. The standardized clinical tests' data are presented as medians and interquartile ranges (IQR). The Shapiro–Wilk test was used to check the normality of the continuous variables. Since most of the data did not follow normal distributions, non-parametric Wilcoxon signed-rank test was used to

compare medians. The Spearman's correlation analysis was used in order to investigate the correlation between the variables related to the physical examination. The degree of difference between the four groups' baseline condition was determined by Kruskal–Wallis ANOVA. Dunn's post hoc test was carried out for pairwise comparison of baseline and final pairwise differences. The results were considered as significant if the p-value was below 0.05. The data were processed using Microsoft Excel and the statistical analysis of the data and calculation were made using the Intercooled Stata v13 programme [40].

2.5. Sample Size Calculation

A priori sample size calculation was performed with a power level of 80% and an α level of 0.05 based on relevant studies. [22,24] An online invitation was launched among all physiotherapist students in order to recruit the appropriate number of participants. Refusals, exclusions and group size (to ensure proper attention) were also taken into consideration.

2.6. Ethics

Informed consent was obtained from all volunteering participants according to the Declaration of Helsinki [41]. This study was approved by the Institutional and Regional Ethics Committee of University of Debrecen (registration number: 4598-2016).

3. Results

3.1. Description of the Participants

The previously designed number of students in each programme was 20, but it was decreased in each group according to inclusion and exclusion criteria. More than accepted numbers of absences and dropouts were not observed during the motion programmes.

The BE, Y, and P groups had similar anthropometric mean values, and there were no significant differences between them. The IT group differed from the other groups in body mass index (BMI) (ANOVA test (p = 0.001), and body fat rate (ANOVA test (p = 0.044), but all fell into the "Normal" category (18.5–24.9 kg/m^2) based on the mean value of BMI, and three groups were categorized into the "Healthy" (21–33%) but the IT group was categorized into the "Overfat" category (34–39%) based on the mean body fat content (Table 1). The students were from all academic years.

The number of sitting hours can be presented based on self-reporting (n = 61). According to the answers, the total of sedentary hours was 2 or 3 h per day in the case of 14.7% of students, 4–6 h per day in the case of 36.1% of students, and 7 h or more in the case of 49.2%.

The physically inactive students accounted for 48.9% of the assessed 61 students. The other 51.1% had different regularity of physical activity: 36.2% of them reported regular weekly sport activity and 14.9% reported only casual physical activity.

3.2. Chest Expansion Results

With respect to chest expansion, statistically significant improvements were observed in all training programmes (BE ($p \leq 0.001$), Y (p = 0.003), P (p = 0.002), IT (p = 0.021) (Table 2). Chest expansion improved in 14 participants (93%) in the BE group, in 14 participants (88%) in the Y group, in 12 participants (80%) in the P group and in 9 participants (60%) in the IT group. Stagnation could be observed only in 8 participants (BE: 1 participant; Y: 2 participants; P: 3 participants; IT: 2 participants). Relapse was observed in 6 persons (Y: 1 participant; P: 1 participant; IT: 4 participants). There was no relapse in the BE group.

Table 2. Results of the chest expansion (cm) of the four groups (target BE programme and three other programmes: yoga, Pilates and dynamic interval training) before and after the training period. The students participated voluntarily in and were randomly assigned to training programmes. The duration of each training session was one hour, twice a week for 7 weeks.

Chest Expansion—Axillar Level (cm)							
	before			after			
	Q1	Median	Q3	Q1	Median	Q3	*p*-Value
Breathing exercises (BE) (*n* = 15)	3.5	4.5 (min 3.0; max 7.0)	5.0	6.0	7.0 (min 6.0; max 8.0)	8.0	≤0.001
Yoga (Y) (*n* = 16)	4.0	5.0 (min 3.0; max 10.0)	6.0	6.0	7.5 (min 4.0; max 9.0)	8.0	≤0.01
Pilates (P) (*n* = 15)	4.0	5.0 (min 2.0; max 9.0)	8.0	5.0	6.0 (min 4.0; max 10.0)	9.0	≤0.01
Interval training (IT) (*n* = 15)	5.0	6.0 (min 4.0; max 8.0)	7.0	5.0	7.0 (min 4.0; max 10.0)	8.0	<0.05

Median ([IQR] (min; max) *p* value. (IQR describes the middle 50% of values when ordered from lowest to highest. Q1 is the "middle" value in the first half of the rank-ordered data set (25%) and Q3 is the "middle" value in the second half of the rank-ordered data set (75%)).

3.3. Schober's Test Results

Statistically significant improvements were achieved in three groups, but no significant development was seen in the IT group (BE ($p \leq 0.05$), Y ($p = 0.002$), P ($p = 0.003$), IT ($p = 0.271$) (Table 3).

Table 3. Results of the Schober's test (cm) of the four groups (target BE programme and three other programmes: yoga, Pilates and dynamic interval training) before and after the training period. The students participated voluntarily in and were randomly assigned to training programmes. The duration of each training session was one hour, twice a week for 7 weeks.

Schober's Test (cm)							
	before			after			
	Q1	Median	Q3	Q1	Median	Q3	*p*-Value
Breathing exercises (BE) (*n* = 15)	4.5	5.0 (min 4.0; max 6.5)	6.0	5.0	5.5 (min 5.0; max 6.5)	6.0	<0.05
Yoga (Y) (*n* = 16)	3.0	4.0 (min 2.0; max 7.0)	6.0	5.0	6.0 (min 3.0; max 7.0)	7.0	≤0.01
Pilates (P) (*n* = 15)	4.0	5.0 (min 3.0; max 7.0)	6.0	6.0	6.0 (min 3.0; max 7.0)	7.0	≤0.01
Interval training (IT) (*n* = 15)	4.5	5.5 (min 3.0; max 7.0)	6.0	5.0	5.5 (min 4.0; max 8.0)	6.0	0.271

Median ([IQR] (min; max) *p* value. (IQR describes the middle 50% of values when ordered from lowest to highest. Q1 is the "middle" value in the first half of the rank-ordered data set (25%) and Q3 is the "middle" value in the second half of the rank-ordered data set (75%)).

3.4. Occiput-to-Wall Distance Test Results

Decreased rate represents an improvement in OWD. Statistically significant improvements were observed in three groups, but no significant development was seen in the IT group: BE ($p \leq 0.001$), Y ($p = 0.003$), P ($p = 0.003$), IT ($p = 0.917$) (Table 4).

Table 4. Results of the occiput-to-wall distance (OWD) test (cm) of the four groups (target BE programme and three other programmes: yoga, Pilates and dynamic interval training) before and after the training period. The students participated voluntarily in and were randomly assigned to training programmes. The duration of each training session was one hour, twice a week for 7 weeks.

Occiput-to-Wall Distance Test (cm)							
	before			after			
	Q1	Median	Q3	Q1	Median	Q3	*p*-Value
Breathing exercises (BE) (*n* = 15)	3.5	4.0 (min 3.0; max 5.0)	4.5	1.0	2.0 (min 1.0; max 3.0)	2.0	≤0.001
Yoga (Y) (*n* = 16)	1.0	3.0 (min 0.0; max 9.0)	4.5	0.0	0.0 (min 0.0; max 8.0)	0.0	≤0.01
Pilates (P) (*n* = 15)	0.0	2.0 (min 0.0; max 10.0)	5.0	0.0	0.0 (min 0.0; max 4.0)	0.0	≤0.01
Interval training (IT) (*n* = 15)	0.0	1.5 (min 0.0; max 4.5)	3.0	0.0	1.5 (min 0.0; max 6.0)	2.0	0.917

Median ([IQR] (min; max) *p* value. (IQR describes the middle 50% of values when ordered from lowest to highest. Q1 is the "middle" value in the first half of the rank-ordered data set (25%) and Q3 is the "middle" value in the second half of the rank-ordered data set (75%)). Decreased rates reflect improvement.

3.5. Fingertip-to-Floor Test Results

Statistically significant improvements were observed in two groups (Y ($p \leq 0.05$), P ($p < 0.01$). The rates were similar in BE group ($p = 0.056$) but did not change significantly. Relapse was observed only in the IT group (Table 5).

Table 5. Results of the fingertip-to-floor test (cm) of the four groups (target BE programme and three other programmes: yoga, Pilates and dynamic interval training) before and after the training period. The students participated voluntarily in and were randomly assigned to training programmes. The duration of each training session was one hour, twice a week for 7 weeks.

Fingertip-to-Floor Test (cm)							
	before			after			
	Q1	Median	Q3	Q1	Median	Q3	*p*-Value
Breathing exercises (BE) (*n* = 15)	0.0	0.0 (min 0.0; max 22.5)	5.0	0.0	0.0 (min 0.0; max 10.0)	0.0	0.056
Yoga (Y) (*n* = 16)	0.0	0.0 (min 0.0; max 23.0)	5.0	0.0	0.0 (min 0.0; max 16.0)	0.0	<0.05
Pilates (P) (*n* = 15)	0.0	1.0 (min 0.0; max 21.0)	4.0	0.0	0.0 (min 0.0; max 9.0)	0.0	<0.01
Interval training (IT) (*n* = 15)	0.0	0.0 (min 0.0; max 3.0)	0.0	0.0	0.0 (min 0.0; max 6.0)	0.0	-

Median ([IQR] (min; max) *p* value. (IQR describes the middle 50% of values when ordered from lowest to highest. Q1 is the "middle" value in the first half of the rank-ordered data set (25%) and Q3 is the "middle" value in the second half of the rank-ordered data set (75%)). Decreased rates reflect improvement.

3.6. Trunk Side Bending (Lateral Flexion) Test Results

Decreased rate represents an improvement in this parameter. The difference was not greater than 2 cm between the mean rates on both sides in all groups during the assessment of side asymmetry.

When lateral flexion towards the right side was assessed, statistically significant changes were found in two groups (BE ($p = 0.001$), IT ($p = 0.014$). The rate of improvement was not significant in the Y and P groups (Table 6).

With respect to lateral flexion to the left side, statistically significant improvements were achieved in three groups (BE ($p = 0.001$), IT ($p = 0.019$), P ($p = 0.031$). The rate of improvement was not significant in the Y group (Table 7).

Table 6. Results of the trunk side bending (lateral flexion) test (cm) to the right side of the four groups (target BE programme and three other programmes: yoga, Pilates and dynamic interval training) before and after the training period. The students participated voluntarily in and were randomly assigned to training programmes. The duration of each training session was one hour, twice a week for 7 weeks.

Trunk Side Bending (Lateral Flexion) to RIGHT Side (cm)							
	before			after			
	Q1	Median	Q3	Q1	Median	Q3	*p*-Value
Breathing exercises (BE) (*n* = 15)	40.0	42.0 (min 33.0; max 46.0)	44.0	35.0	39.0 (min 28.0; max 42.0)	40.0	≤0.001
Yoga (Y) (*n* = 16)	41.5	42.5 (min 39.0; max 52.0)	46.5	39.5	42.0 (min 35.0; max 49.0)	46.0	0.254
Pilates (P) (*n* = 15)	39.0	41.0 (min 35.0; max 48.0)	46.0	36.0	39.0 (min 35.0; max 48.0)	45.0	0.136
Interval training (IT) (*n* = 15)	41.0	45.5 (min 36.5; max 51.5)	47.0	38.0	43.0 (min 34.0; max 48.0)	45.0	≤0.01

Table 7. Results of the trunk side bending (lateral flexion) test (cm) to the left side in the four groups (target BE programme and three other programmes: yoga, Pilates and dynamic interval training) before and after the training period. The students participated voluntarily in and were randomly assigned to training programmes. The duration of each training session was one hour, twice a week for 7 weeks.

Trunk Side Bending (Lateral Flexion) to LEFT Side (cm)							
	before			after			
	Q1	Median	Q3	Q1	Median	Q3	*p*-Value
Breathing exercises (BE) (*n* = 15)	40.0	42.5 (min 30.5; max 48.0)	45.0	37.0	40.0 (min 29.0; max 43.0)	41.0	≤0.001
Yoga (Y) (*n* = 16)	40.5	44.0 (min 37.0; max 49.0)	46.5	39.0	42.5 (min 28.0; max 48.0)	45.0	0.156
Pilates (P) (*n* = 15)	40.0	42.0 (min 35.0; max 49.0)	46.0	37.0	40.0 (min 34.0; max 49.0)	45.0	<0.05
Interval training (IT) (*n* = 15)	42.0	45.0 (min 37.0; max 53.0)	49.0	38.5	42.5 (min 36.0; max 48.5)	47.0	<0.05

Median ([IQR] (min; max) *p* value. (IQR describes the middle 50% of values when ordered from lowest to highest. Q1 is the "middle" value in the first half of the rank-ordered data set (25%) and Q3 is the "middle" value in the second half of the rank-ordered data set (75%)). Decreased rates reflect improvement.

3.7. Results of Kruskal–Wallis ANOVA and Dunn's Post Hoc Tests

The degree of difference between the four groups' baseline condition was determined by Kruskal–Wallis ANOVA test and Dunn's post hoc test was carried out for pairwise comparisons (Table 8).

There was no significant difference between the four groups in the baseline condition of chest expansion before the training programmes ($p = 0.137$) and it remained unchanged as a result of programmes ($p = 0.805$) after the training period.

There was no significant difference between the four groups in the baseline condition of Schober's test before the training programmes ($p = 0.358$) and the difference was borderline significant between the four groups ($p = 0.050$) after the training period.

There was a significant difference between the four groups in the baseline condition of OWD test before training program ($p = 0.009$), but this was the result of the significant difference between BE and IT programmes ($p = 0.004$). The difference was significant too between the four groups ($p = 0.001$) after the training period.

There was no significant difference between the four groups in the baseline condition of fingertip-to-floor test before the training programme ($p = 0.079$) and the difference was not significant between the four groups ($p = 0.947$) after the training period.

Table 8. Baseline and final pairwise differences among the four motion programmes based on Dunn's post hoc test.

Physical Examination Tests	Compared Programs	*p* Value
Occiput-to-wall distance test before the intervention	Breathing-Interval	0.004
Occiput-to-wall distance test after the intervention	Breathing-Pilates	0.002
Occiput-to-wall distance test after the intervention	Breathing-Yoga	0.004
Occiput-to-wall distance test after the intervention	Interval-Pilates	0.038
Occiput-to-wall distance test after the intervention	Interval-Yoga	0.036
Side bending to the right after the intervention	Breathing-Interval	0.028
Side bending to the right after the intervention	Breathing-Yoga	0.030

There was no significant difference between the four groups in the baseline condition of trunk side bending (lateral flexion) to the right test before the training programme ($p = 0.105$) but it was changed due to the program because a significant difference was calculated ($p = 0.019$), after the training period.

There was no significant difference between the four groups in the baseline condition of trunk side bending (lateral flexion) to the left test before the training programme ($p = 0.343$) and the difference was not significant between the four groups ($p = 0.091$) after the training period on the left side.

3.8. Results of Differences between the before and after Values Related to the Four Motion Programs

Significant differences were observed between the before and after values related to the motion programs according to calculation by Wilcoxon signed-rank test (Table 9).

Table 9. Differences between the before and after values related to the four motion programmes based on Wilcoxon signed-rank test.

	BEFORE (Median [IQR])	AFTER (Median [IQR])	*p* Value
Schober test	5 (4–6)	6 (5–6)	<0.001
Occiput-to-wall distance test	3 (1–4)	1 (0–2)	<0.001
Fingertip-to-floor test	0 (0–1)	0 (0–0)	0.001
Side bending (lateral flexion) to the right	42 (40–46)	40 (38–44)	<0.001
Side bending (lateral flexion) to the left	44 (40–46.5)	41 (38–44)	<0.001
Chest expansion	5 (4–6)	7 (6–8)	<0.001

Median ([IQR] *p* value. (IQR describes the middle 50% of values when ordered from lowest to highest. Q1 is the "middle" value in the first half of the rank-ordered data set (25%) and Q3 is the "middle" value in the second half of the rank-ordered data set (75%)).

3.9. The Spearman's Correlation Analysis Results

The Spearman's correlation analysis was used in order to investigate the relation between the variables related to the physical examination. Three significant relations were found:

The results of Spearman's rank-order correlation showed a small, negative but significant relation between the results of Schober's test and the occiput-to-wall distance test (rho = −0.2716; $p = 0.002$).

The results of Spearman's rank-order correlation showed a small, negative but significant relation between the results of fingertip-to-floor test and the chest expansion (rho = −0.1915; $p = 0.035$).

The results of Spearman's rank-order correlation showed a small, positive but significant relation between the results of fingertip-to-floor test and the occiput-to-wall distance test (rho = 0.3696; $p < 0.001$).

4. Discussion

Results suggest that BE may be an effective alternative therapy to improve posture, flexibility, strength and consequently balance of the skeletal muscles and range of motion of the intervertebral joints in healthy young adults because significant changes were achieved by BE in most assessed parameters.

Results measured before and after the interventions by clinical tests can be presented only based on assessment of the women in our study. In order to avoid influencing the outcomes and have reliable results homogenous female groups were assessed and compared to each other in our study because of the difference between genders in strength and flexibility [11,12].

It is known that a sedentary lifestyle and its negative physiological effects are civilizational hazards in developed countries, and it has been recently revealed that this physical inactivity results in shoulder, middle and lower back pain and depression, especially among women with an average sitting time longer than 4 h per day [3,4]. Sedentary behaviour is common in university students, which may be responsible for musculoskeletal complaints [1,2]. According to our results, the physically inactive students accounted for 48.9% of the 61 assessed students. Total sedentary hours were reported as 4–6 h per day in case of 36.1% of students and as 7 h or more in the case of 49.2% in our study. According to these results our third hypothesis was not confirmed because the ratio of a sedentary lifestyle was similar in the assessed students of physiotherapy to the university students around the world in general.

Czakwari et al. assessed [6] spinal abnormalities among students of the Medical University of Silesia (54 female, aged 20–28, and 46 male, aged 20–29) using modified Klapp protocol. Postural faults were widespread in the assessed group. The most common of these deformities were lumbar hypolordosis (71.0–48.1% female and 97.8% male) and thoracic hyperkyphosis (58.0–53.7% female and 63.0% male), and the prevalence of less frequent scoliosis was higher than 50% (50% female and 58.7% male). Physical activity in the assessed group was high (71–76% female and 62.5% male). The level of activity in men was significantly higher than in women ($p < 0.05$). The authors concluded that there was no correlation between levels of physical activity and postural faults according to their results. These findings partially agree with our results as well. Our findings showed that physical inactivity was widespread in our assessed group too. The ratio of physically active students in our assessed group was lower (51.1%) and if regularity is calculated, this number is even lower because 36.2% reported regular weekly sport activity.

We would like to draw attention to the fact that it is necessary to increase the number of those students who have regular physical activity, and the level of regular physical activity level should be improved by different, compulsory registered training programmes providing subject credits to university students in order to achieve and/or maintain better musculoskeletal condition among them. Providing elective subject credits was used to motivate participants in order to avoid absences and dropout and to achieve the active conscientious participation of students. In our opinion, this motivation factor played an important role, in that more than accepted numbers of absences and dropout were not observed during the motion programmes.

Our present study also proved that the flexibility of the examined female university students measured by the special tests is low. The results of the Schober's and finger-tip-to-floor tests suggested that approximately 30% of students had limited range of flexion of the lumbar spine, and more than half of them had complex postural abnormalities reflected by an occiput-to-wall distance larger than 4 cm. Besides the postural and flexibility problems of the spine in the sagittal plain, the difference between the rate of right and left side lateral flexion in 23% of participants was larger than 2 cm, due to functional deviations or structural deformities in frontal plain. These results are in harmony with the ratio of sedentary hours and physical activity among assessed physiotherapist students. The larger ratio of muscular postural problems and limited joint mobility is a consequence of the larger ratio of sedentary hours and the physical inactivity.

The correlation analysis shows the relation between the tests' results and can confirm the effectiveness of a provided motion program. The analysis was provided based on the studies of Viitanen et al. [42] and Heuft et al. [34]. According to our results of Schober's test increase, those of the OWD test decreased (which means that both results show improvement). This analysis can show that if we improve the Schober's test result, we can

achieve an improvement in the rate of the occiput-to-wall distance test. If we improve the mobility of the lumbar spine, we can achieve a more optimal rate of cervical lordosis and a more physiological posture, according to the OWD test. The positive significant relation between the results of fingertip-to-floor test and the occiput-to-wall distance test are in harmony with the previous correlation too, because the decreased rates reflect improvement in both tests and the fingertip-to-floor test is carried out with trunk flexion too similarly to Schober's test. The small, negative significant relation between the results of fingertip-to-floor test and the chest expansion can be logical too because if the results of fingertip-to-floor test decrease, those of the chest expansion increase (which means that both results show improving). The elongation of thoracic spine during touch the floor with fingertips can be the explanation. The results can be more reliable based on the harmony relation between the applied tests. Our results suggest that the used tests can confirm each other during assessment of posture and spinal mobility [34,42].

Our results suggest that specific targeted exercises are necessary to compensate for the effects of a sedentary lifestyle. Regular but not well-structured training programmes are not sufficient for correction, so we supposed that the quality of the training plays as important a role as quantity in the correction and/or maintenance of mobility and muscle balance.

The BE had surprisingly good results. The most significant improvement was achieved in chest expansion and trunk lateral flexion, while the Y programme did not result in a significant improvement in the side bending (lateral flexion) test. A significant improvement was achieved as a result of BE in Schober's and OWD test, in contrast with the IT training, while the fingertip-to-floor test showed relapse in the IT group. These results may be explained by the structure of the training and the effects of direct and indirect effect-mechanisms of the special breathing techniques. BE were performed in different positions, in order to improve trunk and chest mobility. We dictated a number of aimed stretching and strengthening exercises for intercostal muscles, segmental breathing at the basis of the lung tissue by trunk lateral flexion and rotation on all fours and deep crawling positions. The trunk flexion was the least used motion type during BE training. This factor must account for the results of the Schober's and finger-tip-to floor tests.

Stretching exercises for the diaphragm muscle were dictated in those kinds of positions when exhalation is performed by cut-off or help of gravity force, as in all fours, deep crawling or bridge positions. Inhalation can be dictated in all fours position and exhalation in deep crawling position if the aim is the facilitation of exhalation and stretching of the diaphragm muscle. We can use these positions the other way round too, and inhalation is dictated in deep crawling and exhalation on all fours if strengthening of the diaphragm is our aim. The all fours position is the easiest for the diaphragm muscle during respiration. The deep crawling positions are so effective for posture correction because they may positively affect the strength and flexibility of the respiratory and paravertebral muscles and consequently the spinal curves and shoulder girdle. Static isometric exercise was dictated in anterior plank position to activate the serratus muscle and deep core muscles in order to improve their stabiliser functions around the scapulo-thoracic functional attachment and spine.

The exercises of BE were chosen based on the sedentary behaviour-induced postural disturbances [6]. The changed vectors of the muscles can cause limited capability to keep optimal spinal curves against external axial compression forces [10]. The line of gravity is shifted anteriorly because of the forward tilted position of the pelvis and induces larger spinal curves due to a sedentary lifestyle [9]. Flexion is induced in the hip, extension in the knee and plantar flexion in the ankle joint occur [10]. Increased tone, limited function and weakness develop mainly in the quadratus lumborum muscle, in the paravertebral muscle fibres as in the erector spinae muscle on the lumbar spine, in the tight hamstring and iliopsoas muscle fibres [9,10]. The stabiliser cross synergist relation in sagittal plane is weakened between the lower fibres of the rectus abdominis muscle and the gluteus maximus because of their weakness and elongated condition [9]. Forward headed position occurs because of the elevated tone, especially of the upper trapezius, sternocleidomastoid, scalenes, levator

scapulae and suboccipital muscles, and also pectorals, against the elongated and weak middle and lower trapezius fibres and paravertebral muscles on the thoracic spine [9,10]. Posterior tilted pelvis position can also develop, in which case the sagittal spinal curves are decreased and a more rigid structure develops [10]. Overloading occurs on tonic type muscles but decreased cross-sectional size (atrophy) can be experienced on phasic type muscles [9]. The abnormal curves cause an inhibited stabilizer function of the transversal abdominis muscle and deep spinal segmental stabilizers as of the multifidus and rotatores muscles [10]. Larger shear forces can be performed especially in the cervicothoracic and thoracolumbar regions, contributing to disc degeneration process [9,10]. The correction of muscle imbalance is in the focus during posture correction. Muscle imbalance can be influenced effectively by activating the spiral and lateral muscle chains due to applied trunk rotation and lateral flexion based on our results too. The thoracic spinal curve and chest expansion can be treated positively by activating of the thoracic extensors. Activation of the longus colli muscle is a key to the achievement of optimal cervical spinal curve. Balance around the lumbo-pelvic-hip complex can be supported positively by activating the sagittal cross synergism between the trunk flexors and hip extensors [9,10].

According to our results the positive effects of Pilates [15,16] and yoga [17,18] programmes were confirmed in accordance with the literature. Significant changes were observed in all clinical tests due to these programmes except for the lateral flexion. Exercises for improving trunk flexion, extension and rotation were more dominant during the Y and P programmes, but the scale of lateral flexion grew especially during the BE and IT programme. Physiotherapeutic breathing techniques and all phases of respiration were guided only during the BE programme.

Our results seem to confirm our secondary hypothesis. The IT programme is an effective and reliable training method primarily to improve endurance level because of various intensity dynamic exercises [12,39]. The IT training method was used because we wanted to find out whether these dynamic type trainings can compensate as effectively for sedentary behaviour-induced postural deviations as slow, controlled motion programmes. Stretching and relaxation techniques played an important role in all programmes, but in the IT programme there were fewer exercises of this type. Dynamic stretching was used during warm-up and static type during cool-down phase only. The varied results of the IT group were probably due to aimed strengthening exercises performed dynamically. According to our results the flexibility and range of motion of the joints can be improved more effectively by slow and controlled exercises than by dynamic exercises. The ANOVA test showed a significant difference between the baseline conditions in the OWD test because of the IT group, in which the median and IQR were much better than in the other groups before the programme but did not change significantly due to the exercises. The baseline condition was more homogenous in the finger-tip-to-floor test in the IT group than in the other groups, but a relapse of results was observed as a result of the programme. The IT group differed from the other groups in body mass index (BMI) and body fat rate according to the ANOVA test, which could also affect the results. The outcomes may be influenced by the previous differences between the baseline conditions, but our results suggest that exercises to improve postural problems, and correct muscle imbalance should be performed slowly under strict control by an instructor. Effective postural control and improvement in muscle flexibility cannot be achieved by exercises performed dynamically.

Other postural training interventions have also been assessed. Celenay et al. [43] examined the effects of different methods on spinal posture and mobility such as electrical stimulation, exercises, biofeedback posture trainer and postural education. They found that the exercises were more effective in terms of improving thoracic and lumbar curves, and mobility among university students. Other methods had limited effects, electrical stimulation decreased thoracic curve, while sitting posture was improved by a biofeedback posture trainer. These results suggest that exercises provided by real activation of participants' own muscle power are more effective in improving mobility than device-assisted motions.

Our BE therapy, supervised by a physiotherapist consisted of special, slow stretching exercises to improve the flexibility of skeletal, especially respiratory, muscles and chest mobility and involved targeted strengthening combined with voluntary apnoea exercises, deep, segmental and controlled abdominal (diaphragmatic) breathing techniques with hand control and relaxation, through which directly and indirectly functional postural deformities may be corrected more effectively along with the correction of muscular imbalance. The results of this study, similarly to some previous studies, suggest that special structured, short-time training programmes, including targeted exercises, may be effective in improving chest expansion, flexibility of muscles and ROM of joint, because even with a relatively small amount of time, we can do a great deal to prevent our health by using appropriate techniques [35,36].

While different fitness training programmes, Pilates and yoga are essentially preventive movement programmes that assume physiological body structure; however, physiotherapeutic breathing techniques do not assume this (musculoskeletal system, cardiovascular and respiratory system) [30,31].

Our results confirmed our primary hypothesis. Based on our results, the breathing exercise programme, which is a targeted physiotherapist-specific motion therapy and can be used both in the secondary and tertiary prevention of patients, can be used in the primary prevention of sedentary behaviour-induced postural problems and decreased muscle flexibility too to prevent further musculoskeletal complaints and consequences in healthy young adults such as university students. According to the literature, targeted breathing exercises can play an important role in the prevention and rehabilitation of cardiorespiratory diseases especially pulmonary consequences but the targeted breathing exercise programme can not only support the recovery of patients but can also provide further development for healthy adults [44,45].

We recommend the incorporation into our daily routine of 3–5 easily performed exercises such as elongation combined with breathing exercises with trunk flexion, extension, lateral flexion and rotation in standing position during the day, and/or performance of 10–15 min stretching exercises combined with breathing techniques for the improvement of spinal flexibility and chest mobility on non-weight bearing positions at the beginning and/or at the end of the day.

In our opinion, it is also advisable to combine postural exercises with endurance training weekly in order to achieve the most effective prevention of sedentary behaviour-induced consequences [46].

5. Conclusions

The results show that a targeted and specially structured breathing exercise programme supervised by a physiotherapist, with slow and controlled movements, is an effective motion programme to improve posture, muscle balance, spinal and chest mobility, due to direct and indirect effect-mechanisms in healthy young female adults, in comparison with yoga and Pilates motion programmes.

Our study suggests that a breathing exercise programme can be safely used as an adjunct exercise programme not only for patients, as it may have primary preventive positive effects on the posture, flexibility and strength of healthy adults too. Physiotherapeutic breathing techniques combined with targeted stretching and strengthening exercises can be used by everyone, not only in rehabilitation but also in primary prevention as part of cross-training.

6. Limitations

The limitations of this study were the small number of assessed participants, limited sufficient time for the motion programs and physical examinations. The participants were randomly assigned to the motion programs, but the process of participant allocation was complex. A further limitation of this study was the lack of possibility to provide measurements by valid medical devices as, e.g., spirometer and radiography or spinal

mouse device. Further randomized controlled trials are recommended, to gain a deeper understanding of the effects of such an intervention.

Author Contributions: É.C.: conceptualisation, methodology, data curation, investigation, intervention, formal analysis, project administration, writing—original draft. Z.G.: conceptualisation, methodology. I.V.-B.: conceptualisation, methodology. A.C.N.: statistical analysis, review and editing. Z.S.: writing—review and editing. S.S.: project administration, supervision, writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Funding: Project no. TKP2020-NKA-04 has been implemented with the support provided from the National Research, Development and Innovation Fund of Hungary, financed under the 2020-4.1.1-TKP2020 funding scheme.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki. Informed consent was obtained from all volunteering participants according to the Declaration of Helsinki. This study was approved by the Institutional and Regional Ethics Committee of University of Debrecen (registration number: 4598-2016).

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: More materials were provided related to more data and the characteristics of the exercises and four motion programs. More data presented in this study and any other material related to this article and raw data can be available from the first, corresponding author on request. That data which would be used for further analysis are not publicly available now.

Acknowledgments: The authors gratefully thank all the students who participated in this study.

Conflicts of Interest: The authors declare no conflict of interest. There were not any funders who had a role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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International Journal of Social Science and Economic Research

ISSN: 2455-8834

Volume: 04, Issue: 06 "June 2019"

EFFECT OF MEDITATION ON ACHIEVEMENT, ATTENTION & MEMORY OF HIGH SCHOOL STUDENTS

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ABSTRACT

This empirical study explored and found out effect of meditation on achievement (school examination marks, Odia language and arithmetic ability), attention and memory of high school students. Two hundred adolescent high school students, consisting of equal number of boys and girls, belonging to grade nine participated in the study that lasted for one academic session. The study adopted Solomon four-group design in which subjects were divided into four equal groups of 50 students each. Two groups participated in concentration meditation. While two groups, one participating in meditation and another which did not participate in meditation, were pre-tested, all the 4 groups were post tested using Odia language ability test, arithmetic test, test for span of attention and test of memory. The school examination marks of all participants were collected from school records. The data collected from all assessment tools were analysed with SPSS-20. The study proved that meditation could be effectively taught to adolescent high school students. The ANOVA calculated on the four groups found significant differences in post-test performance between the meditating and non-meditating groups. The result also established that pre-testing has impact as the meditating group with pre-testing showed better performance in post-testing among all the groups.

Keywords: Meditation, Achievement, Attention, Memory

INTRODUCTION

Adolescence is an extremely difficult period when students passes through various rapid mental and physical changes. Children and young adults go through a lot of stress (Fontana, David, Slack, & Ingrid, 1997). At a time of rapid pubertal change early adolescents experience increasing desire for autonomy (Stenberg, 1999); increasing focus on peers and social acceptance (Juvonen 2006) and increasing self consciousness (Erikson, 1968). The pressure of school, expectation of family and planning a suitable career for themselves puts them under considerable stress and tension. School related achievement goals include mastering subject matter or meeting

ISSN: 2455-8834

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an achievement standard such as earning an 'A' Grade or 100 % on a test or striving for a perfect GPA. School related social goals include gaining approval from others, making personal relationship with peers, belonging and being dependable and responsible (Goodenow, 1993; Wentzel, 1998).

A lack of education in mind training at this stage will lead to adolescents develop bad mental habits. In a world where high school students are to perform to the rising expectations and put up with all the shortcomings and defects of the school system, meditation seems to hold a great promise. Meditation has been defined as a mental training that brings about long term changes in cognition and emotion (Lazar, et. al., 2005; Lutz, Greischar, Rawilings, Ricard & Davidson, 2004). It has been claimed to have miraculous powers to promote success in life, to burst stress and to boost strength. It seems to hold promise for men, women and children, to overcome their weaknesses and failures and to achieve greater success in many varied fields of life.

Meditation, its preachers and practitioners claim, can bestow positive qualities on the individuals and reduce negative ones. Rishi Patanjali who is credited with collecting, perfecting and codifying Yoga and meditation techniques in his monumental work "*Yoga Sutra*" stands out among the ancient ones while in the modern times Sri Aurobindo, Swami Yogananda, Swami Shivananda Saraswati, Swami Satyananda Saraswati, Nirmala Devi, Mata Amruta Anandamayee, Maharishi Mahesh Yogi, Sri Sri Ravi Shankar, and many more, have tried to preach meditation for fostering spirituality, learning, peace, good health, and happiness among people. According to Walsh (2001) meditation is "a family of practices that train attention in order to heighten awareness and bring mental processes under greater control." According to Shapiro (1980) "meditation refers to a family of techniques which have in common a conscious attempt to focus attention in a non-analytical way and an attempt not to dwell on discursive, ruminating thought". Meditation has been defined as 'a group of practices that self regulate body and mind, thereby effecting mental events by engaging a specific attentional set (Cahn & Polich, 2006). Roger Walsh, (2001) points out that the beginning of meditation are lost in antiquity but can be traced back to at least 3000 years.

John Dewey (1966), world's most influential philosopher of education stated that the education is the fundamental method of social progress and reform. But the ability of education to promote individual as well as social development depends upon the quality of educational system. In most countries around the world, there is wide spread dissatisfaction with the educational system, and specifically, the failure of high schools in providing adequate care and facilities for the adolescents is great concern for all. High school education and grades shape the adolescents' career and life beyond. A success at this stage is seen as a ticket to good life. Failure leads to negative social branding and further problems. So, parents, teachers and others have high

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performance expectations from the adolescent learners at this stage. This puts a lot of pressures and anxiety on the adolescents.

In developing countries like India school systems are awfully inadequate. Access to quality schooling remains a dream even today for the majority of our children and adolescents. Large scale school failures and school drop outs, adolescence delinquency, prevalence of mental and emotional problems among school children, etc. point to the terrible quality of life being experienced by our adolescent population. In view of the fairly large number of research studies confirming the positive influence of meditation on life of people it is normal to expect that it can also bring about positive changes in adolescent school students.

The Rationale:

The practice of transcendental meditation was shown to improve academic performance in university students, academic achievement and psychological health in high school students. While practicing meditation, students gain knowledge by direct experience rather than imposed by an outside authority. Engagement of student in learning events is the main focus of instructional technology. According to performance based measures of cognitive function, mindfulness training can enhance the ability to focus attention (Jha, Krompinger & Baime, 2007). Focused attention bears great significance in the field of learning. The faculty of voluntarily bringing back a wandering attention over and over again is the very root of judgment and will. But systematic attempt to control, train and cultivate attention is very rare. As attentional training has been central to meditative practices, incorporation of these practices into the field of school education will have great benefit.

Taking Sixty-three University of North Carolina, Charlotte students as participants Zeidan, et al. (2010) examined brief meditation training effects on cognition and mood. After four sessions of either meditation training or listening to a recorded book, participants with no past meditation practice were assessed with measures of mood, verbal fluency, visual coding, and working memory. Both interventions were helpful at improving mood but only short meditation training reduced fatigue, anxiety, and increased mindfulness. Moreover, brief mindfulness training significantly improved visuo-spatial processing, working memory, and executive functioning. Napoli, et. al. (2005) evaluated the effect of the participation in mindfulness training in 1st, 2nd and 3rd grade students' attention. The 24-week training included a series of exercises including breath work, body scan, movement and sensory motor awareness activities. Results from 3 attentional measures administered to the students showed significant differences between those who did and did not participate in the mindfulness training. Lisa Desmond (2004), teacher of pre-school children, author and meditation practitioner, states: " I have observed children who

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are in pain from loss of a loved one, children who are sad, fearful, hyperactive or angry, become calm, relaxed and at peace with themselves and the world around them through meditation". She further credits meditation with helping children fall asleep and calming them when they are afraid, anxious or worried as well as helping them with learning difficulties and attention deficits. Rosaen and Benn (2006) presented evidence that students who practiced in meditation displayed greater levels of self control, self awareness, flexibility and better academic performance than peers who did not participate in meditation practice.

Kim's study (2006) showed effects of meditation on children's absorption. In her study of elementary 6th grade children who participated in 30 brain respiration meditation sessions demonstrated significantly better concentration score than the control group in both paper and pencil test and brain wave test. One study by Hall (1999) examined the effect of meditative practice on academic achievements among both college and middle school students. Hall randomly assigned 56 under graduates to two study groups, one of which included concentration based meditation. A one hour session of meditation instruction twice a week for the academic semester was provided to the meditation intervention group. Meditation was practiced for ten minutes at the beginning and end of each one hour study session, in which subjects were provided with guidance in simple attentional focusing and relaxation exercises. The participants were instructed to meditate at home and before examinations. The control group participants also met for one hour of study a week but were not given meditation training. At the beginning of the study, the groups did not differ in grade point average (GPA) but at the end of the semester, the intervention group has significantly higher GPA scores compared to the control group. Another study conducted by Tang, et. al. (2007) showed benefits of short term meditation practice. Forty undergraduate Chinese students participated in five-day meditation training. They demonstrated greater improvement in conflict scores on the Attention Network Test, an increase in immune-reactivity, higher vigour on the Profile of Mood States Scale, and a significant decrease in anxiety, depression, anger, fatigue and stress. The findings of this study were reflected in another study in Taiwan by the same researchers.

In their book "Paths beyond Ego", Walsh, Roger, Vaughan, and Fraces (1993) point out that meditation influences six common elements in the experience of transcendence - ethics, attention training, emotional transformation, motivation, perception and awareness and wisdom. It controls and stabilises attention, forbids unethical behaviour, transforms emotion, redirects motivation and fosters wisdom. Not only the meditator will experience greater emotional wellbeing and become motivated to work for the wellbeing of others, he himself will get a type of cognitive training which will lead to measurable improvement in his ability to concentrate, comprehend and master new academic materials. This attribute of meditation is responsible for enhancement in cognitive functions necessary for academic achievement. Complex cognitive

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tasks that involve critical thinking, reasoning, and problem solving activity are required in high achieving academic environment. Since, significant amount of attention of anxious students is diverted into non-academic and socially maladaptive behaviour, poor academic and social performance on their part can be expected in class room. If students experience fear, hopelessness, anxiety and disappointment during learning, the association is made that learning is a stressful and threatening event. To combat this problem meditation training in the class room will help to alter the way students evaluate and react to incoming data and information. Since all the research in the field indicate toward a beneficial effect of meditation, its utilization for promoting better growth and education in students in schools cannot be ignored.

The present study is an exploratory investigation into the effects of meditation on academic and cognitive characteristics of adolescent high school students. The primary motive is to find out if meditation can help students grow and learn better overcoming the handicaps imposed upon them by the inadequate facilities of a schooling system. Though most research in this area is new, meditation offers promise for application in the educational field where creativity, good socio-personal relationship, motivation, morality, values and other psychological virtues may enhance learning and educational climate. The present study is a humble attempt to enquire into effects of meditation on school achievement, Odia language and arithmetic skills, memory and attention span.

OBJECTIVES

The major objective of this study is to find out effect of meditation on achievement, memory and attention.

The following are the specific objectives of the study.

1. To study the effect of meditation on school examination marks of high school students.
2. To study the effect of meditation on Odia language score of high school students.
3. To study the effect of meditation on arithmetic ability of high school students.
4. To study the effect of meditation on memory of high school students.
5. To study the effect of meditation on span of attention of high school students.
6. To review the available literature on effect of meditation.

METHOD

Design: The present study aimed at finding the effect of meditation on high school children.

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Hence, it was decided to use both experimental and control groups in the study. A modified Solomon's four group design, in which all the four groups were naturally occurring student groups, was conceived as it was found suitable to analyze the effects of meditation thoroughly. Four naturally occurring student groups of equal size were taken for the purpose of the study. Group 1, the experimental group, was to receive experimental treatment and was to be subjected to both pre- and post-tests. Group 2 the control group which was subjected to both pre- and post-tests but no experimental treatment was given to the group. Group 3 received experimental treatment and was subjected to post test. Group 4 was to be post tested only. All the four groups belonged to the same grade and were taken from two schools belonging to the same town. The pre-test and post-test scores of the groups were to be compared and contrasted to find the effect of meditation on the subject's characteristics under investigation.

Table -1

Groups	Pre-test	Treatment	Post-test
1	Yes	Yes	Yes
2	Yes	No	Yes
3	No	Yes	Yes
4	No	No	Yes

Sample: The sample comprised of 200 students, four groups of 50 students each, taken from two Government high schools from Bargarh town in western Orissa. Since they are both Government high schools the students attending them are from a cross section of the population of the town. Students from almost all sections of the population are represented in these schools. It was for this reason that the subjects were drawn from these schools.

Table -2

The group	**No. of boys**	**No. of girls**	**Total no**	**Grade**	**Mean age**
Group - 1	25	25	50	IX	14
Group - 2	25	25	50	IX	14
Group - 3	25	25	50	IX	14
Group - 4	25	25	50	IX	14

Tools: The tools and techniques were used to assess achievement are i) School examination scores ii) Odia language ability test iii) Arithmetic ability test

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2. Span of attention test & 3. Memory test

School Examination scores

In order to measure level of academic achievement of the subject it was thought appropriate to use school examination marks as one of the indices for level of academic achievement as it is the school examination mark that command the most respect. To supplement the school examination two achievement tests were constructed and used in two core school subjects i.e. language (Odia) and mathematics. It was thought that a combination of all these marks will become a strong index for the academic performance of the subjects. Since all the subjects belong to grade-IX aggregate marks secured in the school examination after grade-VIII were collected from the school records as a measure of pre testing score for academic achievement of the subjects. Likewise, aggregate mark secured by the subjects in the examination at the end of grade-IX were collected from school records to be used as a post testing score for academic achievement of subjects.

Test in Odia

The test in Odia which is the mother tongue of participants was prepared keeping in view measuring the language fluency, vocabulary, and grammar of the subjects. The Odia test is a 47-item objective type test consisting of multiple choice items as well as questions seeking very short answers. To construct the test a total of 75 test items were initially prepared by the investigator. This preliminary draft was refined and then the test was placed before five subject experts and teachers of Odia for thorough scrutiny. From among all the 100 questions a total 25 questions were finally retained on the advice of the experts and teachers. Thereafter the test was tried out on a group of 10 students to ascertain if the test worked perfectly. The test posed no problems. The time limit of 45 minutes was fixed to complete the test. The test carries 50marks and the scores of subjects can vary between 0 and 50 marks.

Test in Arithmetic

The arithmetic ability test was randomly selected from all the topics of arithmetic text book appropriate for grade IX. A total 75 test items were initially prepared and given to five subject experts and teachers for their opinion and approval. After getting their opinion finally 30 test items carrying a total of 60 marks were retained for administration. The test in arithmetic was also tried in the same manner as it was for odia test. After the tryout the time to complete the test was fixed for 45 minutes. The questions represent the topics such as HCF, LCM, time and work, time and distance, profit and loss and interest.

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Test of memory

To assess memory a delayed recall test was used. Russel (1979) considers this to be a more difficult test of memory. The test material consists of standard nonsense syllable of three letters, e.g. XOL, YIP which were selected from a prepared list (Baddley, 1993). A total of 10 nonsense syllables were randomly taken for administration. Exposure time for each syllable was five seconds. The correct answer carry one mark and wrong answer a zero.

Span of attention

Span of attention is measured by an apparatus called tachistoscope. When visual stimulus is presented to the subject with this apparatus, subject gets a very brief view of the stimulus. The subject then has to respond by uttering the stimulus digit. Five sets of cards, four in each set were prepared. The first set had four cards with a 3-digit number in each card. The second set had four cards each with a 4-digit number. Likewise all the five sets of cards were prepared with each set of four cards having 3-digit to 7-digit numbers. Hence, twenty cards in total were taken for the administration. On one side of each card one category of digits was written clearly in visible size. The size of each digit and the distance between each digit were kept equal. All the cards were to be exposed for once only through the tachistoscope in a random order. Span of attention is calculated by adding up the fractional values to the basal value for correct responses. Basal value indicates the series of letters or digits which are correctly attended to and prior to which the subject has not committed any mistake. The fractional value is the score when the subject responds only a fraction of the four digits correctly in a set of cards.

Conduct of Experiment

All necessary permissions were secured from both the schools which were to participate in the study. The students in grade-IX of both the schools on which the study is to be conducted were contacted in groups in their own class and a rapport was established with them. All students in group–I i.e. the experimental group secured consent from their parents to participate in the study. However, group-IV which was to be post-tested only was contacted just before the post- test. After the pretesting in all the variables, the two experimental groups, group-1 and group-3, were given meditation training in concentration meditation.

The meditation program continued for one academic session. Both the schools willingly utilized one period of 45 minutes duration everyday for the meditation programme. In the first high school the meditation programme took place at 3pm to 3.45pm and in the second school from 4pm to 4.45pm. The instructor who was engaged to impart meditation training to the subjects was yoga and meditation instructor in a Government managed college. He has a diploma in yoga

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from Bihar School of Yoga. The meditation class was held in sufficiently large halls of the two schools. The participants were asked to keep their stomach empty before and during meditation. The halls where meditation classes were held had both natural light and artificial over head lighting. Both halls were silent with no bad odor or no noise coming from outside. The halls had fresh circulating air from four open windows. The participants were supplied with yoga mats to sit on. In order to meditate every day they learned first a suitable meditational posture. The detailed instructions for meditation were given by the instructor. After giving experimental treatment to the Group 1 and Group 3, the investigator conducted a post-testing in all the variables taken for the study on all the subjects of both experimental and control groups.

RESULTS

Data collected through pre- and post- tests for all the five variables were subjected to descriptive, correlational and inferential statistical analyses. The Mean and Standard Deviations of all the five variables of all the groups on both the pre- and post- tests shows that school examination score, the meditating group has shown significant improvement on all other variables. Inter-correlations indicate a high and positive correlation among all the academic and cognitive variables. The ANOVA done on five scores showed significant differences among the group means in most of the cases leading to rejection of the null hypothesis.

Table 3: Mean scores of all the 5 variables in both the pre and post tests for the 4 groups (N=50 per group)

Sl. No	**Scores**	**Gr 1 Pretest**		**Gr-1** Post test		**Gr-2 Pretest**		**Gr-2 Post test**		**Gr-3 Post test**		**Gr-4 Post test**	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	School Exam	159.72	5.43	189.18	6.11	161.12	6.22	165.26	5.16	164.82	4.77	166.46	4.98
2	Test in Odia	16.96	7.41	23.92	6.6	18.58	8.2	21.38	7.63	20.56	7.32	19.8	7.62
3	Test in Arith	18.58	7.95	25.58	7.99	19.56	8.75	23.23	9.16	20.62	7.13	18.86	8.1
4	Test In Memory	4.12	1.22	8.36	1.17	4.44	1.54	6.12	1.49	5.99	1.32	5.23	1.55
5	Span of Attn	4.94	0.64	5.86	0.58	4.68	0.81	4.66	0.82	5.57	0.66	4.91	0.63

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Table 4: One-way ANOVAs among the six group mean scores

Sl.No	Variables	Sources	Sum of Squares	df	Mean Square	F	p
1	School Exam	Between Groups	29206.5600	5	5841.3120	195.0525	0
		Within Groups	8804.5307	294	29.9474		
		Total	38011.0907	299			
2	Test in Odia	Between Groups	1309.43	5	261.886	4.676	0
		Within Groups	16464.82	294	56.003		
		Total	17774.25	299			
3	Test in Arith	Between Groups	1717.387	5	343.477	5.096	0
		Within Groups	19814.16	294	67.395		
		Total	21531.547	299			
4	Test In Memory	Between Groups	87.8	5	17.56	9.046	0
		Within Groups	570.68	294	1.941		
		Total	658.48	299			
5	Span of Attn	Between Groups	60.942	5	12.188	24.823	0

Summary of results

(1) Meditation could be effectively taught to adolescent high school students with positive and beneficial influence on the participating students. (2) Meditation enhanced memory of high school students significantly. High school students with meditation practice were found to have better memory than those who did not have meditation practice. (3) Meditation increased span of attention of high school students significantly. High school students who practiced meditation

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were found to have better span of attention than those who did not practice meditation. (4) High school students participating in meditation programme improved their Odia language ability significantly. (5) High school students participating in meditation programme improved their arithmetic ability significantly.

CONCLUSION & IMPLICATIONS

The results strongly suggest that practice of meditation improves memory of adolescent high school students. Collectively, attention and memory constitute the cognitive domain. Development of these two faculties is closely related not only to academic achievement but to maintain psychological wellbeing of all segments of population. The present study found positive effect of meditation on these fundamental cognitive faculties and these findings are backed by number of theoretical and empirical investigations and findings. Results of the study are in line with earlier research results of Kozhevnikov, et. al. and Newberg, et. al.(2001). The studies led by Newberg, Alavi, Baime, Pourdehnad, Sanntanna and d'Aquilli,(2001), Hotzel, Ott, Hempel, Wolf, Stark et al.(2007), Pegnoni and Cekic (2007), Lutz, Greischer, Rawlings, Ricard and Davidson (2004) provided significant evidence that meditation has a significant impact on cognitive structures associated with attention, concentration, processing of dissonant or painful experiences and emotional self-regulation. Since paying attention to information, instructions and learning activities in the classroom is essential for academic success it seems reasonable to conclude that mental training that increase a student's attentional capacity would enhance academic performance.

So far as academic achievement, which bears utmost significance for adolescent high school students, is concerned, some prior studies (Hall, 1999; Franco, Manas, Kangal & Gaalego, 2010) have established positive beneficial effects of meditation. This study also confirmed the beneficial effect of meditation on two important academic variables - language and arithmetic ability. There is a need to undertake further rigorous studies to draw conclusions regarding the role which meditation can play in improving students' academic ability.

Although meditation has been in use since ancient times modern scientific research into this area is of recent origin. Indian Psychology of Yoga and meditation contain valuable information on psychological health and exceptional abilities and prescribed methods for cultivating them. Research suggests that meditation and Yoga have effects ranging across Psychology, Physiology and Bio-Chemistry and can enhance both psychological and physical health (Walsh, 2001). The results of the present study are quite encouraging to suggest that participation in meditation programme is useful for the students in enhancing the cognitive capacities. These results of the present study have important implications for the theory of cognitive psychology. This study

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have important implications for practical application in the fields of adolescent development, educational and school practices, intervention programmes for adolescent students under remedial teachings, for slow learners and backward students.

ACKNOWLEDGEMENT

The author is grateful to the headmaster and all teachers of George High School and Government Girls High School for the necessary permission to conduct the study. The author expresses heartfelt thanks to all the teachers and students for their support and cooperation.

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International Journal of Social Science and Economic Research

ISSN: 2455-8834

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USING ARTIFICIAL INTELLIGENCE TO ENHANCE THE EFFECTIVENESS OF MULTIMEDIA-BASED INSTRUCTION

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Author note: The project was sponsored in part by the National Science Foundation under award 0740435 to Education Online, Inc.

ABSTRACT

The Internet has given rise to a plethora of multimedia educational resources that are available to students. Two of the most popular instructional formats are video-based instruction and educational television. These are attractive since they provide engaging education and reach wide audiences. However, a potential weakness is that the type of personalized instruction a teacher provides is typically lost. The present paper investigates whether combining these formats with artificial intelligence (AI) technology can enhance student performance. Two experiments were conducted, one that added AI to Internet-delivered educational TV and one that added AI to Internet-delivered VBI. In both cases, student performance was dramatically improved. The results suggest that AI can improve educational performance when added to the multimedia-based instruction.

Keywords: Artificial Intelligence, Multimedia-Based Instruction, Effectiveness

ISSN: 2455-8834

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INTRODUCTION

The past two decades have seen an enormous increase in the use of technology to supplement and even replace traditional classroom instruction. Nowhere is this more prevalent than with the Internet where there are now countless sites, many of them free, that offer supplemental educational resources for students. Technology-based education, often referred to as e-learning, has received a lot of attention in the research community. E-learning has increased in popularity over the years because it provides benefits such as: provides time and location flexibility; results in cost and time savings for educational institutions; fosters self-directed and self-paced learning by enabling learner-centered activities; creates a collaborative learning environment by linking each learner with physically dispersed experts and peers; allows unlimited access to electronic learning material; and allows knowledge to be updated and maintained in a more timely and efficient manner (Baloian et al., 2000; Kumar et al., 2001; Piccoli et al., 2001).

Two of the most popular forms of supplemental instruction resources are video-based instruction (VBI) and educational television (TV). VBI is generally well-received by students. Accordingly, much research has been devoted to studying its effectiveness. Adding videos was shown to improve performance in third and eighth graders (Boster et al., 2006). Videos have been shown to improve educational achievement compared to other formats such as text (Khan et al., 2010), lecture (Siegel et al., 1997), and simulation (Morgan et al., 2002).

One of the reasons why videos may enhance learning is that videos tend to be engaging, which fosters student learning (Roblyer and Edwards, 2001). Videos lead to higher acceptance and satisfaction among students (Donkor, 2011). Such engagement and acceptance leads to greater attention to the material being taught and deeper cognitive processing of the material, thus enhancing learning (Balslev et al, 2005).

The effectiveness of videos as part of instruction is enhanced when the videos are interactive as demonstrated by Zhang et al. (2006). Zhang and his colleagues investigated four conditions: a classroom environment, an e-learning environment with no video, non-interactive videos that students had no control over, and interactive videos where users could control what they saw and when they saw it. Results showed that both learning satisfaction and performance was greatest in the interactive video condition.

As with VBI, Internet-based TV is gaining increased interest from both the research community (Carey, 2003; Claros and Cobos, 2012; Van Tassel, 2001) and the commercial marketplace. While websites that provide multimedia instruction are widely popular and freely available, the very prevalence of such resources gives rise to the basic question of how effective are they and is there a way to make them even better?

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One possibility, which is the focus of the present paper, is through the incorporation of artificial intelligence (AI) into the multimedia-based instruction paradigm. The combination of multimedia-based instruction and AI seems promising for an online e-learning resource aimed at a wide audience. The multimedia offers the chance to teach students in an engaging and effective manner and the AI technology offers a means emulate the expertise of a human teacher to guide the learning process. For example, instead of simply requiring students to enter an answer and check to see if the answer is correct, students can be given the opportunity to enter their work and be shown what their mistakes are and how to correct them. We hypothesize that this would lead to greater learning performance compared to multimedia-based instruction alone.

In order to test this hypothesis, we compared systems that embed AI into both educational TV and VBI platforms against those that did not. Mathematics was chosen since there is evidence in the literature that AI-based technology can lead to enhanced mathematics performance (Steenbergen-Hu and Cooper, 2013). If the hypothesis is correct, students using the AI-based technologies will show higher performance than those who do not.

ADDING AI TO MULTIMEDIA TECHNOLOGY

There are essentially two major components of an AI-based multimedia system: the multimedia component and the AI component. There are variations on how each component can be created. Since the focus of the present paper is not on innovations in multimedia per se, we will not discuss the general process of creating multimedia instruction, but rather how AI can be added to that instruction. There are two broad considerations in how to do this. The first is what AI model will be used. The second is how to integrate the AI into the multimedia technology. These are discussed in turn.

AI-based Instruction

Researchers in the field of AI have focused in making technology-based instruction act more like a human teacher by encoding the deep knowledge regarding subject matter, teaching methods, and assessment abilities into the technology itself. This field is often referred to as intelligent tutoring systems (Graesser et al., 2012; Sottilare et al., 2013). Many intelligent tutoring systems (ITSs) are modeled after John Anderson's ACT-R theory (1990), which focuses on how people learn to proceduralize the knowledge they are taught so that they can apply that knowledge to practical problem solving. Accordingly, ITSs that are modeled after ACT-R start by giving students lessons that describe the concepts they need to learn and follow this instruction by having the students engage in step-by-step problem solving. A key component of this approach is ensuring that students correctly execute the procedures that they are taught. To accomplish this, the student's work is recorded and compared to a protocol of correct solutions. When

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students deviate from the correct approach, they are given feedback on what they need to do to correct their mistakes (cf., Graesser et al., 2012).

The AI component of the technology used in the present studies is based on John Anderson's ACT-R framework (Anderson, 1990) that has formed the basis of numerous AI-based instructional systems. The core of ACT-R is a production rule system where sequential procedures are stored based on the antecedent conditions that trigger them. The system then matches the student's input to the step that is listed in the production rule sequence. A match is considered to be a correct step and a mismatch is considered to be an incorrect step. ACT-R allows for more than one pathway to a solution, which is beneficial to the topics taught in the present studies since there is generally more than one way to solve a problem. Typically, people who build AI-based systems for education that are modeled after ACT-R enumerate each problem solving path that is possible for solving the problem. This is done for each specific problem that the system will deliver (cf., Aleven et al., 2006). This becomes particularly cumbersome if the software will ultimately deliver many problems (as would any large scale educational system) or if the system is intended to be flexible enough to allow students to enter their own homework or test-study guide problems (as we intend to allow in future versions of our system).

Therefore, in order to create a more flexible system that can support any problem within a problem class, the technology used in the present experiments operates on generalized problem types where the numbers used in the underlying production rule model the AI engine uses are parameterized rather than instantiated. For example, a typical ACT-R system might model a simple solution path for adding (2 + 3i) + (3 + 4i) as

Step 1: (2 + 3i) + (3 + 4i)

Step 2: (2 + 3) + (3i + 4i)

Step 3: 5 + 7i.

This would require a separate model for every possible problem that the system would deliver to a student. Parameterizing each variable results in a system that requires only one knowledge model per problem type plus the particular variable values for each problem. Therefore, the new solution path for the same problem looks like

Step 1: (a + bi) + (c + di)

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Step 2: (a + c) + (bi + di)

Step 3: evl(a+c) + evl(b+d)i. (evl means to evaluate the sum of a+c)

Problem 1: a=2, b=3, c=3, d=4, and so on for each problem to be used.

This method means that the system can generate unlimited problems to present to the students and the AI technology can respond to them since its representation of the problem is generic rather than hardcoded. For each possible step, there are multiple pathways that are permissible and the algorithm is supplemented with mathematical expression evaluators that recognize equivalent inputs (e.g., a+bi and bi+a are mathematically equivalent).

For each step in the process, the possible errors a student could make are enumerated. For each error, there is associated text that describes the error and the way to correct it. Similarly, three hints, each progressively more specific, are also created for each step in the process. The benefit of the parameterized approach to representing the problems is that these hints and feedback can also be written generically and then populated with specifics from the problem. For example, in a standard algebra problem type of ax+b=c, if a person subtracts the value of b from one side of the equation and not the other, the corrective feedback can be written as "You subtracted b from one side of the equation and not the other. You need to subtract b from both sides of the equation." This format allows for one general piece of feedback to be used in any problem of this type where the user makes this particular mistake.

Integrating AI Technology into Multimedia-based Instruction

Ultimately, the possible ways of integrating AI into multimedia-based instruction are perhaps limited only by the human imagination. We discuss two methods here, which were instantiated into technologies that were experimentally tested to determine their effectiveness.

The first method keeps the two technologies separate. In this method, students may learn a topic using multimedia technology such as a video or TV show and then practice what they learned in a separate AI-based system. This is perhaps the simplest form of integration and one that provides maximum flexibility since each component is then portable and reusable in other systems. It is also the easiest form to create from an architectural perspective since there is no need to worry about compatibility in programming languages, data structures, or operating systems.

This is the method used in the A-list Empire technology that combined AI with video-based instruction. In that example, the AI -based instruction was a standalone software product that could be paired with an existing video-based instruction system (in this case Khan Academy).

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The only "integration" issue is to make sure that the content for the two systems is aligned. This approach seems especially useful for a "learn then practice" teaching paradigm.

The second method actually embeds the AI directly into the multimedia platform. This is what was done in the interactive (AI) TV technology. Here, the student has the ability to interact directly with the TV characters during both the teaching and practice phases of the learning process. This method is more complex and less flexible, but may create a more powerful learning environment since it gives the student the opportunity to influence the delivery of the multimedia instruction through his or her responses.

Embedding AI into multimedia creates two main requirements. The first is technical: the AI must be created using a compatible architecture and programming language. For example, in the interactive TV technology, the core AI technology needed to be recoded into Action Script so that it could be embedded into Flash, which was the programming language used to create the animated TV show that the viewers saw.

The second requirement is to allow the AI to drive the multimedia instruction as needed. There are two components to this. First, a communication mechanism is needed between multimedia system and AI component. In this communication method, the multimedia system notifies the AI component of the user's actions, including questions the students ask or performance on practical problems. One method of doing this is through the use of "triggers" (Leddo, 1997) that record what the student does and then translates that information into a form that is readable by the AI engine's knowledge base. The AI component then analyzes the actions to assess student mastery of the subject matter and learning needs. This analysis is used to select any modifications to the instruction, including providing corrective feedback.

This leads to the second component, a means to alter what the multimedia presents to the student based on the input of the AI component. If the alteration is a change to the flow of the content, as may be the case in a TV show or game, this can be accomplished either by having branches within the content flow as has been the case in classical interactive video training (cf., Schaffer and Hannafin, 1986) or by real time rendering as often happens within games (cf., Stricker, 2013). In the present interactive (AI) TV technology, a branching format was used to simplify the number of paths a student could take within the TV show.

The other form of alteration to the flow of the TV show is to provide corrective instruction. In the present interactive (AI) TV technology used instructional sequences that were separately recorded with an eye to how they would be integrated into the point in the show where they would be called. When corrective instruction was needed, the flow of actions would be

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suspended and a TV character would deliver the needed instruction. Once the AI engine determined that the student learned what s/he needed to, the story line continued.

Accordingly, two versions of AI-based multimedia instructional technology were investigated. One was an embedded system used to provide interactive instruction within an Internet-delivered TV paradigm (developed by Education Online, Inc.) and the other was a standalone system (developed by A-list Empire) to piggyback on an Internet-delivered video-based instruction paradigm. The former used technology that was completely created from scratch. The latter was paired with instructional videos produced by Khan Academy.

EXPERIMENT 1

Methods

Participants

The experiment was conducted at Memorial Middle School in Spotswood, New Jersey, USA. There were 72 6th grade students originally scheduled to participate in the study. Of these 36 were assigned to each group (interactive, non-interactive TV versions). Assignment was done by Spotswood School's superintendent based on students' 5th grade scores on New Jersey's ASK math assessment. Students were assigned so that each group was comprised of students with comparable math scores. Because of absenteeism, the final number of students was 33 in the interactive condition and 35 in the non-interactive condition.

Materials

The subject matter being taught was the mathematics topic of computing the number that changes a mean or average from one value to another. There were three types of materials used in the study: a pre-test, the TV shows themselves, and a post-test. The purpose of the pretest was to determine what pre-requisite knowledge participating students already had. The research team had been informed by Spotswood's superintendent that 6th graders had learned averages/means but had not learned how to compute an individual score that caused a previous mean to change its value to a new mean. In order to verify that the TV shows would be teaching new mathematics content, and therefore, could be considered responsible for any resulting performance, a two-problem pretest was constructed. The first problem gave the student seven numbers and asked them to find the mean or average of those numbers (both terms were used in case students were only familiar with one of those terms). The second problem gave students a table of a week's worth of cumulative average pitches thrown as of each day of the week and asked students to calculate how many pitches were thrown on Saturday. This problem had a format identical to the content taught in the TV shows.

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The second kind of material used in the study was the two TV show versions: the non-interactive version and the interactive (AI) version. The third type of material was the post-test. The post-test contained questions of identical format taught in the TV shows. The first two post-test questions presented students with weekly tables of cumulative average soil temperatures and asked students to compute the soil temperature on Saturday. Question 3 had a similar format but involved number of trucks arriving at a warehouse, rather than soil temperature. Question 4 also had a similar format but involved number of classrooms visited by someone. At the end of the math questions, students were asked to rate the program they saw on a 4-point Likert scale with values very good, good, poor, very poor.

Procedure

The format of the study was as follows: a general project orientation, break up into groups, administration of a pretest, brief instruction on the user interface of the software (for the interactive (AI) condition), viewing the TV show, taking a post-test and then reconvening in a common room for a Q&A on the research.

The project orientation involved telling the students that they would be involved in a study evaluating new TV technology for the Internet. In the general orientation, students were not told of the different conditions. They were told that they would be asked to solve some math problems, they would watch a TV show on the computer that would teach them some math and then they would be given some problems to solve that used what they were taught. Students were encouraged to pay close attention to what they were taught on the TV show because they would take a test on the material afterwards even though they would not receive a school grade for the test.

After the orientation, students were split into three groups. The non-interactive group remained together and the interactive group was split into groups of 16 and 17 students to accommodate the school's computer facilities. Each group had an experimenter to give instructions and a middle school teacher to proctor the students' work.

Once the groups were split, each group was given the pretest. Students were asked to show all work. In order to avoid confusion, students were told that the tables they were given showed cumulative averages and not individual scores. They were given the example of grade point averages to illustrate what was meant by cumulative averages. They were reminded how a grade point average is the average of their tests to date and that each time they take a new test, the average changes. They were reminded that the problems were asking for the score that changed the average from one value to another just as a test score can change a grade point average from one score to another.

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Once the pretest was completed, students used the software. In the interactive condition, students were given instructions on how to use the interactive parts of the software. The students were told that if they had questions on how to enter their work into the computer, they could ask the experimenter, but that the experimenter could not do the math for them. Students in the interactive TV condition were told that they could use calculators to help with the computations during the interactive part of the show and all students were told that they could use calculators during the post-test.

Students were then allowed to work at their own pace. In the non-interactive condition, two students watched the show on each computer. In the interactive condition, each student had his or her own computer. In all cases, students used headphones to listen to the show so that they would not be distracted by sound coming from other students' computers. Each room had an experimenter and a Spotswood teacher to proctor the students' work to insure there was no copying each other's work.

When students completed watching the show, they were given the post-test. Students were asked to show all work and were allowed to work at their own pace. Students turned in their work when they completed their tests to minimize the possibility of cheating. When all students completed their work, the three groups convened in the school's media room for a Q&A session.

Results

The primary purpose of the evaluation study was to test whether students using the interactive version of the TV technology would learn better than those using the non-interactive version. In order to insure that the comparison of these groups was valid, the pre-test scores were first analyzed. Question 1 of the pretest asked students to compute the average of seven numbers. Of the 35 students in the non-interactive group, 20 were able to solve this problem (57%). Of the 33 students in the interactive group, 13 were able to solve the problem (39%). This difference was not statistically significant. Question 2 of the pretest asked students to compute a daily soil temperature from a table of average soil temperatures (identical in format to the problem taught in the TV show). None of the students in either condition could solve that problem. Therefore, the pretest established that students learned something new in the TV show and that neither group had a significant advantage in baseline mathematics knowledge regarding averages.

The next step was to look at performance on the post-test. There were four questions in all. The first two mirrored the format and domains they had just learned (soil temperatures) and the second two had similar formats but different domains.

All scoring of student responses was done by raters who were blind to which condition the students were in. In non-interactive TV condition, students, on average, correctly answered .29

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questions out of four. In the interactive TV condition, students, on average, correctly answered 1.24 questions out of four. Given that the hypothesis was that the students in the interactive TV condition would score higher than those in the non-interactive TV condition, a one-tailed t-test was used to compare the two means. The difference was statistically significant, $t = 3.39$, $df = 66$, $p < .01$. However, the results would still be statistically significant if two-tailed tests were used.

Overall, students in the interactive TV condition performed about four times better than those in the non-interactive TV condition. These data suggest that interactive TV can produce larger learning gains than traditional TV where students merely watch the show.

Finally, students were asked to rate how much they liked the programs they saw. Choices were very poor, poor, good, very good. 97% of the students seeing the non-interactive version of the TV show and 88% of the students seeing the interactive version of the TV show rated the shows as "good" or "very good". This difference was not statistically significant. These ratings suggest that students can not only learn from interactive TV, but will enjoy the process as well.

EXPERIMENT 2

Methods

Participants

Participants were 20 students who were recruited from middle school and high schools in Fairfax and Loudoun counties in Virginia. Each one was enrolled in a geometry math class, which means that they had previously taken Algebra I, but had not taken Algebra II. It was necessary that each student had previously taken Algebra I since knowledge of the distributive property was necessary to learn the subject matter taught in the present study. However, it was also necessary that each student had not yet taken Algebra II since the subject matter of the present study, arithmetic operations with complex numbers, is a topic that is covered in the Algebra II curriculum. We wanted to make sure that participants in the present study had no prior knowledge of this topic. Each participated in the study without compensation.

Materials

The topic used in the present study was arithmetic operations (addition, subtraction, multiplication, and division) with complex numbers of the form $a + bi$, where i is the square root of -1. This topic is typically part of the Algebra II curriculum.

There were two core technologies used. First, for the control condition, there was the video-based lesson that teaches students how to perform arithmetic operations with complex numbers.

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This video-based lesson can be found on the Khan Academy website, www.khanacademy.org. It consists of seven videos, two that provide an introduction to complex numbers, one on complex conjugates and one each for addition, subtraction, multiplication, and division of complex numbers. The Khan Academy lesson software also includes a set of three practice problems per video (except for the introduction to complex numbers) and a space for entering the answer. Once the student answers an answer, there is a button, which, when clicked, states whether the answer is correct. If the student is unsure of how to do the problem, another button reveals hints, which students can use until they get the solution. These hints are not tied to the student's work but are general in nature. At no point does the student enter his or her work in solving the problem or is the student's work evaluated in any way by the Khan Academy software.

The AI software was taken from A-list Empire, www.alistempire.com, also presents videos that deliver general instruction on the topic followed by practice problems. The primary difference between the Khan Academy software and the A-list Empire software is that the latter includes an electronic worksheet that allows students to type in their work step-by-step. The worksheet is organized by lines, with one line given for each step. When a student is through typing in a step, s/he clicks on an enter button and the step is evaluated by the AI technology. If the step is correct, the student is notified in a feedback box below the worksheet. If the step is incorrect, the worksheet line the step is on is highlighted in yellow and the feedback box explains why the step is wrong and how the step is should be corrected. When the student completes the problem by entering the correct answer, the students is notified in the feedback box. As with the Khan Academy software, there is a hint button that students can use. In this case, the hints are tied to the step that the student has recently completed and gives the student information on how to complete the next step. There are three hints available, each at successive levels of detail. For example, in the problems involving division of complex numbers, the general hint tells the students to multiply by 1. The second hint tells the students to try to eliminate the imaginary part of the denominator. The third hint tells the student to multiply by the complex conjugate.

Procedure

The participants were first given a pre-test consisting of five problems to make sure that they did not already know the subject matter being taught in the experiment. The pre-test including problems in addition (one problem), subtraction (one problem), multiplication (two problems) and division of complex numbers (one problem). None of the participants had to be eliminated from the experiment because they already knew how to solve the pre-test problems.

Upon completion of the pre-test, participants were randomly assigned to experimental condition (Khan Academy software vs. A-list Empire software). As a result of the assignment, 10 participants wound up in the Khan Academy software condition and 10 participants wound up in

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the A-list Empire software condition. The first part of the instructional process was having participants in each group watch the Khan Academy videos on solving complex number problems using arithmetic operations. There were seven videos in all, two that were an introduction to complex numbers, one that taught addition of complex numbers, one that taught subtraction of complex numbers, one that taught multiplication of complex numbers, and two that taught division of complex numbers (one taught complex number conjugates and the other taught division of complex numbers). Since the main difference between the Khan Academy instructional software and the A-list Empire software is the use of AI to evaluate students' step-by-step work and provide hints and corrective instruction as needed, we wanted to keep the two conditions as close as possible. Using the same instructional videos in both conditions eliminates the possibility that any differences in resulting post-test performance could be attributed to differences in the instructional videos rather than the AI software.

After participants completed watching each instructional video (except the introduction), they were given three practice problems to solve for each type of arithmetic operation. In the Khan Academy software condition, participants were only able to enter answers to the practice problems. If they were stuck, they could press the button provided on the Khan Academy website to get general hints on how to solve the problem. These hints were not tied to the actual work done by the students, since the students had no way of entering their work on the Khan Academy website. In the A-list Empire software condition, students were given an electronic worksheet in which they entered their problem solving, step-by-step. If they were stuck, they would press the hint button and receive up to three hints as described in the educational technology section above. When they completed each step of the problem, they clicked on an enter button and would be notified if the step they entered was correct or would receive feedback on any mistake that they made. Participants then corrected the mistakes before moving on to the next step. The problem was considered complete once the student entered the correct answer.

When participants completed each instructional video and practice problem set, they were given a post-test. The post-test consisted of 20 problems of similar format to the ones taught in the Khan Academy videos. There were five questions each for complex number operations involving addition, subtraction, multiplication, and division. Participants were allowed no additional resources, such as calculators, to assist them in solving the problems. They were given scratch paper and pencils for computations. Also, to insure consistency, participants were not allowed to replay any of the videos.

Results

The answers to the 20 questions on the post-test were scored based on whether the correct answer was given. Because there were different types of problems based on the arithmetic

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operation involved, the data were broken out by both condition and problem type so that we could investigate whether there were any interaction effects as well as a main effect due to technology. The mean number of correct answers by participants, broken out by condition and problem type, is shown in Table 1. As can be seen in Table 1, participants in the Khan Academy software condition averaged 49.5% on the post-test. In US schools, this is generally considered to be a failing grade (F). Participants in the A-list Empire software condition averaged 90% on the post-test. In US schools, this is generally considered to be somewhere in the A grade range.

An analysis of variance was performed on the data and revealed a main effect of technology. The difference between the two means was statistically significant, $F(1,72) = 33.53$, $p < .0001$. This suggests that adding AI technology, as A-list Empire did, to a video-based e-learning system can greatly improve performance. There is a secondary finding that is worth noting in addition to the main effect. In any educational setting, there will always be some students who learn no matter how they are taught and some who will struggle. Therefore, in addition to looking at overall means, it is useful to explore how robust an educational technology is in teaching all of the students who use it. To do this, we examined the variability in scores between the two groups to see the degree to which the technology appears to help all students who use it.

In the Khan Academy group, the post-test scores ranged from 0 to 100, i.e., the full range of possible scores, suggesting that the technology is more effective for some students than others and that it is not particularly robust across students. Five of the Khan Academy students scored below 60 in the post-test (considered an F in most school districts) and with the exception of the one student who scored 100, no other student scored above 70 (considered in the C grade range in most school districts). In the A-list Empire group, the post-test scores ranged from 80 to 100. This suggested that, while some students did outperform others, in general, all students performed reasonably well. Of the 10 students in the A-list Empire condition, seven achieved scores of 90 or above (considered in the A grade range in most school districts) and the remaining three scored in the B grade range for most school districts. It is probably rare to find an educational intervention that produces performance in the A grade range for the vast majority of the students who use it and no performance lower than the B grade range.

In order to test statistically whether A-list Empire software is more robust across students than the Khan Academy software, we looked at the variability in performance. To do this, we conducted a Levene's Test for Homogeneity of Scores Variance across the eight different cells (2, technologies x 4 problem types). The results was statistically significant, $F(7,72) = 5.08$, $p < .001$, indicating that the A-list Empire software showed more consistent performance across students than did the Khan Academy software.

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Another way to evaluate an educational technology's performance is to determine its robustness across the different types of content it teaches. Clearly, some content is easier for students to master than others, so it is no real achievement for an educational technology to claim that it can teach easy content. A review of the means in Table 1, along with a consideration of the procedures involved, suggests that some arithmetic operations involving complex numbers, such as division, are more difficult than others. This was confirmed by an analysis of variance, which revealed a main effect due to problem type $F(3,72) = 3.43$, $p < .05$.

Given that some problem types are more difficult than others, in order to test how robust the Khan Academy and A-list Empire softwares are with respect to problem type, we look at the technology by problem type interaction. An analysis of variance revealed that this interaction is significant, $F(3,72)=2.74$, $p < .05$. Looking at the individual problem types, we see a trend in the Khan Academy software condition for performance to drop off as students progressed from addition to subtraction to multiplication to division. In fact, the mean performance on division problems was statistically lower than it was for addition ($p < .01$) and subtraction ($p < .05$) problems. On the other hand, in the A-list Empire software condition, there was no significant difference in the mean performance across problem types. This suggests that the Khan Academy software works better on easier subject matter but poorly on complex subject matter (the mean performance in the division problems was 16%). In contrast, the A-list Empire software worked roughly equally well on both the easiest and most complex subject matter with mean performance ranging between 88% and 92%.

GENERAL DISCUSSION

The primary purpose of the research was to investigate whether adding an AI capability to multimedia-based instructional technology could enhance learning. Educational TV and video-based e-learning were chosen as platforms for investigation because these are two of the most prominent and popular forms of multimedia-based instructional technologies. Since there is no "brand name" leader in educational TV, we used software supplied by Education Online, Inc. for the versions of the interactive (AI) and non-interactive TV shows. Since Khan Academy is perhaps the most widely known and used video-based e-learning platform in the United States, it served as an ideal comparison to the AI-based counterpart, A-list Empire, which added AI technology to the video-based e-learning paradigm.

The results of both experiments show that the AI-based technology greatly outperforms their non-AI based counterparts. In the video-based instruction experiment, adding AI improved performance by 80% across all topics and by a factor of 5.5 in the hardest topic. The difference in performance amounted to the equivalent of mean student performance equating to an F grade in the typical public school system for students in the non-AI condition and to something in the

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A range for students in the AI condition. Moreover, the AI technology showed itself to be robust across difficult educational topics and individual students, while the non-AI version showed a marked decline in student performance as subject matter got harder and had enormous variability in student performance. In the TV experiment, the difference in performance between AI and non-AI groups was greater than a factor of four. This is consistent with the results of the video-based instruction condition.

Earlier, we discussed two different ways of linking AI to multimedia instruction: pairing AI with multimedia as a separate module and embedded AI directly into the multimedia. It was suggested that embedded AI into multimedia might be more powerful. Unfortunately, the present experiments were not set up to do a direct comparison of standalone vs. embedded AI since both subject matter and student populations differed across experiments. However, we note that the standalone AI led to an 80% across the board increase in performance compared to the no-AI condition (although a ceiling effect certainly contributed to this), while embedded AI led to a fourfold increase in performance compared to the no-AI condition. Further research can help clarify whether embedded vs. standalone AI is a factor that matters and if so, under what conditions.

CONCLUSION

Members of the education community are always looking for ways to boost student achievement, particularly those that will be robust across both students and content. The AI technology reported in these experiments presents itself as a potential solution. The additional benefit of this technology is that it is relatively easy to implement and is scalable to the geographically disperse student population. Moreover, student ratings from Experiment 2 suggest that such AI-based technology is viewed highly favorably by the students who use it, suggesting that students would readily adopt the technology if used on a wide scale.

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ISSN: 2455-8834

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Table 1: Mean Number of Questions Answered Correctly Based on Question Type and Condition

	Addition	Subtraction	Multiplication	Division	Total
Khan Academy	3.5	3.2	2.4	0.8	9.9
A-list Empire	4.5	4.6	4.5	4.4	18

