

# TALK SESSION I

**Steve Kennerley**

*Neurons in the frontal lobe encode an abstract representation of choice value*

Steve Kennerley  
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A central question in the behavioral sciences is how we select among multiple choice alternatives to obtain consistently those outcomes most beneficial to us. A key brain area in this regard is the frontal cortex since damage to this area can impair the ability to make optimal choices. Economists, psychologists and behavioral ecologists have emphasized the importance of three variables in how humans and animals determine the value of a choice alternative: the payoff of a choice, the probability the choice will yield a particular outcome, and the cost in time and effort to obtain an outcome. To examine how the frontal lobe represents the value of choices to optimize decision-making, we simultaneously recorded the activity of single neurons in three areas of the frontal lobe while monkeys made choices that varied along three physically different dimensions: payoff, probability, and effort. We found that neurons in the frontal lobe, particularly in anterior cingulate cortex (ACC), encoded these decision variables to calculate the value of a choice. Furthermore many neurons encoded the choice's value in an abstract manner that was independent of the specific decision variable and physical means by which value was manipulated. Such an abstract value signal could serve as a type of 'neuronal currency' which would be computationally useful for decision-making, providing the flexibility to determine optimal choice for disparate behavioral outcomes as well as the capacity to deal with novelty, two of the hallmark features of frontal lobe function.

**Robert S. Blumenfeld**

*Neural and behavioral distinctions between item-specific and relational memory encoding*

Robert S. Blumenfeld, Colleen M. Parks, Andrew P. Yonelinas, & Charan Ranganath  
UC Davis

Recent neuroimaging research has suggested that encoding of specific-item information and inter-item relational information are supported by different regions of prefrontal cortex (PFC). Some behavioral research has suggested that these encoding processes might also be functionally dissociable, but this topic remains controversial. Here, we will report behavioral and neuroimaging results that bridge the gap between these two parallel streams of research. In these studies, participants encoded word-pairs using two strategies: On "item-specific" trials, they imagined the item on the left in a large size and the item on the right in a small size, on opposite ends of a room. On "relational" trials, participants imagined the referents of the words interacting in some way. After encoding, participants were tested for recognition of specific item details, or for inter-item associative memory. In a behavioral experiment, we found that relational trials led to better inter-item associative memory, yet item-specific trials led to better memory for item-details. These results suggest that relational and item-specific encoding processes are functionally dissociable. In an event-related fMRI experiment, we scanned participants during similar item-specific and relational encoding trials, and activity was averaged as a function of subsequent memory for specific item details and for inter-item associations. Preliminary analyses revealed that PFC activation was increased during both encoding tasks and predictive of subsequent memory performance. Further analyses will contrast PFC activation between encoding tasks and compare PFC activation as a function of memory for item details and inter-item associations.

**Rosanna K. Olsen**

*High-resolution fMRI of the medial temporal lobe during delayed-match-to-sample*

R.K. Olsen, E.A. Nichols, J. Chen, J.D.E Gabrieli, A.D. Wagner  
Stanford University & Massachusetts Institute of Technology

The medial temporal lobe (MTL) is known to be critical for long-term memory for events and facts. However, recent functional neuroimaging and neuropsychological data using short-delay task paradigms have suggested that the MTL contributes to performance even after brief retention intervals. Moreover, single-unit data in rodents have demonstrated performance-related delay activity in the MTL in the context of delayed-non-match-to-sample tasks. In the current study, healthy adults were scanned using high-resolution functional MRI to explore the contributions of human MTL subregions to performance during a short-delay (30 s) delayed-match-to-sample task. On half of the trials, two faces were presented (1 s) followed by a 30-s delay, after which participants encountered a two-alternative forced choice probe (720 trials). On the other half of trials, the delay period was 4 s. Accuracy on the 30-s trials was 72% correct. Initial fMRI results (n=11) revealed significant delay-period activity in subregions of the hippocampus (anterior hippocampus and CA2/3/DG), as well as in entorhinal cortex. Furthermore, a significant linear increase in delay-period activity over the course of the 30-s delay was observed in several subregions of the MTL (subiculum and parahippocampal cortex) extending into the fusiform gyrus. These results advance understanding of the MTL mechanisms supporting recognition memory across short and long delays.

## POSTER SESSION I

**Crystal L. Cook Reeck**

*Encoding predictors of graded source recollection: A high-resolution fMRI study of conjunctive encoding in the medial temporal lobe*

Crystal L. Cook Reeck, Alison R. Preston, Gwen M. Lawson, & Anthony D. Wagner  
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The medial temporal lobe is critical for declarative memory, including item recognition and source recollection. While prior data have documented that the magnitude of encoding activation in the anterior medial temporal cortex (~perirhinal cortex) varies in a continuous manner that tracks gradations in subsequent item familiarity, it is unclear whether encoding activation in the medial temporal lobe also continuously varies according to gradations in subsequent source recollection. The present high-resolution fMRI study examined the relationship between encoding activation and partial vs. full subsequent source recollection. Participants were scanned while incidentally encoding visually-presented words in one of four imagery orienting conditions: generating an image of an (1) indoor or (2) outdoor scene, or generating the name of a famous (3) male or (4) female person. A post-scan memory test evaluated item and conjunctive (source) memory, using a three-step procedure that assessed item recognition (old/new), task recollection (scene/person), and specific detail recollection (indoor/outdoor; male/female). Initial fMRI analyses (n=20) revealed that activation in entorhinal and perirhinal cortices showed greater activation for recollection of source information as compared to item recognition (specific recollection and task recollection > item only). In contrast, activation of the CA1 field of the hippocampus demonstrated a continuous encoding effect, tracking the extent of subsequent recollection (specific recollection > task recollection > item only). These results indicate that conjunctive encoding in the hippocampus can vary in a continuous manner, whereas anterior MTL cortical processes contribute to the encoding of source information but do not vary based on the amount of detail subsequently recollected. This distinction suggests that hippocampus and anterior MTL cortex differentially subserve the encoding of information into a conjunctive representation. [Supported by the NIMH 1R01MH076932-01A1, NSF, and NARSAD]

## **Dana DeMaster**

### *Neurodevelopmental correlates of recollection and familiarity*

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Dual-process theories of memory contend that recognition is based on two distinct processes: recollection (retrieval of qualitative features associated with the context of a target event) and familiarity (a general sense that the event occurred in the absence of memory for contextual features). Recent behavioral studies indicate a developmental dissociation between these two processes. Whereas familiarity stabilizes during childhood, substantial gains in recollection are observed throughout childhood and adolescence. The neural mechanisms underlying this dissociation remain largely unknown. The research goal was to address this gap by examining how distinct brain activity at encoding predicts subsequent recollection and familiarity. Seventy-two right handed, native English speakers from four age groups (8-year-olds, 10-11-year-olds, 14-year-olds, and adults) participated in an fMRI study. During fMRI data acquisition of an incidental task, participants encoded 200 drawings presented half in green ink and half in red ink. After the scanning session, participants completed self-paced old/new and source recognition tests on 200 studied and 100 new drawings in random order. Behavioral results confirm age-related improvements in recollection (as indicated by correct memory for source), but not in familiarity (as indicated by item recognition). Imaging results suggest that dissociable brain activity between recollection and familiarity is detected among adults and is increasingly evident with age, particularly within the medial temporal regions.

## **Sandrine Duverne**

### *Effects of age on the neural correlates of retrieval orientation are modulated by task demands*

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A prior study from our laboratory demonstrated that the electrophysiological correlates of retrieval orientation – the differential processing of cues according to the form of the sought-for information – were delayed and attenuated in healthy older subjects relative to young individuals in a recognition task. In the present study, we asked whether this effect of aging reflected the tendency of older subjects to rely on item familiarity when performing recognition memory and that differential cue processing would be enhanced when the retrieval task demanded retrieval of episodic detail. The study employed 16 healthy older (63-77 yrs) and 16 healthy young (18-20 yrs) subjects. In one pair of study-test cycles (recognition condition), subjects studied either words or pictures and, following each study phase, attempted to recognize the studied items using visually presented words as cues. In a second pair study-test cycles (source condition), subjects were required at test not only to discriminate studied and unstudied items, but also to signal the presentation context (left/green vs. right/red) for each item judged 'old'. As reported previously, young subjects' ERPs for unstudied items were more negative-going when the study material was pictures rather than words, and this ERP effect onseted earlier in the source condition. Relative to the young subjects, older subjects' ERP retrieval orientation effects were attenuated in the recognition task, but were similar in both onset and magnitude in the source task. Thus, age-related differences in goal-directed cue processing likely reflect differences in retrieval strategy rather than irreversible degradation of the underlying neural circuitry. [Supported by National Institute of Aging grant (number 5P50AG16573)]

## **Hiroki Hayama**

*The role of dorsolateral prefrontal cortex in post-retrieval processing: Is it specific to episodic memory?*

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Post-retrieval processes are engaged when the outcome of a retrieval attempt must be monitored or evaluated. Functional neuroimaging studies have implicated right dorsolateral prefrontal cortex (DLPFC) as playing a role in post-retrieval processing. The present study used event-related fMRI to test whether DLPFC activity is specifically associated with monitoring the episodic content of a retrieval attempt. During study, subjects were cued to make one of two semantic judgments on serially presented pictures. One study phase was followed by a source memory task, in which subjects responded 'new' to unstudied pictures while responding to studied pictures according to which semantic judgment they had been subjected to at study. A separate study phase was followed by a semantic memory task, in which studied items required a judgment about a semantic attribute that had not been probed at study. Both tasks required that the outcome of a retrieval attempt be evaluated prior to response selection, but only the source memory task required evaluation of the content of the retrieved episodic information. The neural correlates of successful retrieval were operationalized by the contrast between correctly classified studied and unstudied items. Crucially, in both tasks, activity in a common region of right DLPFC was greater for studied than unstudied items, and the magnitude of this effect did not differ between the tasks. Thus, activity in this region is not associated exclusively with monitoring or evaluating episodic content. Rather, the region supports processing likely associated with monitoring or decision-making in multiple cognitive domains.

## **Pedro M. Paz-Alonso**

*Developmental correlates of inhibitory-control processes: Suppressing unwanted memories*

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The Think/No-Think paradigm has attracted substantial interest for the study of the intentional suppression of memory. In this paradigm, participants learn a series of paired stimuli, and are then presented with the first member of the pair (the cue), and asked to either remember or suppress the second member of the pair (the target). In a final recall phase, targets that they were asked to suppress are typically remembered less well than other targets. Despite neuroimaging evidence that interactions between the hippocampus and DLPFC in memory suppression in adults (Anderson et al., 2004; Depue et al., 2007), how this ability develops with age is unknown. The goal of the present behavioral study was to investigate developmental changes in the ability to suppress unwanted memories using the TNT paradigm. The study included a total of 54 healthy, native English speakers, from two age groups (8-12-year-olds and adults). Our results revealed age-related increases between the ages of 8 and 12 in the ability to suppress unwanted memories. Specifically, 8-9-year-olds were less able to suppress memories than 10-12-year-olds and adults. These results are consistent with evidence indicating that the structural and functional connection between the DLPFC and MTL develops during the childhood. Based on these behavioral findings, we are currently conducting an fMRI study to investigate the neurodevelopmental correlates of suppressing unwanted memories with children aged 8- 9-years-olds, 11- 12-years-old, and adults.

Anne Richards

*The relationship between emotion regulation and working memory accuracy*

Anne Richards  
UC Davis

**Background:** Understanding emotion regulation will facilitate studies of psychiatric disorders characterized by impaired regulation of emotion. Previous studies have found that emotional distracters decrease cognitive performance compared to neutral distracters. This relationship between emotional reaction and decrease in cognitive performance suggests that change in cognitive performance could serve as a measure of successful emotion regulation. We hypothesized that working memory performance would improve when subjects were instructed to regulate their reactions to emotional distracters. **Methods:** Undergraduates performed a facial recognition working memory task with emotional and neutral photographs as distracters. For half of the blocks, subjects were instructed to down-regulate their emotional responses to the photographs by being detached. During the other half of the blocks, subjects were instructed to respond naturally. Subjects also rated their reactions to the unpleasant photographs, using valence and arousal rating scales, at the end of each block. Skin conductance response (SCR) to the distracters was recorded. **Results:** A repeated measures ANOVA showed an interaction between distracter valence and the effect of emotion regulation instructions on performance ( $df= 1,25$ ,  $F=5.846$ ,  $p = 0.0232$ ). Working memory performance improved on the trials with emotional distracters when the instructions were to regulate. Subjective ratings and SCR amplitude also showed evidence of a significant decrease in emotional reactions to the photographs when subjects were trying to be emotionally detached. **Conclusion:** Change in working memory performance, subjective ratings, and SCR indicate that subjects were successful in regulating their emotions using a detachment strategy.

Tracy H. Wang

*Overlap between recollection- and novelty-sensitive neural activity as revealed by fMRI*

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It has long been proposed that retrieval and encoding operations may occur within a single memory test, with successfully recollected (episodic retrieval) and unstudied ('new') items (encoding of novel information) both engaging the medial temporal lobe (MTL), such that the contrast between these items types yields no differential effect. The present findings provide further support for this view, and in addition, suggest that a similar phenomenon can occur at the cortical level. Subjects ( $N=16$ ) studied a series of pictures of objects, displayed in one of two physically distinct backgrounds (left/green vs. right/red). At test, they indicated whether the picture was previously studied and, if so, also the context in which it had been presented, or whether the picture was new. Relative to items correctly judged old but associated with incorrect or indeterminate source judgments ('source misses'), recognized items associated with correct source judgments ('source hits') elicited greater activity in anterior MTL, left inferior parietal and occipital cortex, and right superior temporal sulcus. Inclusive masking revealed overlap between these regions and those identified by the contrast between activity elicited by items correctly judged new ('correct rejections') vs. source misses. Thus, relative to items that have accrued experimental familiarity, the same medial temporal and cortical regions can be specifically engaged both during successful recollection and during the processing of experimentally novel items. These findings emphasize the close relationship between episodic encoding and retrieval, and highlight the question of where and how item familiarity is computed. [Supported by National Institute of Aging grant 5P50AG16573]

## Maheen M. Adamson

*Influence of APOE e4 and age on memory recall, hippocampal and entorhinal cortex volume in aging pilots*

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Studies focus on the Apolipoprotein E (*APOE*)  $\epsilon 4$  allele as a correlate or predictor of cognitive impairment in nondemented populations to facilitate early detection of Alzheimer's Disease (AD). *APOE*  $\epsilon 4$ -related memory differences are reported in healthy middle-aged to older adults. Cognitively normal older  $\epsilon 4$  carriers also show decrease in hippocampus size over time compared to non-carriers. Decrease in entorhinal cortex (ERC) volume, a region strongly associated with memory and implicated in AD, occurs over time in mild AD patients and is yet to be detected in  $\epsilon 4$  carriers. There is a need to examine the impact of *APOE*  $\epsilon 4$  on memory and brain structures implicated in AD in middle-aged to older workers in cognitively demanding occupations. The ability to fly an airplane has previously provided an ideal platform to study aging workers. The present study investigates brain-cognitive-genetic relationships in normal older pilots, half of whom are  $\epsilon 4$  carriers. Forty-four medically certified general aviation pilots aged 50-76 years were studied with structural MRI and the Rey AVLT memory test. Memory performance was lower in *APOE*  $\epsilon 4$  carriers than non-carriers. This memory recall score correlated positively with hippocampal volume, yet no differences were found in hippocampal (or ERC) volumes in *APOE*  $\epsilon 4$  carriers as compared to non-carriers. This effect was evident in healthy professionals without any presenting memory problems and without selection for a family history of AD. These findings point to basic memory testing as a sensitive tool for detecting *APOE*  $\epsilon 4$ -related influences on verbal memory in aging workers.

## Gabriele Scheler

*Network topology and pattern storage: Applications to hippocampal CA3 synaptic connectivity*

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How can we determine the relationship between the topology of a (neural) network and its capacity to store and access information? Given a network of size  $(N,K)$  with weighted edges, and patterns that are defined by their size  $X$  (no of nodes), and internal connection structure, we can determine the capacity of a network by tiling the graph with patterns of size  $X$ . Tiling may be defined with or without node overlap (GrossYellen2004, Scheler2007). We compare a network with ergodic degree distribution with a network with a bimodal outdegree distribution. The bimodal distribution arises from genetical alterations in synaptic connectivity within the hippocampal area CA3 in the brain (HansonJetal2006). We find a reduced storage capacity for patterns of size  $>4$ , which is further dependent on pattern-internal structure and node overlap during tiling. We also show that access to patterns on the network is negatively influenced by the increase in cyclic structures in the bimodal case. In agreement with experimental evidence, we assume that the overall weight distribution is unaltered. Using weights as probabilities of access we can rectify the access problem, but not the storage problem, by reducing weights on outgoing links of highly connected neurons. This study shows that graph topology, not just connection density or weights, influences storage capacity for structured patterns in networks.

Gross, JL and J Yellen: Handbook of Graph Theory. CRC 2004.

Hanson, J. et al: Presynaptic FMR1 genotype influences the degree of synaptic connectivity in a mosaic mouse model of fragile X syndrome. J Neurosci. 2007 Apr 11;27(15):4014-8.

Scheler, G.: Tiling with cycles and terminals in protein interaction graphs. SMB Meeting, San Jose, August 2007.

# TALK SESSION II

**Jessy Lancaster**

*Implicit knowledge of biomechanics and its effects on human motion perception*

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Does knowledge about the human body affect how we perceive human movements? More specifically, does our own implicit knowledge of biomechanical constraints of the human body affect perception in a representational momentum (RM) experiment? Three experiments using human movements as stimuli in a representational momentum paradigm offer evidence that knowledge of a movement's constraints can affect the perception of its motion. Using signs from American Sign Language (ASL) with non-signing participants, we found that RM is maximized for downward movements of the arm, and for movements shown in the direction that they were originally filmed. We further investigated the effects of biomechanical knowledge on perception by using movements that are easier and more natural to perform in a particular direction. When these movements are shown in the "easy" direction, making predictions about the movements should be easier than when the movements are shown in the opposite direction. From this experiment, we found that RM is also maximized for movements shown in a biomechanically more natural direction.

**Francesca Fortenbaugh**

*The peripheral visual field and spatial representations: What you have now affects what you remember*

Francesca Fortenbaugh, John Hicks, Lei Hao, & Kathleen Turano  
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Three experiments were conducted to examine how the peripheral visual field mediates the development of spatial representations. Using a gaze-contingent multi-resolution technique for simulating peripheral field losses in virtual environments, the field-of-view (FOV) of normal-vision participants was systematically manipulated while they learned and were tested on the locations of six statues in a virtual replication of the actual laboratory.

In Experiment 1 participants learned the locations of the six statues by walking a predetermined path while their FOV was restricted to 40°, 20°, 10°, or 0° (diam). After the Learning Phase, the statues were removed and participants were required to walk out and stand where they thought the statues had been located. Estimated statue locations were recorded. As FOV decreased overall placement errors, estimated distances, and angular offsets increased. When the statues were split into two groups (Near-Space and Far-Space statues) distance errors showed greater compressions for Far-Space statues than Near-Space statues as FOV decreased, suggesting a heterogeneous compression of distances in the spatial representations. Analyses of eye-movement and gaze parameters did not show significant differences across FOV sizes, suggesting that the behavioral differences cannot be explained by the adoption of different learning strategies.

Experiment 2 investigated whether the results of Experiment 1 were due to perceptual distortions. Using the same environment and three different statue configurations, participants made distance and height estimates while viewing the environment with a 40°, 20°, or 10° FOV. Participants also completed blind walks to three of the six statues at the end of each block, with the statues presented one at a time. The results showed large compressions of estimated distances but no effect of FOV for perceptual estimates of statue locations, suggesting that perceptual distortions cannot explain the results of Experiment 1.

Experiment 3 was conducted to test whether the availability of proprioceptive cues during the Learning Phase and visual cues during the Testing Phase influenced the spatial representations of the participants. Participants completed four blocks with either a 40° or 10° FOV. For each FOV size, participants learned the statues locations by either viewing the statues from the starting position (Stand condition) or walking to each of the statue locations (Walk condition). In all cases, participants were required to walk to each of the estimated statue locations without vision during the Testing Phase. The results showed a FOVxTask interaction but no effect of FOV. Interestingly, the distance errors for the Stand and Walk conditions completed with a 10° FOV were comparable to the distance errors in Experiments 1 and 2. However, while the distance errors for the Stand condition completed with a 40° FOV were comparable to those seen in Experiment 2, the distance errors in the Walk condition were larger than those observed in Experiment 1.

Collectively, these results suggest an important role for the peripheral visual field in the development of spatial representations. In particular, the results suggest that having a large FOV facilitates the encoding of global spatial cues that are utilized when remembering object locations within an environment.

## **Kristen Lyons**

### *The development of metamemory monitoring in early childhood*

Kristen Lyons  
UC Davis

Although age-related improvement in metamemory monitoring may be a driving force in memory development, little is known about the emergence and early development of this capacity, largely due to beliefs that preschoolers' ability to introspect is limited and because current methods may be inappropriate for testing young children. The goal of the present research was to examine the development of metamemory monitoring in early childhood, as indicated by confidence judgments of retrieved responses.

Three-, 4-, and 5-year-old children were trained to use a simple, minimally verbally-demanding, 2-point confidence scale. Children used this scale to rate their confidence in responses on: (1) a forced-choice recognition test, on which children were asked to identify which of two line drawings (normed for use with children) was viewed during encoding, and (2) a perceptual identification task, in which children were asked to identify, by name, the contents of line drawings. The perceptual task was included to examine whether age differences in metamemory monitoring generalized to other cognitive functions.

Monitoring was assessed by comparing confidence ratings for accurate vs. inaccurate responses. As predicted, only 5-year-olds' confidence ratings discriminated between hits and misses on the memory test, but even 3-year-olds reported higher confidence in accurate compared to inaccurate perceptual identifications. These results suggest that young children's failure to monitor their memory is not due to a general inability to monitor subjective certainty, but rather a specific deficit at introspecting on memory operations. Factors underlying differences in these developmental trajectories (e.g., representational demands) will be discussed.

# TALK SESSION III

## Deborah Hannula

*Medial temporal lobe contributions to the expression of eye-movement-based relational memory effects*

Deborah Hannula  
UC Davis

Recent research has shown that patterns of eye movements provide important insights about the integrity of memory for inter-item relationships in neurologically intact participants and hippocampal amnesic patients. Here, we used functional magnetic resonance imaging (fMRI) to determine when and how medial temporal lobe (MTL) structures contribute to formation and retrieval of relational memories and the rapid expression of these memories in eye movement behavior. During study trials, participants viewed several face-scene pairs. At test, they were given a preview of a studied scene, followed by a brief delay, and finally presentation of three studied faces superimposed on that scene. Critically, one of the faces had been paired with that scene during the study phase, whereas the other two had been paired with different scenes; eye movements and behavioral responses were recorded in the scanner. MTL activity during the scene preview was expected to be greater on trials in which eye movements were captured by, and lingered on, the matching face early in viewing versus those in which the eye-movement-based memory effects developed more slowly, or were less robust. We found that participants exhibited rapid, disproportionate viewing of the matching face on several test trials – a result which suggests that the scene preview elicits retrieval of the entire relationally-bound representation. Preliminary fMRI analyses revealed that MTL activity was correlated with relational memory, as measured by eye movements and behavioral responses. These results implicate the MTL in retrieving relationally-bound information, and suggest that this information can influence subsequent eye movement behavior.

## Janice Chen

*Associative retrieval and mismatch signals in the CA fields of human hippocampus*

Janice Chen, Rosanna K. Olsen, Alison R. Preston, & Anthony D. Wagner  
Stanford University

While the role of the hippocampus in declarative memory is well established, the mechanisms subserved by component subfields remain underspecified. Within the hippocampus—which includes dentate gyrus, CA3, CA1, and subiculum—it has been hypothesized that CA3 and CA1 differentially support memory-based associative predictions and the detection of associative prediction error. From this perspective, CA3 is posited to encode conjunctive memories that are subsequently “pattern completed” during associative retrieval, in essence making predictions about the present based on associative knowledge acquired in the past. CA3 is thought to pass these predictions to CA1, which is positioned to compare this output from memory with input from entorhinal cortex that transmits the present state of “sensory reality”. To examine the functional contributions of human CA3 and CA1 to associative retrieval and the detection of associative prediction error, we used high-resolution fMRI to measure the functional response of MTL cortices—perirhinal, parahippocampal, and entorhinal—and the subfields of hippocampus. Subjects encoded face-house pairs, and were subsequently scanned at 3T while performing cued-recall followed by a match/mismatch probe decision. On each recall trial, one element of a studied pair served as the retrieval cue, which was followed by a 7.5-s delay during which the subject attempted to retrieve the associate. Following the delay, a probe was presented—either the correct associate (match) or an incorrect item (mismatch); subjects had 750 ms to respond. Initial fMRI analyses revealed that delay-period activity in bilateral CA3 was greater for successfully vs. unsuccessfully retrieved associations. On successful trials, probe period activity in bilateral CA1 was greater when the probe mismatched vs. matched memory, with this associative mismatch effect being significant when the probe was a house. These results support the

hypothesis that CA3 and CA1 differentially subserve pattern completion (associative retrieval) and the detection of associative prediction errors. [Supported by the NIMH 1R01MH076932-01A1 and NARSAD]

## **Bradley Buchsbaum**

### *Neural Mechanisms underlying auditory-verbal sequence learning*

Bradley Buchsbaum  
UC Berkeley

When confronted with novel sequences of stimuli, humans are limited in what they can keep in mind by the finite capacity of the brain's short-term memory system. Thus, in tests of short-term serial recall the average person has great difficulty with sequences longer than about 7 items. With repeated presentation, however, arbitrary sequences of longer length – the letters of the alphabet, the way back to the hotel, the layout of a keyboard – can be learned perfectly. Here we study, using the Hebb repetition paradigm, the neural mechanisms that underlie the learning of an arbitrary sequence of stimuli that are repeatedly tested across a succession of serial recall trials. In our version of the Hebb repetition task, subjects perform a serial recall task where two supraspan (9 letter) sequences of letters are occasionally repeated. The extent to which repetition leads to long-term learning is assessed by comparing performance on trials in which a sequence was repeated to performance on trials with novel sequences. We scanned a set of 8 normal subjects performing this task using functional magnetic resonance imaging and recording vocal responses using a noise-cancelling optical microphone. Statistical analyses showed that as subjects' performance improved with sequence repetition, the activated neural circuitry shifted from fronto-parietal regions associated with working memory, to regions in ventral premotor, insular, and the sensorimotor cortex of the parietal operculum. In addition, activity in the posterior superior temporal gyrus, a region known to be important for verbal-mnemonic encoding, was negatively correlated with variation in trial-to-trial performance (number correct) on the serial recall task. We conclude that verbal sequence learning is associated with an increased efficiency in neural encoding in posterior auditory regions, coupled with a shift from neural networks associated with controlled attention and working memory, to effector systems involved in the articulation of planned motor sequences.

## **POSTER SESSION II**

### **Rui S. Costa**

#### *Let's put it in order! Memory for serial order in social cognition*

Rui S. Costa, Leonel Garcia-Marques, & Jeff Sherman  
UC Davis, FPCE-UL, & ISCTE, Lisbon, Portugal

The study of memory for serial order is a key topic in human memory research. In fact, much of our cognitive performance that uses memory involves compilations of events whose order of occurrence is determinant.

In social cognition, more specifically in the person memory literature, the systematic study of memory for order remains absent, though many order output effects are very well known (e.g. primacy effect, Asch, 1946).

According to the associative person memory models the organizational process underlying the formation of personality impressions is very dynamic. During encoding, each element of information is integrated with items previously known in the emergent impression of a specific target (Hamilton, Katz & Leirer, 1980). The

resultant cognitive representation – a network of associative links between the encoded behaviors (Sherman & Hamilton, 1994) –, should facilitate the recall of item information, but make the recall of order information more difficult, when this information is about different targets, or easier, when this information is about a single target, since the organization by target disrupts the behavior's sequence of presentation. Therefore, a direct comparison between an impression formation (IF) and a memorization (M) goal condition should highlight the amount of associative elaboration that characterizes these two tasks.

We generally followed Hamilton, Katz & Leirer (1980), but we presented participants with information about multiple (Experiment 1 and 2) and single targets (Experiment 3). Furthermore, we included measures for both memory for the order information and memory for item information (or source information).

In 3 experiments we found that item information is better recalled under impression formation conditions, compared to the memorization conditions. Order information seems to follow this trend. These data seem to suggest that impressions are associative cognitive representations that tend to preserve the order information of behaviors in a temporal sequence.

### **Lauren J. Gottlieb**

*ERP correlates of retrieval processing of objects are modulated by level of perceptual overlap*

Lauren J. Gottlieb, Hiroki Hayama, & Michael D. Rugg  
UC Irvine

Successful recognition memory depends on overlap between an encoded memory representation and the processing engaged by a test item (retrieval cue). As the number of levels at which overlap can occur diminishes, it becomes increasingly necessary to 'constrain' the processing of retrieval cues to maximize the potential for overlap. We propose that differing degrees of cue-constraint are reflected in the adoption of different 'retrieval orientations' (sustained cognitive sets that bias cue processing). In the present study we tested this proposal by contrasting event-related potentials (ERPs) elicited by retrieval cues according to whether study-test overlap was present at all representational levels, or was confined primarily to more abstract levels. Subjects encoded a series of pictures; in two of four test phases, subjects were instructed to discriminate between studied and unstudied objects ('Same' condition). In the remaining test phases subjects were to discriminate between unstudied objects and different exemplars of studied objects ('Similar' condition). ERPs elicited by 'new' items were more negative-going for the Similar than for the Same condition, a pattern suggestive of adoption of different retrieval orientations. In addition, waveforms elicited by recognized and new items diverged within 200 msec post-stimulus onset in the Same condition, whereas 'old/new' effects in the Similar condition did not emerge until around 100-150 ms later. These findings are consistent with i) the proposal that differential cue-constraint is indeed associated with the adoption of different retrieval orientations, and ii) neural circuits supporting the rapid detection of prior occurrence respond to perceptual rather than conceptual overlap. [Supported by NIMH grant R01-MH072966]

## **Ellen C. Klostermann**

### *Functional connectivity of frontal-parietal circuits during successful retrieval of auditory stimuli*

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In previous fMRI studies, successful recognition performance has been associated with a left frontal-parietal network that includes prefrontal, posterior parietal and precuneus regions. While the specific role of the posterior parietal cortex (PPC) in memory retrieval remains unclear, recent evidence suggests that this area is not simply related to bottom-up visuospatial processes but may be more directly related to memory processes (Shannon & Buckner, 2004; Wagner, Shannon, Kahn, & Buckner, 2005). Here, we examined the functional connectivity of this PPC region during successful recognition to examine whether activity in the PPC during memory retrieval is correlated with visuospatial or memory-related areas. Areas that are functionally correlated with the PPC during hit trials include bilateral prefrontal cortex, precuneus and bilateral PPC areas. Because these areas are traditionally involved in memory retrieval, not visuospatial processing, this provides further evidence that this area is an important component of the network involved in successful retrieval.

## **Adriane Mayda**

### *Context processing and executive function deficits in normal aging are explained by white matter hyperintensities*

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Current evidence suggests that age-related memory decline is mediated by prefrontal cortex dysfunction; however, the biological processes that underlie these deficits are poorly understood. To examine the role of WMH in age-related cognitive decline, elderly individuals with severe WMH burden (WMH+, n=14), elderly individuals with low WMH burden (WMH-, n=20), and young adults (n=20) were tested on behavioral tasks tapping working memory, episodic memory, and various frontal lobe functions including the item recognition, color picture association, Stroop, and AX-CPT tasks. We observed significant between-group differences in accuracy on the item recognition task such that both WMH+ and WMH- groups performed worse than young controls at all loads. The performance on the color picture association task was also affected by age, but not WMH burden. On the Stroop, WMH+ individuals performed significantly worse than young individuals on the congruent and neutral conditions and worse than all groups on the incongruent condition. On the AX-CPT, WMH+ individuals performed significantly worse than both WMH- and young individuals on the AX condition. There was also a trend such that the WMH+ group performed worse on the BX condition compared to young subjects. No group differences were found on the AY or BY condition. This pattern of AX-CPT results suggests context processing deficits in the WMH+ group. We hypothesize that WMH associated with cerebrovascular disease may alter the connectivity of frontal white matter circuits given the effects of WMH on performance of tasks tapping executive function and context processing commonly attributed to the aging process.

## **Elizabeth Race**

### *Prefrontal and medial temporal correlates of response learning contributions to repetition priming*

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Repeated perceptual and conceptual processing of a stimulus results in behavioral facilitation (priming) and functional activation reductions in prefrontal and posterior neocortical regions. Emerging evidence suggests that priming effects may also stem from the formation, and subsequent retrieval, of medial-temporally dependent stimulus-response associations. The present fMRI study aimed to characterize neural responses associated with response repetition. During initial exposure, participants performed one of two semantic classification tasks on words. Subsequently, these initially encountered (old) words were represented along with a set of new words. Half of the old words were classified in the same manner as during the initial encounter (within-task repetition), and half were classified according to the other task (across-task repetition). Of the across-task trials, half required the same response as was previously appropriate (response repetition) and half a different response (response switch). Behavioral evidence for response learning was observed: reaction times were faster for across-task response-repeat items compared to both across-task response-switch and novel items. Moreover, a response-switch cost was observed for across-task response-switch items compared to novel items, providing further evidence of stimulus-response learning. Initial fMRI analyses revealed: (a) decreased activation in frontal and occipito-temporal regions for within-task items, and (b) medial temporal and frontal sensitivity to response-repetition for across-task items. These data implicate multiple prefrontal, posterior neocortical, and medial temporal contributions to repetition-related behavioral facilitation.

## **Shanti Shanker**

### *Effects of Stimulus and Associative Novelty on Feedback-based Learning and Flexible Transfer*

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Converging evidence suggests that different forms of learning and memory depend on distinct cognitive and neural systems. Incremental, feedback-based stimulus-response learning depends on the basal ganglia, while the medial temporal lobe (MTL) supports rapid learning of single episodes. Stimulus-response learning is thought to result in knowledge that is highly specific and inflexible, while MTL-based memories are thought to be characterized by representational flexibility - the ability to flexibly transfer acquired knowledge towards novel contexts and stimuli. Currently, many open questions remain regarding the relationship between these systems, specifically whether both systems contribute to learning independently, or whether there is a functional interaction between them. Here, we examined the impact of stimulus novelty (Expt 1) and associative novelty (Expt 2) on different forms of learning. Subjects engaged in a feedback-based associative learning task, followed by a transfer phase, where subjects were probed to flexibly use previously learned knowledge in a new context. In Expt 1, we compared learning and transfer to novel vs. familiar items. We found that novelty led to slightly worse performance during feedback-based learning, but significantly enhanced transfer. In Expt 2, we manipulated the extent of associative training prior to testing for transfer. We found that extended training improved accuracy during associative learning, but had a detrimental effect on subsequent transfer. Taken together, these data indicate opposing effects of novelty vs. familiarity on different forms of learning: familiarity and practice enhance learning, but also results in more specific, less flexible representations. These findings are discussed in the context of the nature of the relationship between the MTL and the basal ganglia in learning.

**Jessica Wilson**

*Age-related decline in sleep-dependent memory consolidation*

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Sleep-dependent consolidation is observed following motor skill learning: performance improvements are greater over a 12-hour period containing sleep relative to an equivalent interval without sleep. We show that sleep-dependent memory consolidation is diminished with age. We tested individuals ranging from 45 to 80 years of age on two sequence learning tasks, explicit and implicit-contextual sequence learning. We found a benefit of sleep on performance of both of these tasks in a previous study of young adults (18-25 years of age). The older adults, however, failed to exhibit sleep-dependent improvements on either task indicating that sleep-dependent consolidation declines with age. These results suggest a novel mechanism underlying age-related deficits in learning and memory.

**Weiwei Zhang**

*Loose binding in visual working memory: Direct evidence*

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Visual objects we encounter in everyday life always consist of multiple features that vary along multiple feature dimensions. Several studies suggested that multiple features of an object can be bound together to form an integrated representation in VWM. For example, objects consisting of multiple features can be held in visual working memory as accurately as objects of single feature (Luck & Vogel, 1997). Evidence of this sort (defined as “performance parity”), however, is also computationally consistent with independence between feature dimensions. In the present study, a recently developed model was used in several recall experiments to obtain independent estimates of accuracy, resolutions, and capacities in VWM. Correlation and contingency analyses of recall errors provided direct evidence that colors and orientations of colored orientation bars are bound in VWM while their capacities remain intact. Further analyses of orientation recall data revealed some categorical effects that could be attributed to decision factors instead of systematic shifts in VWM.

# TALK SESSION IV

**Diane E. Marian**

*The Emotional Monster: Effects of Context on Memory for Emotional Expression*

Diane E. Marian & Arthur P. Shimamura  
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We employed a commonly-used size illusion to demonstrate that two physically identical figures are often remembered as displaying different emotions based on context. The absolute size of the two figures depicted was the same (i.e. they had the same visual angle), but one appeared to be larger than the other due to depth cues in the picture. We found that the smaller figure was almost always remembered as being fearful whereas the larger figure was more likely to be remembered as being angry. This effect may have been due, in part, to the appearance that one figure was chasing the other. However, when one figure was replaced with an inanimate object, or even removed entirely from the picture, the effect remained. This manipulation suggested that only a portion of the discrepancy was caused by the relation of the two figures and some must have been caused simply by the placement of the figure within the picture. Furthermore, to examine the influence of the perceived relative size of the figures, we reduced the visual angle of the figure in the background so that both figures appeared to be the same size. Under these conditions, the magnitude of the effect diminished. Therefore, we propose that the difference in memory for the emotions displayed by the two identical figures is caused by several contextual elements: the relation between the figures, the placement of the figure within the picture, and the perceived relative size of the figure.

**Linda Murray**

*The Effects of Complexity on Source Memory ROCs*

Linda Murray  
UC Davis

Source-memory receiver operating characteristics (ROCs) are typically flatter than those seen in item recognition, and they are U-shaped in z-space. There is considerable debate, however, regarding why the zROCs are U-shaped and what conditions are necessary to observe these effects. In the current study, we examined whether source zROCs become more linear as the complexity of the study event increases by manipulating stimulus type (simple or complex) and source type (simple or complex) in a fully crossed design. Participants listened to an audio file (simple source) or watched a video (complex source) of a man and a woman reading words (simple stimulus) or sentences (complex stimulus); the source task was to identify which speaker said each word or sentence. Preliminary results show source zROCs that are U-shaped in the simple stimulus- simple source condition, somewhat flatter in the simple stimulus- complex source condition, even flatter in the complex stimulus- simple source condition, and almost perfectly linear in the complex stimulus- complex source condition. This pattern indicates that increasing stimulus complexity or source complexity leads source zROCs to become more linear, and that stimulus complexity has a larger effect than source complexity. Whether these effects reflect changes in recollection or familiarity is discussed.

## **Colleen Parks**

### *Testing the threshold nature of recollection using a second-choice procedure*

Colleen Parks & Andrew Yonelinas  
UC Davis

We tested the predictions of various hybrid models of recognition that assume that recognition relies on a signal detection familiarity process and a threshold recollection process. In a four-alternative forced-choice recognition test, subjects were required to make a recognition response, as well as a second response in case the first one was wrong. When recognition performance is dominated by recollection, the models predict little to no relationship between first- and second-choice accuracy, whereas when familiarity contributes more to performance the models predict a positive relationship. As predicted, we found a fairly strong first-second choice relationship in a test of item recognition, but not in a standard associative recognition test. Moreover, a modest relationship emerged in associative recognition under conditions designed to allow familiarity to provide more substantial support of associative recognition. These results provide further evidence that recollection is subject to failure and is therefore well-described as a threshold process.

## **Bernadette Guimberteau**

### *What is the role of the prefrontal cortex in learning and remembering? Searching for insights using a new model of learning with the Tower of Hanoi*

Bernadette Guimberteau  
UC Berkeley

The Tower of Hanoi is a classic neuroscience task that is considered especially sensitive to frontal lobe dysfunction. The neuropsychology literature shows that patients with lesions in the prefrontal cortex experience problem-solving difficulties with the Tower of Hanoi puzzle, compared to controls who perform significantly better than patients. However, a number of issues have been raised regarding the interpretation of cognitive neuroscience data from the Tower of Hanoi. The present project seeks to apply a new model of problem solving with the Tower of Hanoi task to resolve issues of data interpretation and shed new light on the role of the prefrontal cortex in learning and remembering.