BAMM 11
Talk Abstracts

Talk session 1

Michael Waskom
Stanford University

The engagement of cognitive control reflects a predictive model of the task environment

Many decisions require a context-dependent mapping from sensory evidence to action. Although cognitive control can be used to enable this flexibility, control processes are both costly and limited. When the structure of the environment favors one decision context, it would thus be advantageous to configure the decision-making system to prioritize it. There is considerable evidence that the brain learns from its environment to support predictions about reward. We hypothesized that decision-making processes are tuned by a similar predictive model that learns over representations of task context; control is then required when events diverge from the predictions of this model.
To explore this idea, we scanned human participants while they performed a context- dependent perceptual decision task. Participants were cued on each trial to judge either the direction of coherent motion or the dominant color of a noisy random dot stimulus. Within this paradigm, we parametrically manipulated the relative frequency of motion and color trials over different task epochs, although we did not indicate to participants which context was more likely at any given time. To perform optimally, participants should infer the current structure from recent experience and configure their decision-making to favor the more likely context. We formalized this learning process with a Bayesian ideal observer model, which allowed us to define a metric of context prediction error (CPE). If control is recruited in response to violations of a predictive model, trials with larger CPEs would require more top-down influence to effectively complete.
Behavioral and model-driven fMRI analyses supported this hypothesis: both reaction times and the amplitude of task-evoked activation in the frontoparietal control network parametrically scaled with CPE. To further understand the effects of CPE on control mechanisms, we used a multivariate analysis of frontoparietal population activity. This allowed us to define an axis corresponding to the task context representation in the population response space. We found that trials with high CPE were more separated along this axis, further supporting the theory that control is engaged in response to CPEs. Together, these results provide a novel computational perspective on mechanisms of context-dependent decision-making.

David Ziegler
UC San Francisco

Dynamics and plasticity of self-regulating internal attention

Attention can be oriented externally or internally and can be derailed by interference originating from both external (e.g., distracting sights or sounds) and internal sources (e.g., distracting or intrusive thoughts), but few studies have explored the nature and underlying mechanisms of internal interference. We will describe a series of experiments in healthy young and older adults that investigated whether internal distractibility is affected by the presence of external distractions, how modulation of internal distractibility in the presence of external distraction relates to task performance, and whether self-regulation of internal distractibility is amenable to cognitive training. In the first experiment, we found that auditory noise induced a significant decrease in

performance on a visual discrimination task that was generally more pronounced in older adults and that was also accompanied by changes in the type of distractions reported (internal vs external). Further, we found that participants who showed reduced internal distraction in the noise condition had the highest task accuracy. Next, we designed a mobile meditation-inspired training program that draws upon focused-attention meditation practices such as directing attention to the breath and cultivating awareness of distractions. After three weeks of meditation training, participants demonstrated a significant decrease in reports of internal distractions during an untrained discrimination task and showed a correlation between the reduction of internal distractions post-training and the time they could maintain focus during their meditation training. Importantly, the degree of improvement in attentional focus during meditation training was positively correlated with improved accuracy on an attentionally-demanding discrimination task. These results suggest that internal distractibility is affected by the presence of external noise, that increased suppression of internal distraction amid external noise facilitates performance, and that meditation-inspired training can improve the ability to suppress internal distractions, leading to generalized gains in cognitive control.

Yixuan Ku
UC San Francisco

Neural oscillations underlying distraction and interruption

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Theta (4-7.5 Hz) and Alpha (8-13 Hz) oscillations have been suggested to play important roles in working memory (WM) processes. However, it is less clear how these oscillations change with age and whether they may contribute to known WM declines in aging. In the present study, 21 younger (aged 18-30 years) and 24 older adults (aged 61-82 years) underwent two kinds of interference (distraction (to be ignored) and interruption (to be attended)) during a face delayed-match-to-sample task. Both types of interference deteriorated WM performance and aging exaggerated these deficits, with larger detrimental effects for interruption than distraction. Posterior EEG alpha activity was larger in younger compared to older adults prior to distraction as well as following an interruption. Those participants with more alpha in anticipation of a distraction, or following an interruption, exhibited better WM performance. Source connectivity analysis in the alpha band between fusiform face area (FFA) and middle frontal gyrus (MFG) showed similar patterns. Furthermore, frontal theta activity was observed to decrease over time following an interruption concurrent with an increase in posterior alpha. However, compared to younger adults, older adults exhibited greater frontal theta activity after an interruption and the time point at which posterior alpha exceeded frontal theta activity was delayed, suggesting a reduced ability to disengage from the interruption. Together, these results suggest age-related declines in WM performance during interference may stem from deficient fronto-posterior alpha activity that serves to inhibit impending distraction and release temporarily attended interruptions from WM.

Cammie Rolle
UC San Francisco

Distributed attention training enhances spatial working memory performance

Rolle, C.E., Voytek, B., Gazzaley, A.

Attention is fundamental to our ability to navigate the complex sensory input we face day-to-day and effectively engage in goal-directed activities. We have developed a spatial attention task to assess the ability to focus and distribute spatial attention based on manipulating the amount of cued information about where a target will appear. The goal of the current study was to test, using an adaptive training version of this paradigm ("DAT"), whether individuals can train and improve their spatial attention abilities, and if there was an aging effect in the plasticity of this cognitive modality. Healthy adults who trained on this paradigm were given a central spatial cue, with varying degrees of information, indicating where in space on the screen a go/no-go target was going to appear. The participant played this task for 10 days over 2 weeks, 30 minutes a day for a total of 5 hours training. For both Older Adults and Young Adults, an age-matched group of controls played a non-cognitive task for the same training duration. All participants played the DAT assessment with EEG prior to and following training. Participants completed a battery of assessments as outcome measures to test for cognitive transfer induced by training. We found that training on DAT improved participant's focused and distributed attention abilities for both Older and Young Adults comparably; i.e. response time significantly improved over all information conditions on the assessment (0% information, 50% information, 75% information, and 100% information), whereas the control group showed no improvement. In the Young Adult group, participant's who trained on DAT exhibited a transfer of effect to the Change Detection Task, showing improved working memory performance from pre to post training, whereas controls did not. We did not see a similar transfer effect in Older Adults due to apparent practice effects. Importantly, there was no difference in improvement between groups in a simple reaction time test for both Older Adults and Young Adults, ensuring that the enhanced attention and working memory performance seen in the Train group was not driven by a training-induced motor speed inflation. These results suggest that spatial attention can be trained using this paradigm and should be evaluated as an effective treatment for attention deficits.

Talk session 2

Brett Foster
Stanford University

Correlated electrocortical activity between medial and lateral parietal cortex during episodic retrieval and resting state

Although historically associated with visuospatial sensory-motor behavior, the human parietal lobe has progressively been shown to play an important role in episodic memory retrieval. Subregions of the medial and lateral parietal cortex display reliable responses during the recollection of past events, and together with structures in the medial temporal lobe form part of a large-scale brain network (i.e. the default mode network). Using simultaneous recordings directly from the medial and lateral parietal cortex in human subjects, we quantified the electrophysiology underlying task and resting state connectivity between these regions for the first time. During task conditions we observed strong correlations between medial (retrosplenial and posterior cingulate cortices) and lateral (angular gyrus) parietal subregions. Strikingly, these specific subregions displayed no difference (i.e. delay) in their response onset during episodic retrieval, suggesting a shared driving input. Electrophysiological patterns of task connectivity were found to be highly similar to those observed during resting and sleep states, when focusing on ultra-slow cortical activity. In addition, resting state electrophysiology was highly correlated with resting state fMRI acquired within subjects. These data provide clear electrophysiological correlates of task and resting state connectivity in the human parietal lobe.

Amy Frithsen
UC Santa Barbara

Retrieval-related activity within the posterior parietal cortex is modulated by changes in task demands

Numerous neuroimaging studies have shown retrieval-related activations within the left posterior parietal cortex (PPC). Additionally, there seems to be a dissociation within this area between items that are retrieved via familiarity from those that are retrieved via recollection. The dorsal PPC regions, usually activated by familiarity, have been shown to be modulated by task demands, such as increases in response monitoring and increases in a subject's criterion placement. Partly due to these findings, it is generally thought that the dorsal area is most likely playing a functional role that is *related* to memory retrieval, but that it is not storing the retrieved memory content itself. The ventral PPC regions on the other hand, which are usually activated by recollection, have been argued by some as acting as an episodic buffer, temporarily storing memory content online until a decision can be made. In this talk I will go over recent research that has shown that the ventral PPC region is also modulated by task demands, including the way recollection is operationalized and by manipulating the underlying base rates of old and new items. These findings suggest that the ventral PPC, like the dorsal area, is not storing memory content itself but is instead playing some other functional role that is associated with successful memory retrieval.

Yana Fandakova
UC Davis

The importance of knowing what you don't know: Exploring the neural basis of uncertainty monitoring in episodic memory

Fandakova, Y., Wendelken, C., Lee, J.K., Bunge, S.A. & Ghetti, S.

The ability to flexibly monitor the uncertainty of one's own memory has important implications for learning and goal-directed behavior. While some ability to introspect on uncertainty is already present in the preschool years, children's tendency to strategically withhold responses continues to develop during middle and late childhood. The goal of the present study was to examine the neural underpinnings of uncertainty monitoring during episodic retrieval and its contribution to memory performance. Children (8-11 years) and adults encoded object-scene pairs followed by a source memory task while undergoing fMRI scanning. During this retrieval task, participants could select an 'I don't know' (DK) answer if they were uncertain about which scene had been originally studied in association with the target object. In all age groups there was pronounced heterogeneity in DK response use. Higher DK response rates were associated with higher source accuracy across all participants. Whole-brain analyses revealed that compared to correct source judgments DK responses were associated with increased activation in bilateral insula, ACC, anterior PFC, lateral temporal gyrus and right inferior parietal lobe. Incorrect source and DK decisions were similarly slower than correct source decisions, but both types of responses were associated with different brain networks. While incorrect source desicions engaged primarily posterior regions including bilateral precuneus, occipital lobe and parahippocampal gyrus, DK responses were associated with stroger activation in ACC/medial PFC, bilateral anterior PFC, lateral temporal gyrus and right inferior parietal lobe. Stronger activation in ACC/medial PFC was related to higher source accuracy across participants of all ages. Taken together, these results suggest that a fronto-parietal brain network plays an important role in uncertainty monitoring during episodic retrieval with implications for memory performance.

Tsvi Achler
Los Alamos National Laboratory

A neural network memory model for both pattern recognition and recall

Pattern recognition (matching a pattern from a sensory system with ones stored in memory) and recall (describing or predicting a recognizable pattern from memory) are essential functions for the brain to interact with its environment: recognize, predict, plan, communicate, perform logic, and reason. Most computational neural network models can either efficiently perform recognition or recall but not both. By using auto-inhibitory connections in conjunction with a modified Hebbian learning, a neural network that does both is implemented.
Predominant feedforward neural network models of recognition perform recognition with one multiplication per layer (based on inputs times weights). In order to perform recognition in this manner not only the memory, but also how important each individual component of the memory is for recognition, must be incorporated into memory weights. This information makes recall difficult and memory weights of each neuron depend on other patterns learned that are not directly associated with that neuron. This type of weights and learning is referred to as global. To learn global weights, a gradient descent (iterative minimization of error) algorithm is used, which also makes it computationally costly to change memory: to add, edit, or remove individual memories.
In simple Hebbian learning each neuron only learns direct information about its own inputs, thus is referred to as local learning, does not encode uniqueness (importance) information into memory weights, and is easier to recall. It requires a mechanism akin to evaluating how important each input is during recognition (instead of during learning) and the predominant mechanism is auto- associative. Auto-associative networks have symmetrical feedforward-feedback connections where the feedback is positive and reinforces previous activation (hence the name). The memory weights are those learned by Hebbian learning. However the positive feedback effectively limits the network memory weights and activation to be binary (because auto-associating nodes will self- activate until they reach their maximum activation).
My computational studies suggest that recognition is more optimal if symmetrical feedback is inhibitory. Initially this architecture may be counterintuitive since neurons inhibit their own inputs. However this configuration implements a gradient descent mechanism (iteratively minimizing error) during recognition. This gradient descent mechanism is NOT used to learn weights, it uses previously learned memories during recognition to find the important inputs for recognition and helps determine neuron activation. Because it does not have runaway self-activation, it allows more refined weights and I introduce a new version of local Hebbian learning to take advantage of these properties which I call “cumulative average” Hebbian learning. Cumulative average Hebbian learning allows the memory weights to represent the average learned pattern which can be updated as new information becomes available.
I show mathematically and through examples that this method can achieve similar recognition results as global learning but has advantages of local learning such as the ability to recall. In fact when evaluating computational costs, this is more efficient than global methods (because it does not require gradient descent iterations through all the patterns to be learned). Moreover, it hypothesizes that iterations (a likely source for brain oscillations) occur during recognition. Lastly, it provides a measure of recognition error which is available during recognition (for every input) which can be used further to better guide attention.

Talk session 3

Michael Cohen
UC Los Angeles

Dual process analysis of effects of value on recognition memory subsequent to free recall

Cohen, M.S., Rissman, J., Castel, A.D. & Knowlton, B.J.

In the value-directed remembering task, subjects study lists of words that are associated with different point values. Subjects learn that in order to maximize their score on each free recall test, it is beneficial to prioritize the encoding of high-value words. Here, we show that while subjects preferentially recalled high value words at the expense of low value words, there was also a significant effect of value on later recognition memory for words that were not initially recalled. Specifically, we conducted three behavioral experiments that differed only in the nature of the surprise recognition task that was administered to subjects following completion all study-recall cycles. In the first experiment, Remember/Know judgments were solicited on the recognition test. In two other experiments, each item was tested in a forced-choice format, requiring either recollection of details (specifically, whether the item was previously presented as plural or singular), or a speeded judgment (intended to assess familiarity-based recognition). Across all experiments, high-value words were recollected at a much greater rate than words that were low value. This was true even for words that subjects had initially failed to recall during the preceding free recall test. In addition, there was a trend across experiments for greater familiarity for high vs. low value words that had not been recalled, suggesting that subjects may be able to limit encoding of low-value words to some extent. These results support the idea that subjects can become aware of limitations in their free recall ability during learning and engage in selective encoding strategies that optimize performance.

Will Shirer
Stanford University

Reshaping Brain Networks for Superior Memory

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Introduction: Successful participants of the annual World Memory Championships do not generally exhibit superior cognitive abilities or obvious brain changes compared to controls, but make use of mnemonic strategies to achieve their exceptional memory performance [1,2]. Here we identify the resting state fMRI (rs-fMRI) functional connectivity (FC) profile supporting superior memory in the world's leading memory athletes, and induce similar network organization in naïve subjects by using six weeks of mnemonic training.
Methods: 23 memory athletes (aged 28±8.6 years, 9 female) out of the Top-50 of the memory sports world ranking list participated in the study. They were compared with a closely matched control group. In addition, 51 subjects (aged 24±3.0 years, all male) without experience in mnemonic strategies participated in a training arm of the study. Memory athletes and matched controls underwent one experimental session; subjects in the training arm completed two sessions with a six weeks' intervention in between. During each session, subjects underwent a rs-fMRI scan; subjects in the training arm also performed a memory test in which they memorized 72 words. Memory was tested after 20 minutes and again after 24 hours with free recall. After the 24h retest, subjects were pseudo-randomly assigned to either six weeks (40 x 30 min.) of mnemonic training in the method of loci; or six weeks in an active (n-back training) or passive (no training) control condition. Eight minutes of rs-fMRI data were collected with a 3.0T scanner. After preprocessing, FC for all participants was calculated across 71 regions of interest (ROIs) based on [3]. FC was compared between athletes and controls with a two-sample t-test, producing a 71 x 71 matrix reflecting differences in pairwise FC (Fig. 1). In the training arm, pre- and post-training FC were similarly compared with a paired-samples t-test. The FC changes that occurred in each

training group were compared with the FC patterns that distinguish athletes from controls by calculating the spatial correlation of the T-score matrices. Additionally, we calculated the spatial correlation of each subject's change-in-FC matrix (pre- minus post-training FC matrix), to the athletes-controls matrix. Change-in-FC matrices were compared with change in free-recall performance to determine the relationship between network reorganization and memory improvement. Bonferroni correction was applied where appropriate.
Results: We observed significantly improved memory performance in the subjects in the mnemonic condition, and this improvement was significantly greater than observed in subjects in the active and passive control groups (effect sizes $d>1.5$). Likewise, mnemonic training elicited changes in functional network organization that significantly resembled the network connectivity patterns that distinguish memory athletes from controls ($Z = 11.73$, $p < 0.0001$). Further, the spatial correlation strength of change-in-FC matrices to the athletes-controls matrix was significantly related to the subjects' performance on the free-recall tasks ($Z = 2.12$, $p < 0.017$). Neither the active nor passive control group experienced similar changes in functional network organization.
Conclusions: Superior memory skills, as displayed during the annual World Memory Championships, rely critically on mnemonic strategies. Here we show that the memory of naïve subjects can be boosted by 6 weeks of mnemonic training in the method of loci. Training-related memory improvements are accompanied by changes at the neural level: rs-fMRI connectivity of subjects in the mnemonic training group, but not in subjects in the active or passive control groups, is reorganized by training towards the connectivity pattern of the world's leading memory athletes. Further, the enhanced memory provided by mnemonic training persists for at least 4 months following the conclusion of training. These results demonstrate the role of mnemonic strategies in altering functional networks and improving memory performance, and support the use of resting-state fMRI as a powerful tool in the study of brain plasticity.

Amber Schedlbauer
UC Davis

Multiple interacting brain areas underlie successful spatiotemporal memory retrieval in humans

Episodic memory, or memory for personal events, consists of a myriad of united contextual details, those of which predominantly include space and time. Retrieval of these memory features depends on the assembly of disparate information in order to mentally reproduce a prior event. Past research has emphasized a particular role for the hippocampus in this process, but current theories propose important contributions from neocortical areas, such as prefrontal and parietal cortex, to successful retrieval. As of yet, the nature of their still unmapped interactions has not been characterized due to insufficient analytical approaches. We conducted a functional connectivity analysis to construct networks that were subsequently characterized by graph theory metrics. Subjects navigated a virtual environment where they learned the spatial layout of the city and the temporal order of deliveries of a passenger to different stores. Immediately after in a source memory task, participants' memories were probed when asked questions regarding the Euclidean distance between stores or the temporal distance between deliveries. Dense, large-scale increases in connectivity during successful memory retrieval typified network topology and positively correlated with behavioral accuracy. Importantly, particular hubs, as assessed by a high degree of connectivity and participation in information flow within the network (node degree and betweenness centrality metrics), emerged in the hippocampus, prefrontal cortex, precuneus, and visual cortex. When remembering dissimilar contextual details, specifically spatial versus temporal information, differential patterns of whole brain connectivity emerged, constituting two separate yet overlapping subnetworks with higher connectivity within posterior (parietal, occipital cortex) and anterior (prefrontal cortex) brain areas, respectively. Consistent with past research, the hippocampus occupied a central and prominent role within the correct, spatial, and temporal

retrieval networks. This new evidence underscores the importance of network dynamics to understanding the process episodic memory retrieval.

Tyler Boyd-Meredith
Stanford University

Decoding the age and rehearsal of real-world memories

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Using fMRI and multivoxel pattern analyses (MVPA), we recently demonstrated that individual lab-based memories can be detected from distributed patterns of brain activity. However, it is currently unclear whether these methods would be similarly effective in decoding more ecologically valid factors, such as memory for real-world events that may vary in recency and past rehearsal. Here we scanned participants while they retrieved memories of events captured by motion- and light-sensitive wearable cameras. Eight months, five months, and two months prior to scanning, participants wore cameras for two-week intervals; 80 events were selected from each interval for a later (scanned) recognition memory test. After each camera-wearing session, participants reviewed half of the events (40) from the prior session. MVPA yielded reliable decoding of whether participants correctly recognized events from their own camera (hits) relative to rejecting those from others' cameras (correct rejections). We also successfully decoded the rehearsal status of events, but only when examining those most recently experienced (2mo interval). Finally, we were able to decode the age of a memory, and did best when the event was rehearsed. Univariate analyses further revealed a dissociation in left parietal cortex during successful retrieval, wherein rehearsed and recent memories elicited greater activity in SMG/aIPS (a region associated with stimulus salience), while unrehearsed events evoked greater activity in AnG (a region implicated in detailed recollection). Collectively, the findings reveal that various signatures of real-world memory, specifically rehearsal status and temporal remoteness, are detectable from distinct distributed neural patterns.

Talk session 4

Dana Waltzman
Stanford University

Corticostriatal dysfunction and gray matter abnormalities in relation to cognitive skill learning in adolescent siblings of patients with childhood-onset schizophrenia

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Patients with childhood onset schizophrenia (COS) perform poorly on cognitive skill learning tasks and display widespread gray matter (GM) structural brain abnormalities. Healthy siblings of COS patients share some of these impairments in skill learning and structural abnormalities,

suggesting that corticostriatal dysfunction and GM abnormalities are endophenotypes for schizophrenia. We used fMRI to compare activation at two stages of training on a cognitive skill learning task (the Weather Prediction Task-WPT) in non-psychotic, adolescent siblings of patients with childhood onset schizophrenia (COS) compared to controls to determine whether impaired cognitive skill learning in individuals with genetic risk for schizophrenia was associated with specific patterns of neural activation. Results demonstrated corticostriatal dysfunction in COS siblings with a profound skill learning deficit and abnormal pattern of brain activation during skill learning. Next, we investigated whether structural abnormalities could account for the learning deficit, and if there was a relationship to cognitive skill learning. Results revealed smaller GM volume in COS siblings relative to controls in a number of regions, including occipital, parietal, and subcortical regions including the striatum, and greater GM volume relative to controls in several subcortical regions. Volume in the right superior frontal gyrus and cerebellum were related to performance differences between groups on the WPT. Our results support the idea that corticostriatal and cerebellar impairment in unaffected siblings of COS patients are behaviorally relevant and may reflect genetic risk for schizophrenia.

Evan Layher
UC Davis

Monitoring eye movements to dissociate the neural correlates of relational versus item specific memory impairments in schizophrenia

In a previous behavioral study, we used eye-tracking to demonstrate that individuals with schizophrenia (SZ) could demonstrate an eye-movement memory effect for specific item changes in a complex visual scene (e.g., replacing an apple with an orange) but failed to demonstrate an eye-movement memory effect for relational changes (e.g., moving the apple from the counter to the table). This was consistent with evidence of a disproportionate relational memory deficit in SZ. The purpose of the current study was to perform this same eye-movement memory analysis during fMRI to replicate behavioral findings and begin to identify the brain regions responsible for this pattern of group differences. 26 healthy controls (HC) and 24 SZ patients viewed scenes and answered questions about a specific object in the scene such as “Is the apple red?” (item-oriented) or “Is the apple on the table?” (relation-oriented). During testing, subjects determined if scenes were unchanged (Repeat), changed by an item replacement (Item) or item relocation (Relation), or new (Novel). As in the previous study, HC and SZ showed eye-movement memory effects for item changes, but only HC showed eye-movement memory effects for relational changes. HC also showed greater hippocampal (HI), and dorso-lateral and ventro-lateral prefrontal cortex (PFC) activation compared to SZ when correctly identifying relational changes, but there were no between-group differences in PFC or HI regions when correctly recognizing new items in the scene. This eye-movement memory effect may be a feasible way to measure complex cognitive tasks in both human and animal models to develop treatments that specifically target PFC and HI structures to improve relational memory in SZ, potentially leading to better functional outcomes in the disease.

Shai Porat
UC Los Angeles

Personal experience with dance and cortical gray matter thickness in the cognitively normal and mild cognitive impaired elderly population

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Background: Few research studies have explored the effect dancing may have on structural brain changes. Unexpectedly, these studies found lower gray matter volume in areas such as premotor cortex in professional dancers when compared to non-dancers. To our knowledge, no studies have reported on dance experience and structural brain differences in Cognitively Normal (NC) and Mild Cognitive Impaired (MCI) participants at risk for declining into dementia.
Objective: We investigated the differences in cortical thickness of gray matter between those who identified as "Dancers" against "Non-Dancers" from 39 NC and 48 MCI participants. Additionally, we correlated cortical thickness levels between groups to neuropsychological exam scores.
Methods: Participants who previously enrolled in the longitudinal ImaGene study at the Mary S. Easton Alzheimer's Disease Center at the University of California – Los Angeles, were mailed a questionnaire regarding their lifetime experience with music, dance, and song. All participants received structural 1.5T MRI scans and detailed clinical and neuropsychological evaluations. An advanced 3D cortical mapping technique was then applied to calculate cortical thickness values.
Results: Agreeing with previous studies, dancers had significantly *lower* cortical thickness in areas such as primary somatosensory cortex, motor cortex, dorsolateral prefrontal cortex, and Broca's area, when compared to non-dancers; participants in the dance group were a mix of amateurs and professionals. The results remained significant after correcting for age, sex, diagnosis, MMSE, and education. Despite having a thinner cortex (i.e., less gray matter), dancers preformed better in certain cognitive domain tasks such as verbal fluency ($p = 0.041$), verbal recall ($p = 0.006$), and attention/concentration ($p = 0.043$).
Implications: Our results agree with previous MRI studies of dancers, in regards to lower gray matter volume when compared to non-dancers. Correlating cortical thickness to neuropsychological scores may suggest that exposure to dancing may result in an enhancement of cognitive reserve.

Talk session 5

Andrew McCullough
UC Davis

Examining relationships between basal cortisol levels and stress-induced cortisol responses on recognition memory

McCullough A.M., Ritchey, M., Ranganath, C., & Yonelinas, A.P.

It is well established that stress can affect memory processing, and these effects are mediated in part by cortisol levels. Understanding how cortisol levels and stress influence memory-related processes is an important question for disciplines ranging from developmental and educational research to age-related memory deficits and traumatic stress research. We examined the effects of post-encoding stress on recognition memory using a cold-pressor task, and measured cortisol levels before and after the encoding and stress tasks. Basal cortisol levels were negatively related to estimates of recollection and familiarity. In contrast, the magnitude of cortisol response to stress was differentially related to recollection and familiarity estimates such that recollection had an inverted-u relationship with the magnitude of cortisol response, while familiarity estimates increased linearly with the cortisol responses. I will describe these differential relationships with respect to the neuroanatomy of the brain regions involved in recognition memory, and discuss the importance of understanding these relationships for research and applied purposes.

Maureen Ritchey
UC Davis

Medial temporal lobe responses during encoding predict the influence of post-encoding stress on memory

Ritchey, M., McCullough A.M., Ranganath, C., & Yonelinas, A.P.

Stress has pronounced effects on memory processes. For instance, stress experienced shortly after learning has been shown to improve recall and recognition, an effect that has been linked to the influence of stress hormones on medial temporal lobe (MTL) function. It is unknown, however, whether post-encoding stress modulates all memories equivalently, or whether its influence on memory interacts with processes initiated at the time of encoding. One possibility is that post-encoding stress selectively enhances memory for information that received special processing by the MTL during initial encoding. Under this hypothesis, post-encoding stress would alter the relationship between encoding processes and subsequent memory. In this study, we acquired functional magnetic resonance imaging (fMRI) data from healthy young male adults while they encoded emotionally-arousing and neutral images. Immediately after encoding, half of the participants completed the cold-pressor stress task (Stress group) and the other half completed a warm-water control task (Control group). Confirming the effectiveness of this manipulation, the stress task reliably increased salivary cortisol levels from pre- to post-stress. One day later, we assessed participants' recognition memory for the images. Encoding trials were binned according to whether the images were subsequently recollected, familiar, or forgotten, allowing us to investigate neural processes predictive of these different memory outcomes. Because the stress manipulation occurred after encoding, we expected to see differences between the two groups only with respect to how neural processes corresponded to subsequent memory. Indeed, overall activation in the MTL did not differ between the Stress and Control groups. The groups did, however, differ in terms of memory-related activity: a region in the anterior hippocampus was more active for subsequently-recollected than familiar items in the Stress group relative to the Control group. This finding suggests that the anterior hippocampus was involved in initiating memory-related processes that were later augmented by post-encoding stress. Interestingly, these effects did not vary by the emotional properties of the memoranda. Within the Stress group, the hippocampal recollection effect scaled with changes in salivary cortisol, with a larger effect for participants showing a larger change in stress hormones. Taken together, these findings provide novel evidence that stress experienced after learning selectively influences memories tagged by the hippocampus during encoding.

Tara Patterson
UC Los Angeles

Putting the brakes on the brakes: Negative emotion disrupts cognitive control network functioning and alters subsequent stopping ability

The ability to inhibit unwanted responses is critical for effective control of behavior, and inhibition failures can have disastrous consequences in real-world situations. Here, we examined how prior exposure to negative emotional stimuli affects the response-stopping network. Participants performed the stop-signal task, which relies on inhibitory control processes, after they viewed blocks of either negatively emotional or neutral images. In Experiment 1, we found that neural activity and connectivity were reduced following negative image viewing. When participants were required to inhibit responding after neutral image viewing, we observed activation consistent with previous studies using the stop-signal task. However, when participants were required to inhibit responding after negative image viewing, we observed reductions in the activation of ventrolateral prefrontal cortex, dorsolateral prefrontal cortex, medial frontal cortex, and parietal cortex.

Furthermore, analysis of neural connectivity during stop-signal task blocks indicated that connectivity within a subset of the regions activated during stop trials was diminished after negative image viewing. In Experiment 2, we collected behavioral data from a larger sample of participants, and found that stopping performance was impaired after negative image viewing, as seen in longer stop-signal reaction times. The present results demonstrate that negative emotional events can prospectively disrupt the neural network supporting response inhibition.

Poster Abstracts

Wes Ashford
Stanford University

A continuous recognition task paradigm implemented on-line for measurement of memory function

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MemTrax, LLC; City University, London; Psychiatry & Behavioral Sciences, Stanford, Stanford / VA Aging Clinical Research and Alzheimer Centers; Test data provided by HAPPYneuron, Lyon, France

MemTrax is a short cognitive test for memory measurement which implements a "continuous recognition task" (CRT) paradigm on-line. CRT is an approach to memory assessment that is widely used in advanced research on memory mechanisms. CRTs are especially sensitive for early detection of memory problems, such as those caused by dementia and Alzheimer's disease. CRTs are also useful for detecting changes that occur with head injury, altered levels of consciousness, and a variety of other brain illnesses or injuries that cause memory changes. MemTrax provides an efficient on-line CRT for measuring memory as well as attention and recognition reaction time, within a period of less than three minutes. MemTrax users are provided with a set of images on any video screen, which they either look at and remember, or indicate that they recognize a repeated image by a specific movement response, within the shortest period of time possible. MemTrax is implemented as a test with 25 unique images and 25 repeats (5 of the repeats being second repeats). The pictures are scenes or objects occurring in 5 sets of 5 images (e.g., water scenes, mountains, clothing, vehicles, etc.). True-positives and correct rejections are recorded, as well as all reaction times. In a prior study, the test was administered in an audience setting, allowing audience members 5 seconds to indicate on a sheet of paper whether they had seen a picture before, and testing of over 1,000 individuals indicated an age effect on a transformation of percent correct (d'). In examining 18,282 individuals who provided ages, 21 – 99, and gender, took the test for the first time on-line, and performed better than random chance, age explained 4% of the variance in reaction time and 2% of the variance in total errors. The 4% and 2% of the variance were well modelled by an exponential equation, suggesting that performance deteriorates exponentially with age, consistent with Gompertz kinetics. Specific standard deviations for reaction time and total errors at each age allows an estimation of performance impairment at any level of specificity chosen and analysis of performance in older individuals either with respect to optimum young performance or to the age-matched population. In conclusion, MemTrax is a quick, fun, widely accessible memory assessment tool providing information that can be analyzed to determine whether MemTrax can screen effectively and efficiently for a variety of brain dysfunctions. Further analysis is needed to determine test-retest stability and the correspondence to traditional memory tests.

Yevgeniy Gnedash
UC Davis
Memory is often a tricky construct to study and often there are more variables to consider than we can consider at any given point. Among many effects observed with memory, one of the most robust is that of emotional effects. Stress is often one of the main methods of studying negative affect effects on memory, and has some of the most robust results (Luethi, Meier, &Sandi 2009; Eich & Metcalfe 2009; Kazen, Kuenne, Frankenberg & Quirin, 2012; Li, Chan & Luo, 2010). However, some research is starting to suggest that emotion-based effects are mostly explained by arousal. In a series of experiments, we show that positive and negative emotion impact memory differently when matched for arousal, suggesting that arousal does not fully explain these effects.

Brian Lopez
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The Uncertain Relationship between BOLD Variability and Age

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Given the vast amount of complex data typically acquired across scans in fMRI studies, researchers tend to focus their efforts on measures of central tendency of the time series. However, an increasing number of researchers have begun to systematically explore within-individual brain signal variability. Rather than being attributed to mere noise, their findings suggest that moment-to-moment variability is actually a functional property of the human brain and is related to task performance and changes in the brain associated with aging and disease. Given this rising interest in BOLD signal variability, it is important to address certain methodological issues and possible confounds that may obscure the relationship of interest. Toward that end, we demonstrate the impact of a variety of analysis choices on the relationship between age and BOLD variability with data acquired from participants ages 18-75 during a recognition memory test involving criterion shifting. We show that subtle changes in preprocessing or analysis strategy can have a profound effect on the qualitative story told by the data—for example, swinging from a map showing extensive positive correlation between age and BOLD variability to one showing mostly negative correlation when more stringent corrections (i.e., partialing out grand mean intensity normalization factor and mean relative motion) are applied. Given the considerable uncertainty regarding what the true pattern is for our dataset, we believe caution should be exercised when making claims about how within-individual brain variability is related to other variables such as age. As we have illustrated, the relationship depends critically on the exact analysis pipeline used.

Nikki Marinsek
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Expectation Violation in the Brain

Nikki Marinsek, Benjamin Turner, Michael Miller

Research on split-brain, delusional, and stroke patients suggests that the left hemisphere concocts stories, or hypotheses, to explain unexpected events and the right hemisphere evaluates these hypotheses. We aimed to identify brain regions that support hypothesis formation and evaluation in healthy participicants by recording their brain activity with fMRI as they attempted to generate appropriate category labels for a series of word sets. We used novel word sets that were designed to either elicit hypothesis formation and evaluation (“ad hoc” word sets) or minimize these processes (“automatic” word sets). Based on our assumption that subjects

create and verify hypotheses to a greater extent 1) during the period before generating a possible label and 2) during ad hoc trials, we looked for differential brain activity in ad hoc trials vs. automatic trials and TRs before vs. after label generation. Both contrasts revealed increased activity in the left dmPFC, right dmPFC, and left vlPFC, which we attribute to hypothesis formation, hypothesis evaluation, and memory retrieval. In a follow up experiment, we identified brain regions that are sensitive to expectation violations, since individuals tend to revise or reject their current beliefs and search for new explanations when expectations are violated. We found that activity increases in the left dmPFC, right dmPFC, and left vlPFC when a word violates expectations, supporting the idea these areas may support the search and evaluation of new explanations.

Kimford Meador
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Mechanisms of Conscious Tactile Perception

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Background: Mechanisms of conscious perception are uncertain. In this study, we examined brain areas involved in conscious perception of somatosensory stimuli during a tactile extinction task.
Design/Methods: Electrical pulse (5ms) trains (10Hz) included targets (7-pulses to right index finger) and masks (8-pulses to left index finger extending 50ms before and 50ms after targets). Target intensity was adjusted trial-to-trial to compensate for threshold drift (10% sham trials). Each run had 68 trials with random interstimulus interval (4.5 to 6s; mean=5.2s). fMRI: T1-weighted MP-RAGE images (TR=3200ms, TE=354ms, 256×256 matrix scan with 160 slices and 1×1x1mm resolution), homogeneity field maps, and standard resolution functional MRI (iPAT T2* EPI scan uses a 90-degree flip angle, TE= 35ms, TR=2000ms, 64×64 matrix, 192×192mm FOV, 36 ascending 3mm thick slices with 20% slice gap (effectively 3×3×3.6mm between voxel centers) with continuous acquisition (two ~13 minute runs). Exploratory analyses of directed functional connectivity were conducted.
Results: 15 healthy dextral adult volunteers (mean=21.9 years, 6M/11F). Compared to non-detected targets, areas activated with target perception included contralateral (left) postcentral gyrus, claustrum, insula, and thalamus when target stimuli were more intense for perceived than non-perceived stimuli. Directed connectivity was toward the contralateral primary sensory area. When intensities of perceived and non-perceived stimuli were similar near threshold, activated areas were right thalamus/claustrum/insula (contralateral to mask). Directed connectivity was from the right midbrain.
Conclusions. The findings suggest that perception of lateralized somatosensory stimuli depends on a contralateral corticothalamic network and directed connectivity to the primary somatosensory region. In contrast, failure of perception with targets and masks near perceptual threshold is associated with greater ipsilateral activation in the claustrum, insula and thalamus along with directed connectivity from the right midbrain. Related brain mechanisms are likely involved in other forms of conscious perception and processes strongly affected by perception such as episodic memory.

Shaozheng Qin
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Hippocampal-neocortical functional reorganization underlies maturation of children's memory-based problem solving skills

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It has been known for several decades that Piaget's discrete development stages and abrupt transitions in conceptual knowledge and problem solving approaches is an inaccurate model of children's cognitive development, despite the continued use of this approach in the field of education and its depiction in textbooks across fields.

It is now known that a hallmark feature of children's cognitive development is a gradual transition from procedure-based (such as counting) to efficient memory-based problem solving approaches. At any given time, children might use one or several strategies to solve the same types of problems; for instance, they may count on their fingers to solve one arithmetic problem and then retrieve the answer from long-term memory to solve the next problem. What changes with development is the mix of strategies used in problem solving, with the use of inefficient and effortful procedure-based strategies decreasing in frequency and use of efficient memory-based strategies increasing in frequency. This pattern of developmental change has been demonstrated for children's learning of arithmetic, spelling, scientific reasoning, and social problem solving, among other domains. In other words, a developmental shift in the mix of strategies used in problem solving is a cardinal feature of children's cognitive development.

By integrating unique longitudinal and cross-sectional brain imaging data with behavioral strategy assessments, we examined the functional maturation of brain systems underlying the transition from procedure-based to memory-based problem solving. We demonstrate how the hippocampal system and its functional circuits play a pivotal role in children's cognitive development. Results from several neuroimaging studies revealed that strategic shifts from counting to memory-based problem solving are paralleled by increased hippocampal and decreased prefrontal-parietal engagement from ages 7 to 9 during childhood. Critically, longitudinal gains in children's use of memory-based strategies were predicted by increased hippocampus-neocortical functional connectivity. This hippocampal dependence, however, decreased significantly from middle childhood through adolescence into adulthood. Follow-up longitudinal studies in children ages from 9 to 14 revealed an initial increase and then a subsequent decrease in hippocampal engagement in solving basic addition problems. Next, we used novel trial-by-trial multivoxel representational similarity analysis to investigate how neural representations get refined with maturing problem solving strategies. Remarkably, despite the decrease in overall activation levels, inter-problem stability of neural representations increased with maturation of memory-based problem solving strategies. Our study establishes a critical link between hippocampal-neocortical functional reorganization and shifts in children's problem solving strategies, a key feature of children's knowledge acquisition and cognitive development across skill domains.

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Jared Stokes
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Dissociable codes within the human hippocampal subfields during spatial context processing

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Episodic memory formation is believed to depend upon spatial context representation within the human hippocampus, but it is unclear how the hippocampal circuitry supports this function. In this study, participants underwent high-resolution fMRI targeting the medial temporal lobes while immersed in virtual environments featuring unique contextual layouts. Participants were asked to discriminate between four "cities", which were created by systematically morphing configurations of stores from square to circle. We found that small changes to spatial context correlated with changes in pattern similarity within CA3/DG, but not within CA1. In contrast, CA1 exhibited higher pattern similarity for the geometrically distinct cities (square or circle) when compared to the morphed cities. Interregional pattern similarity between CA1 and parahippocampal cortex was also greater for the geometrically distinct cities. Overall our findings suggest a functional dissociation between CA3/DG and CA1 within the human hippocampus during the processing of spatial context, with CA3/DG differentiating similar environments and CA1 integrating stored cortical input into novel spatial representations.

Monica Thieu
Stanford University

Reduced working memory predicts impaired long-term memory in chronic media multitaskers

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Due to failures to filter distracting information, working memory capacity appears to be lower in heavy relative to light media multitaskers. One potential consequence of lower working memory capacity is worse long-term memory for the working memory targets. Here, we examined subsequent long-term memory for items previously encountered in a working memory task, as well as whether long-term memory performance and working memory capacity vary with media multitasking level. Participants (N=139) were surveyed on their media multitasking habits (heavy media multitaskers=26, light media multitaskers=31), and then performed a working memory task involving trial-unique objects, for which recognition memory was later tested. Replicating prior reports, heavy media multitaskers exhibited reduced working memory capacity. Signal detection analyses indicated that this reduced capacity was due to reduced *sensitivity* (A'_{WM}), suggesting that heavy media multitaskers held fewer or less precise target information in working memory. Moreover, lower working memory capacity predicted worse long-term memory performance, with sensitivity in the working memory task predicting sensitivity in the recognition memory task. These findings suggest that heavy media multitaskers' difficulties in encoding and/or maintaining target objects in working memory, possibly due to failures to filter out distraction, result in a reduced ability to later recognize those objects as having been previously encountered.

Jacob Vogel
UC Berkeley

Subjective cognitive complaint (SCC) may be one of the earliest symptomatic manifestations of Alzheimer's Disease (AD). In this cross-sectional study, we explore the relationship between SCC and markers of brain structure and function, and whether these relationships differ in the presence of beta-amyloid (Aβ) plaques.
A subjective cognitive complaint measure (GDS-SCC) was generated from the Geriatric Depression Scale (GDS) using principle axis factor analysis on data from 347 healthy, non-depressed (GDS < 11) elderly individuals from the Berkeley Aging Cohort Study. Structural magnetic resonance imaging (MRI) and resting ^{18}F-fluorodeoxyglucose positron emission tomography (FDG-PET) scans were acquired from a subsample (n = 112, mean age 76, 56% female). Pittsburgh Compound B (PiB)-PET scans were acquired to determine the presence (PiB+) or absence (PiB-) of Aβ pathology. Whole-brain voxelwise approaches were used to assess the relationship between glucose metabolism (measured with FDG-PET) and GDS-SCC. Hippocampal volumes (HV) were obtained from the MRI using Freesurfer. Relationships between GDS-SCC and other variables were assessed across the whole sample, as well as stratified by PiB status.
GDS-SCC was correlated with other measures of cognitive self-appraisal ($p<0.05$). GDS-SCC predicted global cognition across the whole sample ($p<0.05$), but predicted episodic memory only in PiB+ subjects ($p<0.05$). More cognitive complaints were related to lower glucose metabolism in bilateral caudate nuclei and subgenual anterior cingulate cortex ($p<0.005$ uncorrected, $k > 800$), regions associated with affect and depression. These results were replicated in a separate sample of 334 cognitively normal elderly adults from the Alzheimer's Disease Neuroimaging Initiative. However, in both samples, the relationship between metabolism in these regions and GDS-SCC was present only in PiB- individuals. FDG in the SCC-ROI predicted episodic memory and HV across the whole sample, but HV was related to memory in PiB+ subjects only.
We show SCC to be associated with variance in brain structure and function in healthy elderly. We suggest that this relationship occurs through two distinct pathways according to Aβ status. Complaints in PiB+ subjects may be due to Aβ-dependent changes to hippocampal structure causing a valid perceived decline in memory. In PiB- individuals, complaint may be driven by subsyndromal affective factors, evidenced by metabolic dysfunction in a cortico-striatal network crucial to emotional encoding and integration. The accurate assessment of memory performance by PiB+ individuals supports SCC as an important feature of preclinical AD.

Sarah White
UC Davis

Performance on the Relational and Item Specific Memory Encoding task (RISE) in Individuals at Clinical High Risk for Psychosis

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Background: People with schizophrenia have disproportionate impairments for memory that requires forming relational representations (such as relational encoding or associative recognition) compared to their memory for simple item representations. It has not been examined whether this pattern of memory impairments is a high-risk trait marker, observable prior to the onset of a psychotic disorder, or if this pattern of memory performance is a state marker that arises as the illness progresses. We investigated whether individuals at clinical high risk for psychosis (CHR) show the specific pattern of memory deficits observed in schizophrenia.
Methods: 140 individuals; 45 healthy controls (HC), 73 first episode schizophrenia participants (FE), and 22 CHR participants matched for parental education, handedness, and gender, participated in the study. After clinical assessment, participants performed the RISE task, which previously demonstrated a differential impairment in relational versus item specific memory in individuals with schizophrenia.
Results: CHR and FE individuals both showed worse memory performance then HC participants for item, relational and associative memory. CHR and FE individuals did not have significantly different memory performance from each other in any of the memory tasks.

	CHR	FE	HC	HC vs FE	HC vs CHR	FE vs CHR
	Accuracy (d')	Accuracy (d')	Accuracy (d')	p-value	p-value	p-value
Item Recognition Item Encoding	3.596	2.979	2.983	<.001	.005	.986
Item Recognition Relational Encoding	3.378	2.784	2.679	<.001	<.001	.563
Associative Recognition Relational Encoding	2.402	1.672	1.785	<.001	.002	.540

Conclusions: Episodic memory impairments occur in individuals at CHR for psychosis prior to a psychotic break. Participants at clinical high risk for developing psychotic disorders have a similar pattern of memory deficits to those observed in individuals with schizophrenia. These results suggest that specific impairments in relational encoding and associative recognition appear before the first episode of a psychotic disorder and may serve as a high-risk trait marker.

Jinchen Yang
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ERP Abnormalities Elicited by Word Repetition in Fragile X-associated Tremor/Ataxia Syndrome (FXTAS) and Amnestic MCI

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Background: Fragile X-associated tremor/ataxia syndrome (FXTAS), a neurodegenerative disorder caused by *FMR1* gene premutations, typically associated with frontal-subcortical type cognitive impairments. High prevalence (~50%) of superimposed Alzheimer's pathology has been reported in *FMR1* premutation carriers, and standardized neuropsychological tests have not yielded any robust discriminators between FXTAS and Alzheimer's disease (AD) dementia. The similarities/differences in memory processes between FXTAS and early AD remain underexplored.

Methods: 32-channel event-related potentials (ERPs) were obtained from a semantic judgment task in which semantically congruous (50%) and incongruous pairs repeat pseudorandomly. The N400 and late positive component (LPC) of 25 FXTAS patients (M_{age} = 71.2, MMSE = 26.6) were compared to a matched group of 25 patients with MCI or early AD (1 mild AD dementia, 24 amnestic MCI, of whom 18 later converted to AD; M_{age} = 73.4, MMSE = 26.4), and 25 healthy elderly.

Results: Both patient groups showed similar reductions in the N400 repetition effect and N400 congruity effect amplitudes, compared to controls, reflecting abnormal semantic priming and repetition priming. The MCI/AD group, however, had significantly smaller LPC word repetition effects and poorer learning and memory on the CVLT than FXTAS. The LPC and N400 repetition effects both correlated with verbal memory across all subjects, but only the N400 correlated with memory in FXTAS.

Conclusion: FXTAS patients show relative sparing of the LPC repetition effect, and less disruption of explicit memory than prodromal/early AD. N400 abnormalities in FXTAS appear to account for much of their mild impairments in verbal learning and memory.