TALK SESSION 1

Jesse Rissman

Striatal contributions to explicit remembering: Effects of memory strength and decision confidence

Jesse Rissman & Anthony D. Wagner

Dept. of Psychology and Neurosciences Program, Stanford University

Functional neuroimaging investigations of episodic retrieval consistently identify a network of prefrontal, parietal, and medial temporal lobe regions that exhibit greater activity when individuals recognize previously encountered stimuli than when they perceive stimuli as novel. Interactions between striatal structures and both prefrontal cortex and the medial temporal lobe raise the possibility that basal ganglia processes contribute to explicit remembering. Here we report converging evidence from two fMRI studies that bilateral regions of the ventral striatum (VS) are highly sensitive to the perceived mnemonic status of items during explicit, but not implicit, retrieval tasks, and that the magnitude of activation varies with memory decision confidence. In the first experiment, participants were scanned while rating their level of recognition memory confidence for face stimuli on a 5-point scale. Areas of VS exhibited enhanced activity to old vs. new stimuli. Importantly, rather than showing a monotonic scaling of activity with mnemonic strength, activity levels scaled with the distance of participants' responses from the old/new decision bound––activity levels were greater for hits and correct rejections that were made with the highest confidence relative to those made with low confidence. By contrast, when participants made male/female judgments on studied and novel faces (i.e., implicit retrieval), the old/new effects in VS were abolished. A second experiment revealed similarly robust old/new effects in overlapping regions of VS while participants made source recollection judgments about studied and novel object stimuli, but not while they made semantic judgments (i.e., implicit retrieval) about these stimuli. Taken together, these two studies demonstrate that

regions of VS show a marked sensitivity to the mnemonic status of stimuli during explicit memory tasks. The dependence of these effects on the explicit retrieval demands of the tasks suggests that VS may play a role in goal-directed control processes that facilitate the recovery of memories, evaluate the retrieved information, or select the appropriate behavioral decisions. Alternatively, the activity in VS may track the level of intrinsic reward associated with successful task performance. Functional connectivity analyses promise to further inform how interactions between VS and prefrontal, medial temporal, and midbrain structures contribute to explicit remembering.

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Bradley Voytek

Prefrontal cortex and basal ganglia contributions to visual working memory

Bradley Voytek & Robert T. Knight, UC Berkeley

Visual working memory (VWM) is a remarkable skill dependent on the brain's ability to construct and hold an internal representation of the world for later comparison to an external stimulus. Prefrontal cortex (PFC) and basal ganglia (BG) interact within a cortical and subcortical network supporting VWM. We used scalp electroencephalography in a group of patients with unilateral PFC or BG lesions to show that these regions play complementary but dissociable roles in VWM. PFC patients show behavioral and electrophysiological deficits manifested by attenuation of extrastriate attention and VWM-related neural activity only for stimuli presented to the contralesional visual field. In contrast, patients with BG lesions show behavioral and electrophysiological VWM deficits independent of the hemifield of stimulus presentation but have intact extrastriate attention activity.

Furthermore, patients with BG lesions are perform significantly worse during the first few trials compared to PFC patients and controls, despite an explicit comprehension of the task rules and requirements. The results support a model wherein the PFC is critical for top-down intrahemispheric modulation of attention and VWM with the BG involved in global VWM processes.

Darlene Archer

Individual Differences in Controlling Top-down Attentional Selection

Darlene Archer & Joy Geng, Ph.D.
University of California-Davis

Attention can be directed voluntarily by goal relevant information or it can be captured involuntarily by perceptually salient input. For example, the maintenance of target information in WM can facilitate strategic allocation of attention to an item that fits target criteria or away from items that fail to meet target criteria (Woodman & Luck, 2007). Similarly, eye movement data suggests that top down attentional selection can be controlled when individuals know that a perceptually salient object cannot be the target (Geng & DiQuattro, in press). We measured individuals' visual working memory capacity using a modified version of the change detection task (Luck & Vogel, 1997). Then we examined individuals' performance and eye movements in a visual search task where a cue provided information about the salience of either the target or distractor on a trial-by-trial basis. High-capacity individuals demonstrated greater ability overriding attentional capture than low-capacity individuals, particularly when the cue indicated that the distractor was salient.

Elissa Aminoff

Factors that predict individual differences in criterion shifting in recognition memory

Aminoff, E., Clewett, D., Freeman, S., Grafton, S., & Miller, M.

UC Santa Barbara

A variety of information is used to establish a criterion in recognition memory, such as the mnemonic qualities of the memory, probabilities of a given environment, and consequences of the judgment. If the evidence of a stimulus surpasses the criterion, it is considered an old stimulus. The present study modulated the environmental information given about a stimulus, specifically the likelihood that it was old (either 70% or 30%). In response to this information, some participants switched their criterion based on the probability information (a liberal criterion in the 70% condition, and conservative criterion in the 30% condition), whereas other participants used the same criterion regardless. Our goal was to examine the neural and behavioral factors that could predict whether a participant switched criterion. This study consisted of a pool of 95 participants, 70% of which were combat experienced officers of the army; two independent memory tests; functional MRI at test; and a battery of questionnaires that assessed personality traits, cognitive style, demographic information, and mental state during testing. Our results indicated that behavioral measures (including personality and cognitive characteristics) could account for 35-42% of the individual variability. Differential neural activity analyzed through ROI analysis could account for an additional 24% of the variability above that of the behavioral measures. These results provide a comprehensive examination of the underlying factors that account for individual variability in criterion shifting. Moreover the results provide a clear demonstration that neuroimaging is a critical tool to examine individual differences in behavior over and above paper and pencil assessments.

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Bryce Mander

Sleep Restores the Human Brain Capacity to Learn

Bryce A. Mander[1], Sangeetha Santhanam[1], Matthew P. Walker[1,2]

[1]Sleep and Neuroimaging Laboratory, Department of Psychology, [2]Helen Wills Neuroscience Institute, University of California, Berkeley, CA 94720

In contrast to consolidation, the role of sleep in facilitating the initial stage of memory encoding remains largely uncharacterized. NREM sleep-oscillations have been proposed to restore neural dynamics supporting optimal memory processing. Here we test the hypothesis that episodic learning ability deteriorates with continued time awake, but that NREM sleep-spindle oscillations restore such hippocampal encoding capacity. Thirty-nine participants (20.7±0.3 years) performed two separate episodic memory-encoding sessions: 12-noon and 6PM. After the first learning session participants either remained awake for 6-hr (No-Nap group; n=19), or obtained a 100-minute high-density EEG monitored sleep period (Nap-group; n=20). Episodic learning ability was measured using a face-name associative encoding task known to demand hippocampal-dependent processes. Face-name encoding capacity deteriorated across the 6hr waking interval in the No-Nap group, yet sleep blocked this deterioration in the Nap-group, and actually enhanced learning capacity ($p=0.049$). The enhancement of learning capacity in the Nap-group correlated significantly with NREM stage-2 ($p=0.015$), and specifically the number of fast sleep spindles over left prefrontal cortex ($p=0.018$). EEG source-mapping analysis of these spindles revealed a time-series loop of current-density activity between medial-temporal and left prefrontal regions. Together, these findings demonstrate that episodic learning ability is not stable across a waking day,

deteriorating over a 6-hr period. However, sleep, and specifically NREM-stage-2 fast spindles, restored this hippocampal-dependent encoding capacity, with source analysis suggesting this restoration may be dependent on coordinated fronto-temporal activity during these burst-oscillations. Such evidence supports a model of sleep-dependent hippocampal-neocortical memory transfer, which, as a consequence, reinstates efficient next-day learning ability.

Benjamin Levy

Cognitive control and right ventrolateral prefrontal cortex

Benjamin J. Levy & Anthony D. Wagner

Dept. of Psychology and Neuroscience Program, Stanford University

Delineating the functional organization of prefrontal cortex is central to advancing neural and psychological models of goal-directed cognition. Over the past decade, considerable functional neuroimaging data indicate that specific forms of cognitive control are consistently associated with distinct subregions of ventrolateral prefrontal cortex (VLPFC). While this has led to increasingly specified models of left VLPFC functioning, less is known about functional differentiation within right VLPFC. Recently, two proposals have dominated theories about the role of right VLPFC: stopping of motor responses and reflexive orienting to abrupt perceptual onsets. At present, it remains unclear whether these processes activate the same or distinct VLPFC subregion(s), and whether these putative processes are inherently linked (e.g., stopping typically requires orienting to an infrequent stop cue). Moreover, it is unclear whether and how these perspectives can account for the broad range of goal-directed tasks that activate right VLPFC. For example, it is not obvious how either could account for the frequent observation of right VLPFC

activation during processing of, and episodic memory for, visuospatial stimuli. Here we review these disparate literatures through meta-analysis of right VLPFC function. ALE analyses of the stopping and reflexive orienting tasks revealed overlap within the inferior frontal junction along with divergence in more inferior VLPFC subregions. These results advance understanding of the functional heterogeneity within right VLPFC, and we discuss how this heterogeneity relates to hierarchical theories of PFC functional organization and cognitive control.
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Laura Libby

Unitization Effects on Episodic Memory in Schizophrenia

Laura A. Libby[1], Charan Ranganath[1], Andrew L. Haskins[1], Ian Ramsay[2], Cameron S. Carter[2], J. Daniel Ragland[2]

[1]Psychology, University of California at Davis, Davis, CA,[2]Psychiatry and Behavioral Sciences, University of California at Davis, Sacramento, CA

Patients with schizophrenia may be impaired at relational memory (remembering relationships amongst items and the context in which they were encountered), even when memory for items is intact. This study investigated the impact of reducing relational demands by having patients encode pairs of items as a single unit (i.e., "unitization"). Preliminary data were obtained on nine patients and five controls who studied 280 noun pairs. Pairs were processed either as a single unit by requiring formation of a compound word ("unitized" trials) or as separate units by encoding them as part of a sentence ("non-unitized" trials). Participants were subsequently administered an associative recognition task including initial target pairs, and 280 recombined pairs. Receiver operator characteristics (ROC) were calculated to obtain estimates of recollection and familiarity. Unitization

successfully increased familiarity-based retrieval, and this memory facilitation effect ($p<0.05$) was of similar magnitude for patients and controls. In contrast, recollection was not facilitated by the unitization procedure, and patients' recollection of unitized and non-unitized information remained close to zero. This study provides preliminary evidence that patients may benefit from remediation strategies that encourage them to encode multiple items as a single combined representation to reduce relational memory demands and facilitate familiarity-based retrieval. Additional data will be obtained to confirm these preliminary findings, and future fMRI studies will investigate the hypothesis that patient deficits in hippocampal versus perirhinal function may account for this pattern of behavioral findings.

Jacob Bollinger

Deficits in expectation-driven functional connectivity underlie memory impairments in normal aging.

Jacob Bollinger, Michael T. Rubens, Edrick Masangkay, and Adam Gazzaley

W.M. Keck Center for Integrative Neurosciences, University of California, San Francisco

Expectations generated by predictive cues increase the efficiency of perceptual processing of complex stimuli (e.g. faces, scenes), however the impact that this has on working memory (WM) and long-term memory (LTM) has not yet been investigated. Here, healthy young and older adults performed delayed-recognition tasks that differed only in stimulus-category expectations, while behavioral and functional magnetic resonance imaging (fMRI) data were collected. Univariate and functional-connectivity analyses were utilized to examine expectation-driven, pre-stimulus neural modulation, the networks that regulate this modulation and subsequent memory performance. Analysis of behavioral data revealed age X WM and age X LTM interactions, such that predictive category cuing was associated with enhanced WM and LTM for faces in younger adults, while predictive-cue associated

WM or LTM benefits were absent in older adults. In younger adults, baseline activity shifts were present in a face-selective region of the visual association cortex (i.e., fusiform face area (FFA)), but were absent in older adults. In addition, there was an age-related decrease in functional connectivity between FFA and right inferior frontal junction (IFJ), middle frontal gyrus (MFG), and intraparietal sulcus (IPS), which was correlated with the magnitude of FFA pre-stimulus activity modulation only in younger adults. Moreover, while FFA connectivity with IFJ predicted enhanced expectation-related WM performance, and FFA connectivity with the MFG predicted LTM improvements in younger adults, these correlations with performance were not evident in older adults. These data suggest that normal aging is accompanied by functional changes in frontal-parietal top-down networks that mediate expectation-related processes, which are associated with impaired utilization of predictive information to guide optimal WM and LTM performance.

POSTER SESSION

Milagros Copara

Brain Networks Underlying Spatial and Temporal Source Representation

Milagros Copara, Eve Isham, Wei-chun Wang, Andy Yonelinas, Arne Ekstrom
UC Davis

Episodic memories permeate our lives and define past events. Time and space are critical and integral components of episodic memory; without these essential elements, we would not be able to discern our memories from one another. The neural contributions to these components, however, remain unclear. Spatial and temporal source memory have been examined in several paradigms, but none of them to date have effectively been able to isolate each of these components in order

to test them independently and simultaneously. In our paradigm, we accomplish this by having subjects navigate a virtual environment with various stores, located equidistant to the center, where they encode both the spatial locations and the order in which they encounter each store. To explore the environment, the subjects are instructed to deliver a passenger to each store in a specific order, thus experiencing unique spatial routes and temporal order. During functional magnetic resonance imaging (fMRI) using a 32 channel coil with a 3T Siemens Trio Total imaging matrix (TIM) scanner, subjects retrieved spatial and temporal source information relevant to the task. Subjects first saw a reference store and answered if they saw that store previously. Subjects were then asked to compare two other stores' spatial locations (in the spatial block) or temporal distances (in the temporal block) to the reference store and answer which store is closer spatially or temporally. Imaging brain activity with echo planar imaging (EPI) sequences 2x2x2 mm, we registered our individual activations onto the anatomical images (whole brain 1x1x1 mm MPRAGE sequences) to determine the area active during the task. We conducted both region of interest analyses based on expected areas of brain activation (hippocampus, parahipopcampal cortex, and prefrontal cortex) and whole brain contrasts. Our results show that there is equal hippocampal activity for both spatial and temporal tasks, although hippocampal activity did discriminate between correct and incorrect source retrieval. Furthermore, the prefrontal cortex was uniquely activated for the temporal task, and the parahippocampal cortex was uniquely activated for the spatial task. These results indicate that while spatial and temporal information may be processed by independent networks in the brain, there may be a convergence of these two components of source memory in the hippocampus. This convergence may result in a common source representation that contributes significantly to the encoding and retrieval of our episodic memories.

Kyle Lyman

Neural correlates of response inhibition after-effects

Joaquin A Anguera 1, Kyle Lyman 2, and Adam Gazzaley 1

1. The University of California San Francisco, San Francisco, California

2. The Ohio State University, Columbus, Ohio

Motor inhibition has been studied extensively in recent years through the use of the stop-signal paradigm (Logan and Cowan 1984). Several stop-signal studies have reported a longer reaction time to a 'GO' signal when the immediately preceding trial involved the presentation of a stop signal (Rieger and Gauggel 1999). In the present study, we examined the underlying neural correlates of this behavioral after-effect, hypothesizing that these measures may be indicative of disengagement/inhibition from a previously primed state. Alternatively, this effect may reflect switching between 'GO' and 'Stop' task sets. 19 young adult participants (18-30yrs) performed 6 blocks (100trials/block) of the stop-signal task, with stop-signals appearing on 25% of trials. EEG recordings were taken simultaneously. The ERP effects revealed no conditional modulation of visual attention (P1/N170) or conflict (N2) at the electrode of interest, PO7 (determined by greatest modulation amongst all conditions). ERSP theta (4-7Hz) and alpha (8-12Hz) bands were examined at the FCZ electrode for each condition between -3000 and 1000 msec. There was a difference in ERSP synchronization during the inter-trial interval following a stop-signal trial, in line with neurophysiological indices of strategy development (Smith, MeEvoy, Gevins 1999) that posit frontal midline theta rhythm is associated with the maintenance of distinct task mental sets. These findings suggest that behavioral after-effects may better reflect the conscious decision between task sets ('GO' and 'Stop'), rather than a function of persistent inhibition-related resources.

Joshua Phillips

Rule Maintenance Effects on Episodic Memory in Schizophrenia

Phillips, J., Ragland, J.D., Ranganath C., Ramsay I.S., Heusser A., Niendam, T.A., Yoon J.H., Solomon M., Carter C.S., UC Davis

Background: Individuals with schizophrenia have difficulty maintaining rules to guide behavior, leading to errors on inhibition tasks like the Stroop. The current study tests whether these same rule maintenance problems might help explain episodic memory deficits in patients with schizophrenia.

Methods: Sixteen healthy controls and seventeen patients underwent fMRI while encoding words during 2 conditions:
1) "Rule" – a living/nonliving judgment was made when the color of target words matched the color of a surrounding box. A "skip" response was made when color of non-target words did not match.
2) "No-Rule" – living/nonliving judgments were made for all words. Subjects were instructed to encode only items for which they made a living/non-living judgment. A subsequent recognition task was performed outside the scanner requiring discrimination of target and non-target items from new items.

Results: There were no group differences in encoding task performance, with both groups performing above 90%. Subsequent memory analysis revealed an interaction; patients were uinimpaired in the No-Rule condition, but were impaired in their ability to facilitate memory for targets and inhibit memory for non-targets in the Rule condition. This was accompanied by reduced prefrontal cortex (PFC) activation in patients during the Rule condition in rostrolateral and anterior cingulate regions.

Conclusions: These results provide preliminary evidence that episodic memory impairments in schizophrenia are most prominent when the learning context requires

memory facilitation for some items and inhibition for others. This appears due to dysfunction in areas required for higher-order rule representation (rostrolateral PFC) and conflict detection (anterior cingulate).

Luke Jenkins

Accurate temporal context memory is associated with greater multivoxel pattern change in the prefrontal cortex

Luke Jenkins, UC Davis

One of the defining features of episodic memory is the ability to recall an event in its appropriate temporal context. In this fMRI experiment, we sought to determine whether trial-to-trial change in the pattern of activity across voxels during an encoding task would predict temporal accuracy at recall. Participants were scanned during 72 trials of a serial order working memory task involving pictures of common objects. Following scanning, they were shown one object from each of the encoding trials and asked to indicate approximately when during the course of the experiment this object had been encountered by marking its position on an horizontal line. A standard GLM analysis revealed delay-period activity in the ventro-, dorso-, and rostrolateral prefrontal cortex (RLPFC) that predicted accuracy on the subsequent memory task. We then used these clusters as ROIs in a separate multivariate analysis. Within each ROI, multivoxel activation patterns were recorded from the delay period of each trial, and a measure of multivariate distance (Euclidean) was calculated between each trial and the immediately adjacent trials (lags +/- 1,2,3,4). Repeated-measures ANOVA revealed a significant effect of lag in the RLPFC ROI, such that the activation pattern for a given trial was more similar to the pattern at lag +/- 1 than at +/- 4. Moreover, the distance between a given trial and its adjacent neighbors in either direction was greater for accurate than for inaccurate trials. The fact that trial-to-trial pattern distinctiveness within the RLPFC

predicted subsequent temporal accuracy constitutes novel evidence for the importance of this region in temporal context encoding.

Danielle King

Left parietal activation during retrieval of perceived and imagined events

Danielle King, UC Santa Barbara

The parietal old/new effect is the common finding that regions in left posterior parietal cortex (PPC) are more active during recognition of old than new items. Explanations for this effect include the output buffer hypothesis, proposing that activity reflects the representation of contextual details associated with an episodic memory, and the mnemonic accumulator hypothesis, suggesting that activity reflects the subjective perception that information is old (Wagner, Shannon, Kahn, & Buckner, 2005). We scanned subjects in a reality-monitoring experiment to test whether a contextual detail or subjective perception account could better explain activation in left PPC. Subjects perceived and imagined objects in response to cue words, and were then given a surprise memory test, where they saw old and new words, and judged whether each was previously perceived, imagined, or new. Studies have shown that memories from perception are characterized by greater contextual details than memories from imagination (Johnson, Hashtroudi, & Lindsay, 1993). Therefore, we predicted that if left PPC represents contextual details of episodic memories, than activation should be greater during retrieval of perceived than imagined events. Further, the parietal old/new effect should be more robust during retrieval of memories from perception than imagination. In contrast, if activity reflects the subjective perception that information is old, than activity should be similar across conditions. However, on new trials, activity should be greater for items mistakenly judged as old (false alarms) than those accurately recognized as new (CRs). The results strongly support the predictions of an episodic buffer account.

Theodore Zanto

Spatio-temporal dynamics in working memory for motion direction: An fMRI guided EEG/TMS study

Theodore Zanto, UCSF

Recent studies have indicated that a region within the prefrontal cortex (PFC), the inferior frontal junction (IFJ), is engaged in encoding visual features into working memory, yet the necessity of this region and the timing underlying frontal-posterior communication remains unclear. Here, we utilize transcranial magnetic stimulation (TMS) in conjunction with electroencephalography (EEG) to explore the network dynamics between the PFC and visual association cortex (VAC) during a memory-for-direction task. The experiment consisted of two visits: an initial functional magnetic resonance imaging (fMRI) session to identify TMS targets and a second visit where participants performed the same task as the first session, but EEG was recorded while single pulse TMS was applied. Each trial consisted of two motion stimuli with a 2000 ms inter-stimulus-interval after which participants were required to indicate with a button press whether the two directions of motion were the same or different. Three TMS targets were identified based on the individual participant's fMRI data: IFJ (PFC), V5 (VAC) and vertex (control). During the second session, each of the three TMS target sites were stimulated during separate blocks. A single TMS pulse was applied either -100, -50, 0, 50, 100 or 150 ms post-stimulus one onset (i.e. the stimulus to be remembered). Behavioral and neural measures converge to show that PFC-VAC communication are engaged in an anticipatory fashion and remains online during stimulus presentation, which optimizes encoding motion direction into working memory.

Jin-Chen Yang

Default Mode Network Dysfunction in Mild Alzheimer's Disease: Evidence from an Incidental Verbal Learning Task

Jin-Chen Yang and John Olichney, UC Davis

Exploration on the relationship of memory and default network function impairment may shed light on the mechanism of attention and short-term memory interaction. In the present functional MRI (fMRI) study, a word repetition paradigm was employed to investigate the default mode network activation and deactivation in Normal Elderly (NE) and mild Alzheimer's disease (AD) patients. Results showed that, in the right inferior parietal lobule (IPL), NE had deactivation response for new word and greater activation for old words, whereas the opposite (New word > Old word) response pattern was observed in AD. While in left posterior cingulate cortex (PCC), NE showed a New > Old pattern but AD group had no New > Old effects in this area. Several other regions in default mode network were also examined. The default mode network dysfunction in mild AD and the implication to memory and attention systems were discussed.

Sandra Mineyev

Eye movements suggest binding of spatial and temporal information in episodic memory

Sandra Mineyev[1], Eve A. Isham[1,2], Nicholas DiQuattro[2], Joy J. Geng[2], Arne D. Ekstrom[1]

1. Center for Neuroscience, University of California, Davis, CA..
2. Center for Mind and Brain, University of California, Davis, CA.

Two critical components of episodic memory are spatial and temporal information, which define the "where" and "when" an event occurred. Given that both spatial

and temporal information are integral parts of episodic memory, it is unclear whether these two components are encoded and retrieved together as a single entity (bound) or whether they rely on separate mechanisms. The current study investigated these questions by examining eye movements during a spatial or temporal memory retrieval task. Thirteen participants navigated through a virtual environment and were asked to make deliveries to eleven stores in a specific order. After the navigation task, the participants were tested for their spatial and temporal memory while we recorded their eye movements. During this retrieval task, the participants were asked to make either a spatial or temporal judgment about; the spatial judgment task prompted the participants to choose which of the two stores was closer in distance to the reference store while the temporal judgment task prompted the participants to choose which of the two store choices was closer in delivery order to the reference store. Within a given trial, the participants were presented with a 10 x 10 grid on the computer monitor to represent the map of the environment navigated. An "X" marked the location of the reference store on the grid map. The amount of eye movement dwell time was calculated as the percentage of time spent looking at the unmarked regions of interest on the grid which represented the two store choices. If spatial and temporal information are strictly bound as a single entity within the episodic memory, the amount of eye movement dwell time should be the same during the spatial and temporal tasks. However, if spatial and temporal components operate independently, the dwell time should reflect these differences. Our preliminary data (N=13) suggest that the eye movement dwell time during spatial and temporal tasks are not significantly different from one another, $F(1,12)=1.995$, $p=.18$, $h^2=.14$. This finding suggests the possibility of binding of temporal and spatial information within episodic memory.

Laura Libby

Defining resting state networks within the human hippocampal formation using high-resolution imaging and functional connectivity

*L. A. LIBBY[1], A. D. EKSTROM[2], C. RANGANATH[2];

[1]Psychology, Univ. of California, Davis, CA; [2]Psychology and Ctr. for Neuroscience, Univ. of California - Davis, Davis, CA

Numerous studies support the importance of the human hippocampal formation in episodic memory, with different hippocampal subregions contributing to discrete memory processes. Anatomical studies in rodents suggest that perirhinal cortex (PRC) and parahippocampal cortex (PHC) provide strong input into the hippocampus, and human neuroimaging and lesion work suggests that these two areas play distinct roles in the input of item and context information for recognition memory within the hippocampus. However, how PHC and PRC interact with human hippocampal subregions remains unclear. As a first step toward addressing this issue, we used high-resolution fMRI (hr-fMRI) during rest to examine intrinsic functional connectivity between anatomically-defined PRC and PHC and other hippocampal subregions. Echo-planar imaging was used to obtain a series of images perpendicular to the long axis of the hippocampus at a 1.5 mm^2 in-plane resolution and registered to a high-resolution T2-weighted structural image (0.4 mm^2 in-plane resolution). We demarcated regions of interest for CA1, CA23/dentate gyrus (DG), subiculum, PRC, PHC, entorhinal cortex (ERC), and fusiform cortex. Based on these anatomically-defined regions of interest, we extracted BOLD timecourses for functional connectivity analysis. Preliminary analyses using PRC and PHC seed regions revealed a distributed resting network of functionally connected regions within the hippocampal region. In particular, we noted significant functional connectivity between PRC and PHC seeds and ERC, subiculum, CA1, and CA23/DG. Together, these data suggest convergence with previous anatomical mapping of the hippocampal formation in animal models.

Ben Hutchinson

Effects of decision framing on episodic retrieval

Ben Hutchinson, Stanford University

While neuroimaging studies of episodic retrieval have consistently revealed activation in posterior parietal cortex (PPC), there remains much debate about the functional roles of dorsal and ventral PPC regions in memory. A parallel literature implicates PPC in processes engaged during perceptual decision-making, suggesting similar processes may also contribute to episodic retrieval. The current fMRI study manipulated decision criteria in order to disentangle PPC responses associated with mnemonic evidence from responses associated with decision processes. Participants incidentally encoded visually presented words, and were subsequently scanned while performing two recognition memory tests. In the first test, a between-subject instructional manipulation varied whether participants made a 1-5 point confidence rating about item novelty or item familiarity. In the second test, participants performed a standard old/new recognition task (making old/new/unsure responses). PPC regions showing greater activation during hits vs. correct rejections (i.e., "old/new effects") on this latter test were interrogated for sensitivity to instructional framing in the confidence-rating test. The results suggest that old/new sensitive regions in the inferior parietal lobule, near the intraparietal sulcus, are insensitive to decision criteria. Additional analyses suggest that a region within the superior parietal lobule tracks the decision uncertainty, whereas a region of angular gyrus demonstrates an inverse pattern. These findings underscore that multiple interacting processes within PPC contribute to episodic retrieval.

TALK SESSION 2

Hui Zhang

Theta activity related to utilization of coherent spatial representations

Hui Zhang, Andrew Watrous, Charan Ranganath, Arne Ekstrom, UC Davis

Humans reference to landmarks in order to arrive at unseen spatial locations. While previous work suggests the importance of frontal theta oscillations in object recognition and categorization (Weidemann et al., 2009), there is no direct evidence regarding how low-frequency oscillations relate to viewing and referencing different kinds of landmarks during navigation. To address this issue, subjects first encoded locations of stores from a map-like perspective with reference to a centrally located landmark and a randomly located store. In the test phase, during which we recorded neural activity from the scalp with electroencephalography (EEG) recordings, subjects actively navigated to target stores using landmarks from a first-person perspective in four randomly interspersed conditions. These were: a visible target condition (navigating to the visible target store), a landmark condition (navigating to a hidden store using the landmark), a store-reference condition (navigating to a hidden store using another store as the landmark), and a randomly located target condition (searching for a randomly-located store). Previous data showed that the posterior superior parietal cortex is recruited during survey representation encoding (Shelton and Gabrieli, 2002) suggesting that this region may also participate in survey retrieval. Thus, we hypothesized increases in theta oscillatory power over parietal cortex related to landmark retrieval. We first focused on the time when the landmarks fell into the field of view. We found greater theta power in both the landmark and visible target condition compared to the randomly located target store condition at parietal cortical electrodes when subjects viewed landmarks to localize the hidden targets. We also found higher theta power

when another store served as a landmark in the store-reference condition than when referencing to the landmark. These data together support the role of theta oscillations in landmark processing, particularly when subjects needed to interpret the spatial relations of objects relative to the landmark in a novel fashion.

Maheen Adamsom

Reduced hippocampal activity during encoding in cognitively normal adults carrying the APOE ε4 allele

Maheen M. Adamson, PhD1,2, J. Benjamin Hutchinson3, Amy Shelton, PhD4, Anthony Wagner, PhD3, & Joy L. Taylor, PhD1,2

1Department of Veterans Affairs and Sierra-Pacific MIRECC, Palo Alto, California,
2Department of Psychiatry and Behavioral Sciences,
Stanford University School of Medicine, Stanford, California
3Psychology Department, Stanford University, Stanford, California
4Department of Psychological and Brain Sciences, John Hopkins University, Baltimore, Maryland

Apolipoprotein (APOE) ε4-related differences in memory performance have been detected before age 65. The hippocampus and the surrounding medial temporal lobe (MTL) structures are the first site affected by Alzheimer's Disease (AD) and the MTL is the seat of episodic and visuospatial memory. APOE ε4-related differences in these brain structures are not consistent in either cross-sectional or longitudinal studies. There is increasing evidence that the brain activity at fixation may be different in APOE ε4 carriers compared to non-carriers. In this study, cognitively normal APOE ε4 carriers and non-carriers engage in a perspective-dependent learning task (Shelton & Gabrieli, 2002) previously shown to activate MTL structures in older participants (Borghesani et al., 2008). A low-level, visually engaging dot-control task was used for comparison to provide non-MTL-based

activity, in addition to fixation. Route vs. survey perspectives were not different in ε4 carriers compared to non-carriers ($p > .1$) and there was no Genotype x Perspective interaction, ($p > .1$). When the encoding of the two perspectives was contrasted against the dot-control task the encoding-related activation was significantly higher than the dot-control ($p < .001$) and there was a Genotype x Task interaction ($p < .05$). No ε4-related differences in the hippocampus were found when encoding during the two perspective tasks was compared with fixation. The results of this study have implications for fMRI studies that investigate the task-positive network (TPN) and default-mode network (DMN) in APOE ε4 carriers to help evaluate AD risk in the otherwise cognitively normal population.

Liang-Tien Hsieh

EEG correlates of item and temporal order information in working memory

Liang-Tien Hsieh[1], Arne D. Ekstrom[1,2], Charan Ranganath[1,2]

[1]Department of Psychology, UC Davis; [2]Center for Neuroscience, UC Davis

The ability to maintain temporal order information in working memory (WM) is crucial in our daily life. For instance, when dialing a recently learned phone number, one must maintain not only the relevant items (i.e., the digits), but also their temporal order (i.e., the sequence of digits). Results from scalp electroencephalography (EEG) and intracranial EEG (iEEG) studies have indicated that oscillatory activity in the theta (4-8 Hz) and alpha (9-13 Hz) bands is correlated with WM maintenance. However, little is known about the differences in oscillatory activity between the maintenance of item and temporal order information in WM. One challenge in addressing this question is that differences in task difficulty usually complicate the interpretation of brain activity differences between tests of WM for item information and tests of WM for order information. Accordingly, in the present

study, we attempted to compare the neural correlates of maintenance of item and order information while controlling for overall task difficulty. We recorded EEG while participants completed two types of WM trials: ITEM trials and ORDER trials. On each trial, participants see an instruction word (either "ITEM" or "ORDER"), followed by four sequentially presented fractals, and then a test display. On ORDER trials, the test display consisted of two fractals from the previous sequence in which participants were asked to identify which fractal came earlier in the sequence. On ITEM trials, the test display consisted of one previously presented fractal and another visually similar foil fractal that was not in the sequence with participants identifying the old fractal on ITEM trials. Behavioral results revealed that accuracy and reaction times were similar for ITEM and ORDER trials, suggesting that task difficulty was matched between the two conditions. Preliminary scalp EEG analyses indicate that oscillatory activity, particularly in the theta band, was modulated by maintenance of item and order information. We have also adapted the task for testing with patients who have implanted electrodes for seizure monitoring. We obtained similar results to our scalp EEG with one patient, confirming that theta oscillations play an important role in maintaining temporal information in WM. Together, these data underscore the importance of coordinated neural activity in the theta-band for correctly maintaining the order of information in a recently learned list.

Rick Addante

Pre-stimulus theta activity predicts recollection during retrieval tasks

Rick Addante, UC Davis

Research on the neural basis of human memory has proceeded from the assumption that memory retrieval is driven by incoming stimuli that act as cues to elicit recovery of past experiences. However, recent research suggests that the

neurocognitive state that the brain is in prior to stimulus presentation can also play a critical role in determining how organisms respond to presented stimuli (Fox & Raichle, 2007; Mazaheri et al. 2009). Ongoing brain activity has been related to subsequent psychophysical, motor, and memory performance (Buzaki, 2006; Raichle, 2009). However, whether higher level cognitive functions such as memory retrieval are influenced by endogenous neural activity is unknown. Recent work has shown that neural activity prior to *encoding* a stimulus can influence subsequent memory performance (Guderian et.al. 2009; Park and Rugg, 2010), though the role of ongoing brain activity prior to memory *retrieval* remains unexplored. We tested episodic retrieval of both item and source memory while recording EEG in 17 human subjects, and found that pre-stimulus theta power prior to a retrieval cue selectively predicts successful recollection. Post-stimulus theta activity was also enhanced for accurate memory performance, and was further shown to be modulated by the pre-stimulus theta. Both pre and post-stimulus effects were correlated with behavioral performance of source accuracy, challenging traditional stimulus-response models of brain function. These findings demonstrate that neural processes occurring prior to stimulus onset play an essential role in how brain processes achieve successful memory retrieval.

Miram Aly

Recollection and Familiarity in Long-Term Memory, Perception, and Everything in Between

Mariam Aly and Andrew P. Yonelinas

UC Davis

We investigated whether processes analogous to recollection and familiarity in long-term recognition memory operate in perception and short-term memory tasks. The dual process signal detection model was used to estimate recollection and familiarity from observed receiver operating characteristics (ROCs). The model fit

the perception and short-term memory ROCs well, but in contrast to long-term memory, recollection supported the detection of 'newness', not 'oldness'. The model was tested by manipulating whether discrete or global similarity information was more useful. Discrete compared to global changes increased recollection and decreased familiarity. Insights about recollection and familiarity from these experiments led to predictions about how these processes should operate in long-term memory, which were tested using a novel 'memory change detection' task. We found that participants no longer recollected 'oldness' but rather recollected 'newness' in item recognition. Thus, the same theoretical framework is useful in integrating phenomena across both memory and perception paradigms.

Joshua Koen

The effects of temporal contiguity on the neural correlates supporting recognition memory for novel cross modal associations

Joshua D Koen, UC Davis

It has been well established that the hippocampus is critical in forming novel associations that can be later recollected, whereas regions in the surrounding medial temporal lobe (MTL) are involved in encoding item information that supports familiarity-based memory discriminations. However, recent evidence suggests that patients with focal hippocampal damage can exhibit relatively preserved associative recognition under conditions that promote unitization (i.e., encoding the constituents of an association as a single item), which suggests that familiarity may contribute to associative recognition. Evidence in favor of these unitization effects has come from studies of word pairs, and it is unknown if these effects generalize to nonverbal materials. To examine this issue, participants underwent fMRI scanning while encoding pairs of fractals and abstract sounds that were presented simultaneously or sequentially (e.g., temporally discontinuous), which was followed by an associative recognition test. It was predicted that the

ability of participants to unitize the fractal-sound pairs should be disrupted when the constituents of the pairs are presented in a temporally discontinuous manner. Thus, the ability of familiarity and the anterior MTL to contribute to associative recognition should be reduced under such conditions. As predicted, estimates of familiarity were significantly higher for pairs presented simultaneously than pairs presented sequentially. Moreover, preliminary analyses of the fMRI data reveal that activity in multiple MTL subregions was correlated with subsequent associative recognition. Further analyses will assess the extent to which activity in multiple MTL subregions differentially support associative recognition in the simultaneous and sequential conditions.

TALK SESSION 3

Matthias Gruber

Encoding-related brain activity before an event: The role of strategic control

Matthias Gruber, UC Davis

A new development in our understanding of human long-term memory is that effective memory formation relies on brain activity just before an event. It is unknown whether such prestimulus activity is under voluntary control or a reflection of random fluctuations over time. In Experiment 1, electrical brain activity was recorded while healthy adults memorized series of words. Each word was preceded by a cue, which indicated the monetary reward that would be received if the following word was later remembered. Brain activity before word onset predicted later memory of a word. Crucially, this was only observed when the incentive to memorize a word was high. This suggests that engaging brain activity that benefits the encoding of an upcoming event is under voluntary control. In Experiment 2, we addressed whether encoding-related prestimulus activity

depends on the degree to which neural resources are allocated to an encoding task. Participants had to memorize each word and additionally make an alphabetic judgment on each word. Again, activity before word onset predicted later memory performance. Interestingly, this effect varied according to an individual's accuracy on the alphabetic task. Encoding-related prestimulus effects were larger when individuals made more mistakes on the alphabetic task. These results suggest a trade-off between processes that support encoding versus alphabetic judgments. Together, the two experiments imply that encoding-related brain activity before an upcoming event reflects a resource-dependent preparatory process which is under strategic control. This opens up new avenues to improve memory, especially in clinical and educational settings.

Rachel Diana

Encoding item, context, and relational information: fMRI adaptation in the medial temporal lobes

Rachel A. Diana, Andrew P. Yonelinas, & Charan Ranganath

UC Davis

The medial temporal lobes are critical for encoding of episodic long-term memories, however the specific functions of medial temporal lobe subregions remain unclear. The Binding of Item and Context (BIC) model of medial temporal lobe function proposes that the perirhinal cortex processes item information, the parahippocampal cortex processes context information, and the hippocampus processes the conjunction of item and context information in a relational binding. We used an fMRI adaptation paradigm to test the predictions of the BIC model during encoding of episodic memories. Adpatation studies rely on the general finding that repetition of information leads to reduced activation in brain areas that process the repeated information. Thus, repetition of item information (in this case, concrete nouns, e.g. "HAMMER"), context information (unique semantic encoding

questions, e.g. "Could you balance this item on your nose?), and relational bindings of item and context information (the joint processing of a noun and an encoding question, e.g. "I can't balance a hammer on my nose.") should lead to reduced activation in medial temporal lobe subregions that process each type of information. We found fMRI adaptation effects in perirhinal cortex, parahippocampal cortex, and the hippocampus with repeated encoding of item, context, and item-context bindings eliciting different amounts of adaptation in each medial temporal lobe subregion.

Valerie Carr

High-resolution investigation of pattern separation in the medial temporal lobe using a rapid fMR-adaptation approach

Valerie A. Carr, Serra E. Favila, and Anthony D. Wagner

Tension is thought to exist within the medial temporal lobe (MTL) when events share overlapping features, such that some subfields readily encode a given event as distinct from previously-experienced events (e.g., pattern separation), whereas others generalize across similar events. In an effort to better characterize putative functional heterogeneity among MTL subfields, two studies were conducted examining the manner in which subfields respond to parametric manipulations of either item or relational similarity. In both cases, participants were scanned using high-resolution fMRI and a rapid adaptation paradigm in which trials began with presentation of a novel stimulus, followed by a stimulus varying in similarity to the novel stimulus. We hypothesized that (a) when two stimuli were identical, adaptation would be seen across all MTL subfields, and (b) critically, different levels of adaptation would appear across subfields as a function of stimulus similarity. Analyses were performed in two ways: (1) participant's images were kept in native space, and activity was extracted from anatomical regions of interest (ROI), (2)

participant's images were registered into a group template using an ROI-alignment technique (ROI-AL) to allow for group-level voxel-based analyses. Results reveal regional adaptation differences between the hippocampus and MTL cortices in both studies, as well as subregional differences within the hippocampus such that CA/dentate gyrus plays the clearest role in pattern separation.