Neural mechanisms of human memory for events and spatial locations

Spatial memory in MEG and iEEG

Rodent studies suggest that spatial memory function relies on the hippocampal formation and is mediated by theta and gamma band oscillations, phase- and phase-amplitude coupling. We examine MEG recordings from healthy volunteers and iEEG recordings from epileptic patients performing a spatial memory task to ascertain if these findings can be translated to humans.

The Task

Participants encode the location of four visible objects within a virtual environment with distal cues for orientation. They are subsequently cued with the image of an object, placed back in the environment, and must retrieve the location of that object and make a response.

Movement Onset - iEEG Data

Our findings demonstrate a significant increase in mPFC 4-8Hz theta power during the cue period (A) compared to a baseline period of quiet fixation. There is also a significant increase in theta phase coupling between mPFC and right medial temporal lobe (B), and increased theta-gamma amplitude coupling between mPFC and parietal/occipital regions (C) during this time period. These results suggest that mPFC may coordinate spatial memory retrieval through oscillatory coherence between multiple cortical regions, including the hippocampus.

Interictal Spikes and Performance

Epileptic EEG recordings exhibit interictal spike (IIS) activity that reflects the transient, abnormal discharge of large neural populations. We find that the frequency with which IIS events occur on depth electrode contacts placed in the hippocampus during the cue period is negatively correlated with spatial memory performance.

Pattern completion in the hippocampus

Episodic memories are thought to be retrieved by a process of pattern completion in the hippocampus. We provide behavioural and fMRI evidence that multi-element events are encoded by separate cortical regions and bound together within the hippocampus. At retrieval, the reinstatement of all event elements in the neocortex is initiated by the hippocampus.

Behavioural Dependency

(A) Multi-element events were encoded as pairwise associations. Events were either encoded within closed-loop structures (C) or open-loop chains (D). Memory was tested for all associations (B).

Encoding

We identified specific cortical regions associated with each class of event element during encoding.

(A) Greater subsequent memory effect was observed in the hippocampus for closed- versus open-loop conditions during the third encoding trial of each event (when the loop was closed in closed-loop events).

Opposing effects of emotion on memory

The formation of associations between items in memory relies on hippocampal-dependent mechanisms that go beyond supporting memory for a single item. We show that negative affect can facilitate item memory through amygdala-dependent processes. In contrast, negative affect can disrupt associative memory relating to reduced activity in the hippocampus.

Methods & Behavioural Results

Participants encoded neutral and negative images presented as pure neutral, mixed or pure negative pairs. At test, participants were cued with a neutral or negative image and required to retrieve the paired associate originally presented with the cue.

Recognition was enhanced for negative cues. Associative memory was reduced for pairs that included a negative image at encoding. In addition, retrieval of a negative target associate was enhanced relative to being cued with a negative image to retrieve a neutral target.