Exploring multivariate patterns of neural activity underlying spatial perception and memory in the hippocampus

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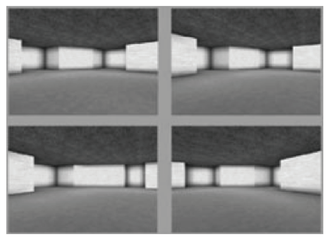
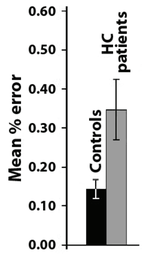
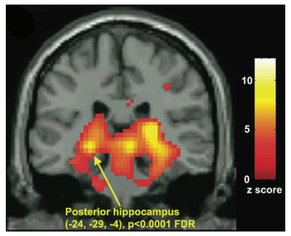
Introduction

Recent work[1-2] has suggested that the hippocampus (HC) is important for complex spatial discrimination tasks that do not require long-term declarative memory. These findings suggest that the HC may play a role in complex spatial perception[3-4].



"Choose the odd-one-out"





It is unknown, however, if the same HC neural mechanisms subserve both spatial perception and spatial memory. To investigate this, we used fMRI with uni- and multivariate analyses to explore whether HC activity associated with spatial perception can be dissociated from that associated with spatial memory.

Methods

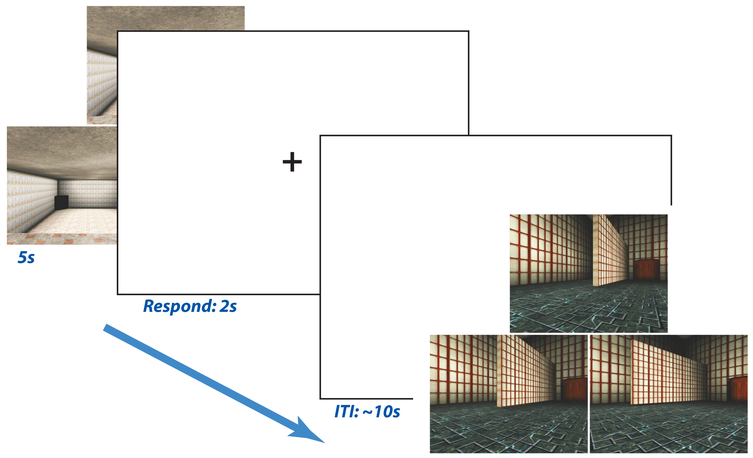
15 neurologically healthy participants (mean 25.1 years) underwent fMRI while solving 200 spatial oddity trials and completed a recognition memory test after scanning. Thus, each trial was labelled as 'correct/incorrect oddity' and 'remembered/forgotten'.

Preliminary univariate analysis - A 2 x 2 factorial general linear model was implemented with 2 factors of 'oddity accuracy' and 'subsequent memory'. Contrasts were conducted between correct and incorrect oddity trials, remembered and forgotten trials, and to investigate the interaction between these two factors. The HC was used as a region of interest (defined anatomically), and a cluster threshold of $z = 2.6$, $p < 0.05$ corrected was applied to identify significant regions of activity.

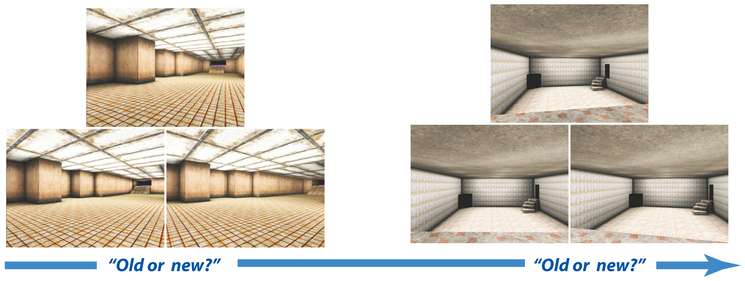
Preliminary multivariate analysis - A classification algorithm was designed to decode whether or not a correct oddity decision was made on each trial and/or whether each trial was subsequently remembered. The classifier operated on Beta maps derived for each trial by deconvolving the measured BOLD response with a canonical haemodynamic response function. We used a linear support vector machine in a leave-one-out cross-validation scheme. Within each repetition, the labels of the training set were balanced using a stochastic oversampling strategy. Fold-specific feature selection was based on finding the most discriminative locally multivariate searchlight environments within subject-specific HC masks. A simple binomial assumption was used to assess whether the resulting classification accuracies were significantly above chance

Experimental paradigm

During scanning - On each trial, participants were presented with 3 images of virtual reality rooms and were instructed to find the odd-one-out.



After scanning - Participants saw previous oddity trials intermixed with new trials and were instructed to decide whether each trial was old (further divided into 'recollect/familiar') or new.



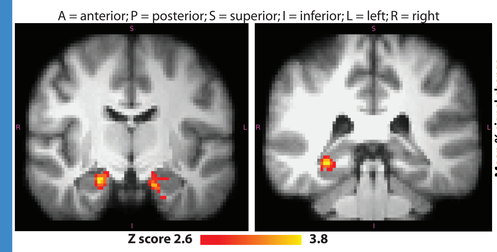
Preliminary results 1

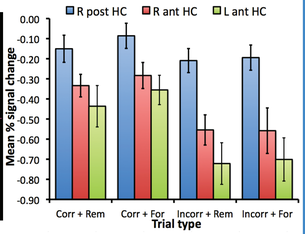
Behavioural - Mean performance on the 200 trials:
Correct oddity + remembered = 35.3% trials
Correct oddity + forgotten = 21.0% trials
Incorrect oddity + remembered = 25.9% trials
Incorrect oddity + forgotten = 17.8% trials

Univariate analysis - No significant regions of HC activity were observed for "incorrect - correct oddity", "remembered - forgotten" or forgotten - remembered", although exploratory analyses revealed sub-threshold right HC activity for "remembered - forgotten" (Z = 2.5; 20, -22, -14). There was no significant interaction between the two factors of interest.

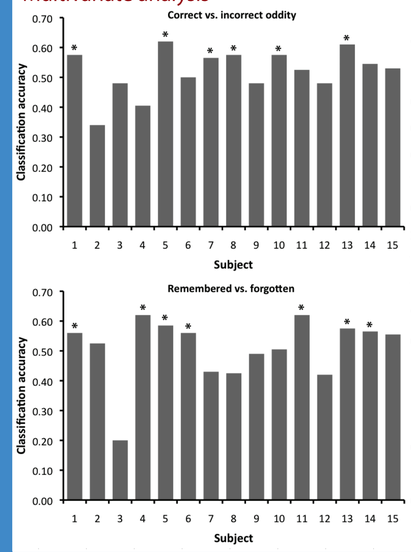
Preliminary results 2

Univariate analysis - Right posterior HC (Z = 3.6; 32, -36, -8) and more anterior bilateral HC activity (**R**: Z = 3.8; -22, -10, -20; **L**: Z = 3.6; -16, -14, -22) was observed for "correct - incorrect oddity", with a similar pattern of activity in all three regions.





Multivariate analysis



While a clear oddity-related difference in hippocampal activity was revealed by our univariate analysis, above-chance classification accuracies for predicting correct vs. incorrect responses from trial-wise data were only observed in 6 out of 15 subjects. Conversely, while no significant univariate activations were found with regard to correct vs. incorrect trials, successful trial-wise predictions were significantly above chance in 7 out of 15 subjects. Both results survived Bonferroni correction ($p < 0.05$).

Decoding each trial on the basis of both oddity accuracy and subsequent memory labels did not improve classification accuracies.

Discussion

(1) HC activity can be observed in assocation with correct spatial oddity judgments, irrespective of subsequent memory. **(2)** This supports the idea that the HC may be critical for complex spatial perception, and hints that spatial perception and long-term spatial memory do not depend on identical HC neural mechanisms. **(3)** Ongoing follow-up analyses taking into account recollection vs. familiarity may be able to reveal interaction effects between perception and memory, and improve classification accuracies.

References (1) Lee et al., 2005 *Hippocampus*; (2) Lee et al., 2008 *Cereb Cortex*; (3) Murray et al., 2007 *Ann Rev Neurosci*; (4) Graham et al., 2010 *Neuropsychologia*. **Acknowledgements** Research supported by the Wellcome Trust, UK.