Hippocampal Recruitment in Implicit Learning: Neuroimaging Evidence from a Visual Search Task

Ruskin H. Hunt, Kathleen M. Thomas

Institute of Child Development, University of Minnesota

Introduction

Previous behavioral research (Chun & Jiang, 1998) has shown reaction time facilitation in visual display search tasks for displays in which distractors reliably predict target location over repeated display exposure. Such learning occurs outside conscious awareness, and is thought to fall under the rubric of implicit learning. In contrast to other implicit learning tasks, this phenomenon, termed contextual cueing, has been reported to rely on medial temporal lobe structures, and the hippocampus in particular (Chun & Phelps, 1999, investigating patients with hippocampal damage). In the present study we collected functional magnetic resonance imaging data from healthy adults as they performed a variant of the contextual cueing task. Our goal was to assess the involvement of the hippocampus in successful performance of this task.

Behavioral Task

Trials

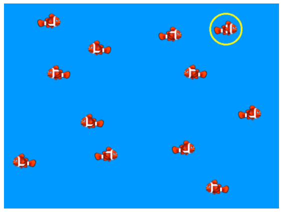
Each trial consisted of a static visual scene containing 1 target stimulus (a fish with three vertical stripes) and 11 distractor stimuli (fish with two vertical stripes). The ITI was 4 seconds.

Stimulus Types

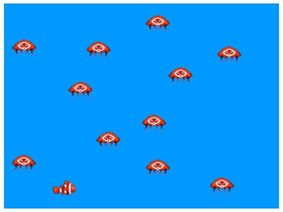
Familiar - Displays (8) with target and distractor locations that repeated during the experiment.

Novel - Displays (8) with target locations that repeated during the experiment. Distractor locations varied with each presentation.

Baseline - Displays with different distractors (jellyfish). Target and distractor locations occurred at random. Displays did not repeat.



Non-Baseline Stimulus



Baseline Stimulus

Response

Button press to indicate left/right direction of target. Direction of target and distractors varied with each presentation (50% left, 50% right within each type). When a button press occurred, target and distractors disappeared and auditory feedback was given.

Blocks

20 data blocks were collected during the experiment (20 displays per block: 8 Familiar, 8 Novel, 4 Baseline, randomly sequenced).

Epochs

fMRI data were collected and analyzed in 4 imaging epochs/runs. Each epoch contained 5 blocks.

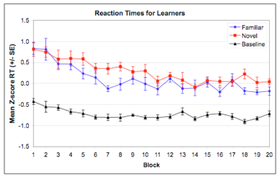
Participants

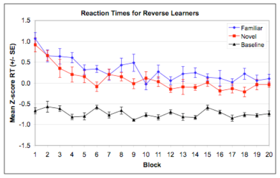
20 Adults; 14 F, 6 M; All normal vision. Mean = 21 yrs (18-29 yrs).

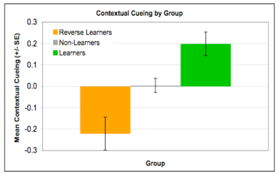
Behavioral Performance

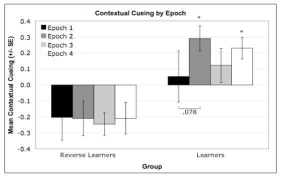
Reaction time data were Z-score normalized. Contextual cueing was assessed as the difference between responses to Familiar and Novel trials for each block. Positive contextual cueing scores indicate facilitation for familiar trials over novel trials, as predicted.

Lleras, & Von Muhlenen (2004) found that performance on the contextual cueing task spans a wide range, with some participants showing strong learning, some showing no learning, and others showing learning opposite that predicted. We found similar patterns in our data.









Participants were divided into three groups: learners (N=8), who showed a significant difference between familiar and novel trials in the predicted direction during at least one epoch; non-learners (N=5), who showed no significant differences; and reverse learners (N=7), who showed significant differences opposite the predicted direction.

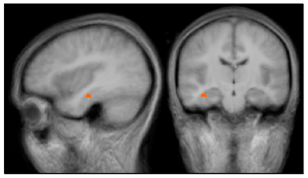
Contextual cueing across epochs was examined for learners and reverse learners. Reverse learners failed to show a significant difference across epochs ($F(3,24)$, $p>.05$), and cueing was not different from zero in any epoch. Learners also failed to show a significant difference across epochs ($F(3,28)$, $p>.05$). However, learners did show contextual cueing significantly different from zero in epochs 2 and 4 ($t(7)$, $p<.05$), as well as a marginal difference between epochs 1 and 2 ($t(7)$, $p=.078$).

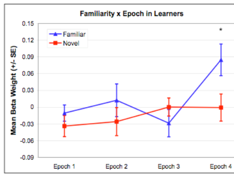
Neuroimaging Methods

Structural: SPGR, 176 sagittal slices, 1mm isovoxel, TR=20, TE=4.7.
Functional: Gradient echo, EPI, 34 interleaved axial slices, 3.125 x 3.125 x 4.0mm voxels, TR=2000, TE=28, FOV=200, flip=90°.
Data were analyzed in Brainvoyager QX. Functional images were motion and slice-time corrected, high pass filtered, and spatially smoothed at 6mm FWHM prior to being resliced into 1mm isotropic voxels. Individual functional data sets were coregistered with their respective structural images and transformed into Talaraich space prior to statistical analysis. Regions of interest in the hippocampus were identified using whole brain analysis at $p<.05$ and a contiguous cluster threshold of 90 voxels. Areas of significant activation outside of hippocampus have been masked.

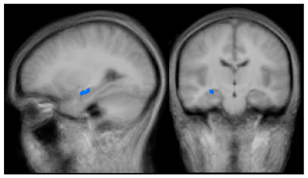
Neuroimaging Results

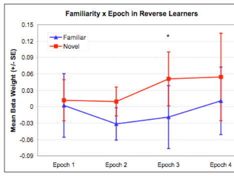
A single site of significant difference between Familiar and Novel trials was found in right hippocampus in both Learners and Reverse Learners. Learners showed greater activation to Familiar trials, whereas Reverse Learners showed greater activation to Novel trials. Followup ROI analyses found a significant main effect of Familiarity for Learners, but no effect of Epoch and no interaction. Planned comparisons revealed a significant difference between Familiar and Novel trial types in Epoch 4. Followup ROI analyses of Reverse Learners showed a significant main effect of Familiarity and an interaction between Familiarity and Epoch, but no main effect of Epoch. Planned comparisons identified a significant difference between Familiar and Novel trial types in Epoch 3.





Right hippocampal activation in Learners, Familiar v. Baseline > Novel v. Baseline (Talaraich X=35, Y=-15, Z=-15, 90 vox.)





Right hippocampal activation in Reverse Learners, Novel v. Baseline > Familiar v. Baseline (Talaraich X=27, Y=-12, Z=-11, 195 vox.)

Conclusions

- Consistent with previous findings, our behavioral data reveal that some participants show learning in the predicted direction, whereas others show learning in the opposite direction.
- Our imaging data confirm differential hippocampal activation to familiar and novel stimulus types in healthy adults. This is true for both learners and reverse learners, though the effects are in opposite directions.
- The current findings are consistent with hippocampal involvement in an implicit learning task. Additional analyses will be required to determine if other brain regions traditionally associated with implicit learning are also engaged in the contextual cueing task.

Chun, M. M. & Jiang, Y. (1998). Contextual cueing: Implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology*, 36, 28-71.
Chun, M. M. & Phelps, E. A. (1999). Memory deficits for implicit contextual information in amnesic patients with hippocampal damage. *Nature Neuroscience*, 2, 844-847.
Lleras, A. & Von Muhlenen, A. (2004). Spatial context and top-down strategies in visual search. *Spatial Vision*, 17, 465-482.

Email: hunti011@umn.edu. Supported in part by the following federal grants: T32-MH15755, K01-MH02024, P41 RR008079, P30 NS057091.