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Memory-Guided Attention: Independent Contributions of the Hippocampus and Striatum

Highlights

- Multiple memory systems concurrently and implicitly facilitate attention
- The striatum predicts attention benefits from reinforcement learning
- The hippocampus predicts attention benefits from implicit context memory
- The hippocampus quickly guides attention, while the striatum is slower

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In Brief

Goldfarb et al. show that attention can be implicitly and concurrently guided by multiple memory systems. Striatal and hippocampal activity independently predict subsequent attention driven by stimulus-response and context memory, respectively.

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Memory-Guided Attention: Independent Contributions of the Hippocampus and Striatum

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SUMMARY

Memory can strongly influence how attention is deployed in future encounters. Though memory dependent on the medial temporal lobes has been shown to drive attention, how other memory systems could concurrently and comparably enhance attention is less clear. Here, we demonstrate that both reinforcement learning and context memory facilitate attention in a visual search task. Using functional magnetic resonance imaging, we dissociate the mechanisms by which these memories guide attention: trial by trial, the hippocampus (not the striatum) predicted attention benefits from context memory, while the striatum (not the hippocampus) predicted facilitation from rewarded stimulus-response associations. Responses in these regions were also distinctly correlated with individual differences in each type of memory-guided attention. This study provides novel evidence for the role of the striatum in guiding attention, dissociable from hippocampus-dependent context memory.

INTRODUCTION

Attention can be profoundly influenced by memory. Even something as simple as having previously viewed a picture or an array of shapes can inform where visual attention will be directed, enhancing perceptual sensitivity (Chun and Jiang, 1998; Patai et al., 2012; Summerfield et al., 2006). While the influence of memory on attention is a relatively recent topic (Hutchinson and Turk-Browne, 2012; Rosen et al., 2015), there is compelling evidence that hippocampal memory can guide attention. The hippocampal memory system rapidly encodes episodic memories, which are flexible and rich in contextual detail (Burgess et al., 2002). Long-term memory for complex scenes engages the hippocampus and facilitates attention and eye movements to targets, even in the absence of explicit recall (Hannula and Ranganath, 2009; Summerfield et al., 2006). The contextual cueing effect demonstrates that memory for a repeated spatial configuration guides attention and improves performance in visual search (Chun and Jiang, 1998). These memories depend on medial temporal lobe (MTL) structures and have frequently been shown to involve the hippocampus (Chun and Phelps, 1999; Giesbrecht et al., 2013; Greene et al., 2007; Preston and Gabrieli, 2008).

Although these studies have demonstrated the critical role of hippocampal memory in guiding attention, memory is not a unitary process (Squire, 1992). Different neural systems support encoding and retrieval of specific kinds of information (Henke, 2010). Thus, the ability of memory for diverse cues to guide attention may depend on distinct memory systems. Unlike hippocampal memory, the striatum slowly acquires rigid associations between stimuli and responses (Bayley et al., 2005; Graybiel, 1998; Yin and Knowlton, 2006). In healthy individuals, hippocampal and striatal systems can concurrently acquire information (Foerde and Shohamy, 2011), and lesion studies in rats (Packard and McGaugh, 1996) and human patients (Knowlton et al., 1996) have dissociated these systems. However, the influence of striatal memory on attention has not been studied.

We hypothesize that people can learn and use multiple informative cues to guide attention. Furthermore, we hypothesize that changing the type of cue can change the memory system that guides attention. We developed a way to directly compare how hippocampal and striatal memory influences attention. Contextual cueing demonstrates the impact of hippocampal memory on attention in visual search. During the search task, participants search for a target (a rotated "T") and press a button once they find it, indicating the direction of the "T" (Figure 1). The influence of hippocampal memory is shown via repeated configurations of target and distractors; on these trials, memory for spatial context guides attention to the exact location of the target. This effect is implicit. Participants do not have explicit memory for the repeated context (Chun and Jiang, 1998, 2003; Chun and Phelps, 1999).

While contextual cueing has been frequently replicated and provides an index of hippocampal memory guiding attention, other forms of predictive associations, potentially reliant on other memory systems, have been less studied. To address this, we modified the search task to include probabilistic stimulus-response (SR) associations known to rely on the striatum as mnemonic cues for attention. Specifically, on some trials, the target and distractors appeared in a different color. The predictive color probabilistically (80% validity) cued the target location (quadrant of the screen) and the button-press response (the