Landmark influence: How attention to sensory cues stabilizes and updates the hippocampal cognitive representation of space

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Abstract

The hippocampus is thought to play a critical role in episodic memory by incorporating the sensory input of an experience, such as when navigating mammals stop to fixate on familiar landmarks, onto a spatial framework embodied by place cells. However, the dual roles of spatial navigation and memory formation appear to conflict: Wayfinding requires spatial stability whereas memory depends on the continual encoding of the items and events of experience. I have investigated distinct neural coding mechanisms that together may provide stability while allowing for rapid, attentive integration of sensory information into hippocampal representations. First, I will describe computational modeling studies that derive from the temporal phase relationship between place cells and the theta (6–10 Hz) rhythm. Integrating self-motion signals in the phase of theta oscillations requires high precision and is not intrinsically robust to noise. By extending previous oscillatory interference models, I will show how an attentive interaction with external cues can provide feedback to theta oscillators, allowing for retrieval of positional fixed points and correction of phase drift, thus ensuring spatial stability. Second, more recent work has focused on behavior-based analysis of place cell recordings from rats navigating closed-loop tracks. While it is known that place fields are constructed through exploration, the interaction between discrete exploratory behaviors and episodic-like modifications of hippocampal representations has not been established. This study found that increased neural activity during exploratory head-scanning behaviors predicted the formation and potentiation of place fields on the next pass through that location. This result is consistent with current theories of hippocampal rate remapping and indexing of long-term memories, in which variations in firing rate encode information about discrete experiences. Thus, these studies begin to demonstrate how multiple neural coding mechanisms may cooperate within the hippocampus to allow for robust spatial navigation in a changing world.

Figure 1: A rat performs a head scan on the hexagonal track in a novel room