What information code hippocampal neurons?

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Overview

We witness a surge in publications of what single neurons in the hippocampus code. We find head direction cells, index cells, engram cells, concept cells, place cells, recognition cells, grid cells, time cells and episode specific cells. Animal work provides good experimental control and single neuron yield. However, not all animal work translates to humans. The important question arises, whether we have a multitude of neuron types in our brain or if there is an underlying coding mechanism. During our symposium experts will present their work. Subsequently we want to discuss some of the apparently contradicting coding mechanisms, find common grounds, and formulate new ideas to improve our understanding of the function of hippocampal neurons.

Lecture 1: *Making memories in mice*
Sheena Josselyn Presenter

Understanding how the brain uses information is a fundamental goal of neuroscience. Several human disorders (ranging from autism spectrum disorder to PTSD to Alzheimer's disease) may stem from disrupted information processing. Therefore, this basic knowledge is not only critical for understanding normal brain function, but also vital for the development of new treatment strategies for these disorders. Memory may be defined as the retention over time of internal representations gained through experience, and the capacity to reconstruct these representations at later times. Long-lasting physical brain changes ('engrams') are thought to encode these internal representations. The concept of a physical memory trace likely originated in ancient Greece, although it wasn't until 1904 that Richard Semon first coined the term 'engram'. Despite its long history, finding a specific engram has been challenging, likely because an engram is encoded at multiple levels (epigenetic, synaptic, cell assembly). My lab is interested in understanding how specific neurons are recruited or allocated to an engram, and how neuronal membership in an engram may change over time or with new experience. Here I will describe both older and new unpublished data in our efforts to understand memories in mice.

Lecture 2: *Single-neuron correlates of spatial memory and navigation*
Joshua Jacobs Presenter

A fundamental aspect of memory is remembering where we are located when events occurred. By using direct human brain recordings of single-neuron activity, my lab has made insights demonstrating how the brain represents memory for spatial events. In this talk I will discuss our work demonstrating how the brain represents information about a person's current spatial location during navigation and how this information is flexibly encoded and retrieved to form memories. In addition to showing how neurons encode spatial memory information by changing the rate of spiking, we also identified novel patterns of temporal coding in humans (phase precession), in which neurons encode location and other information by changing the timing of their spiking. We also demonstrate that the brain uses multiple types of coding mechanisms, egocentric and allocentric, to represent one's spatial location. Together, these results suggest that during spatial memory processing the human brain follows some of the principles found in animal models but that we also exhibit novel spatial coding patterns that are not seen in other species.

Lecture 3: *Concept neurons in the medial temporal lobe as semantic building blocks of memory*
Florian Mormann Presenter

The human medial temporal lobe contains neurons that respond selectively to the semantic contents of a presented stimulus. These "concept cells" may respond to very different pictures of a given person and even to their written or spoken name. Their response latency is far longer than necessary for object recognition, and they are found in brain regions that are crucial for declarative memory formation. It has thus been hypothesized that they may represent the semantic "building blocks" of episodic memories.
In this talk I will present data from single unit recordings in the hippocampus, entorhinal cortex, parahippocampal cortex, and amygdala during paradigms involving encoding of specific concepts in a long-term memory paradigm and during pharmacological manipulation to dissociate conscious perception from memory.

Lecture 4: *Hippocampal neurons code individual episodic memories in humans*
Luca Kolibius Presenter

The hippocampus is an essential hub for episodic memory processing. However, how human hippocampal single neurons code multi-feature associations remains unknown. Some argue that each hippocampal neuron codes for an invariant element within an episode. Instead, others have proposed that hippocampal neurons bind together all features present in a discrete episodic memory. Here, we provide evidence for the latter. We show that individual neurons code discrete memory episodes, which we term Episode Specific Neurons (ESNs). These ESNs do not reflect the coding of a particular feature in the episode (i.e., concept or time). Instead, they code for the conjunction of the different elements that make up the episode.