Neuroscience of Episodic Memory

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Identification of engram cells and their circuit for a specifics memory has led to new insights into the cellular and neural circuit mechanisms for memory encoding, retention, and retrieval. Upon learning, a series of neuronal subpopulations, each residing in a distinct brain region, are activated due to rapid increase of synaptic strength, and their new pattern of connectivity is established through rapid formation of new spines/synapses. While this connectivity between engram cell populations is crucial for memory retention, late LTP-type synaptic strengthening seems to be important for efficient retrieval of the retained memory.

We have investigated the systems consolidation of episodic memory by applying engram and optogenetic technologies. The results indicate that the PFC engrams for remote memory are formed rapidly on day 1 of learning. However, these PFC engrams are inactive in the sense that they cannot be re-activated by natural cues for memory retrieval. The "silent" PFC engrams undergo slow maturations during the following few weeks with the aid of input from hippocampal engram cells via the deep layer of the medial entorhinal cortex. Conversely, the hippocampal engram cells formed rapidly on day 1 de-mature slowly and become silent. For contextual fear memory, an active engram is rapidly formed in BLA and remains active throughout the systems consolidation, but there is a switch in the route through which recall cues are delivered: through the hippocampal-entorhinal circuit at recent times and through PFC engram cells at remote times. This study identified the engrams and neural circuits crucial for systems consolidation of a memory.

Episodic experience is rooted in space and occurs as a sequence of events. Hippocampal neurons are essential for episodic memory and track the physical space, but it is unknown if they also code the temporal relationship of events. We designed a task in which mice experience a series of materially indistinguishable yet temporally distinguishable events. We report hippocampal "serial cells" that track the temporal ordering of discrete events, independent of space and other continuous task progress variables. The number of serial cells is greatly reduced when the temporally distinguishable aspect of events is abolished. The serial code is conjunctive with the spatial code but they can be independently perturbed. The serial code may be one of the fundamental ingredients by which our brain represents an episode.