

Revisiting Hebb and the Hippocampal Index in Humans: Toward a Neurotechnology of Memory

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In this talk I will present two strands of studies where we investigated two prominent mechanisms suggested to underlie human episodic memory. First, Hebbian learning (i.e “fire-together, wire together”) or Spike-Timing-Dependent-Plasticity (STDP), which posits that the firing of neurons in close temporal proximity is crucial for laying down a memory trace. Recording the co-firing of single-neurons in epilepsy patients in the medial-temporal-lobe during a memory task we found results that are consistent with STDP (1). I will also show results from rhythmic stimulation studies demonstrating that the manipulation of temporal patterns in the range of milliseconds modulates episodic memory formation (2). A second idea that has influenced memory research is the “Indexing Theory” (3) which posits that the human hippocampus stores episodic memories via an Index – an agnostic conjunctive type of code that points to the different elements that belong to the episode. I will present recent evidence from human single neuron recordings (4) where we found neurons that are consistent with such an indexing function. I will also present unpublished results from an ultra-highfield fMRI at 7T which support these human single unit findings and suggest that the Index is predominantly located in the hippocampal subfield CA3. I will close the talk by presenting a recent theoretical framework (5) where we integrate these findings with Concept Cells (so-called Jennifer Anniston cells; (6)) and the Engram Allocation Theory (7). At the end I will speculate how results from both streams could lead to the development of novel treatment for patients with memory problems.

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2. Wang, Shapiro, & Hanslmayr (2023) *Altering stimulus timing via fast rhythmic sensory stimulation induces STDP-like recall performance in human episodic memory*. *Current Biology*, 33, 3279–3288.e7 DOI: 10.1016/j.cub.2023.06.062
3. Teyler & DiScenna (1986) *The Hippocampal Memory Indexing Theory*. *Behavioral Neuroscience*, 100, 147–154 DOI: 10.1037/0735-7044.100.2.147
4. Kolibius et al. (2023) *Hippocampal neurons code individual episodic memories in humans*. *Nature Human Behaviour*, 7, 1968–1979 DOI: 10.1038/s41562-023-01706-6
5. Kolibius, Josselyn, & Hanslmayr (2025) *On the origin of memory neurons in the human hippocampus*. *Trends in Cognitive Sciences*, 29(5), 421–433 DOI: 10.1016/j.tics.2025.01.013
6. Quiroga et al. (2005) *Invariant visual representation by single neurons in the human brain*. *Nature*, 435, 1102–1107 DOI: 10.1038/nature03687
7. Josselyn & Frankland (2018) *Memory Allocation: Mechanisms and Function*. *Annual Review of Neuroscience*, 41, 389–413 DOI: 10.1146/annurev-neuro-080317-061956