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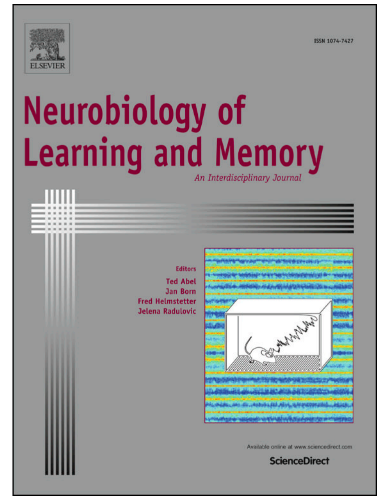

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Neural representations of time-linked memory

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ABSTRACT

Many cognitive processes, such episodic memory and decision making, rely on the ability to form associations between two events that occur separately in time. The formation of such temporal associations depends on neural representations of three types of information: what has been presented (trace holding), what will follow (temporal expectation), and when the following event will occur (explicit timing). The present review seeks to link these representations with firing patterns of single neurons recorded while rodents and non-human primates associate stimuli, outcomes, and motor responses over time intervals. Across these studies, two distinct firing patterns were observed in the hippocampus, neocortex, and striatum: some neurons change firing rates during or shortly after the stimulus presentation and sustain the firing rate stably or sidlingly during the subsequent intervals (tonic firings). Other neurons transiently change firing rates during a specific moment within the time intervals (phasic firings), and as a group, they form a sequential firing pattern that covers the entire interval. Clever task designs used in some of these studies collectively provide evidence that both tonic and phasic firing responses represent trace holding, temporal expectation, and explicit timing. Subsequently, we applied machine-learning based classification approaches to the two firing patterns within the same dataset collected from rat medial prefrontal cortex during trace eyeblink conditioning. This quantitative analysis revealed that phasic-firing patterns showed greater selectivity for stimulus identity and temporal position than tonic-firing patterns. Our summary illuminates distributed