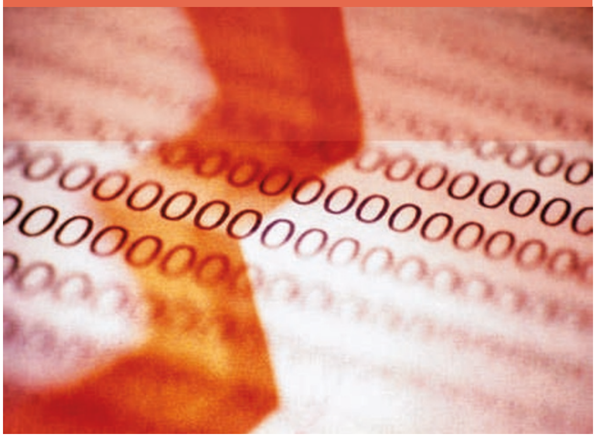
NEURAL CODING

Oscillations help to decode spike patterns



In sensory processing, a neuron's firing rate and the timing of the spikes relative to the stimulus onset together encode information. In reality, however, stimuli are often ongoing, raising the question of what else could provide a reference point for spike timing. Previous studies suggested that the phase of ongoing background oscillations in the local field potential might provide this reference point. The timing of spikes relative to the phase of an oscillation has been referred to as 'phase-of-firing coding' (PoFC). Masquelier *et al.* now show that PoFC indeed has a functional role in information processing. In the *Journal of Neuroscience*, they report that PoFC aids spike timing-dependent plasticity (STDP) and, thus, neural coding and decoding.

STDP is a learning rule according to which synaptic strength is modified as a function of the relative timing of pre- and postsynaptic spikes; it allows neurons to respond selectively to repeating spike patterns in continuous spike trains. Here, the authors show that oscillatory activity facilitates this information decoding. Using computer simulations, they investigated the mechanisms through which a single neuron capable of undergoing STDP can detect and learn to selectively respond to patterns of input from an unknown number of afferents occurring at unpredictable times.

The downstream neuron was unable to learn the repeating patterns when Poisson input neurons (in which the spiking probability at any instant is constant and independent of prior activity) or independent leaky integrate-and-fire (LIF) input neurons (with piecewise constant input currents) were used. However, when the authors occasionally reset the membrane potential of all LIF input neurons (which might be similar to what happens in the brain during saccades in vision or sniffs in olfaction), the downstream STDP neuron began to respond to repeated spiking patterns. The selectivity of this response emerged after several stimulations and resets, indicating that the downstream neuron learned to decode the spiking pattern.

When the authors did not reset the input neurons but instead introduced an oscillatory drive, the input currents automatically became encoded in the spike phases with respect to the oscillation (PoFC). As a result, the downstream STDP neuron received input in the form of 'spike waves', which were even more efficiently detected than in the resetting paradigm and which triggered a learned selective response. These responses were observed even when only a small fraction of the afferents (~10%) exhibited PoFC.

Both theoretical and experimental studies have provided evidence that oscillatory activity improves the reliability of neuronal spike timing, but the functional consequences of this were unknown. This study shows that oscillations facilitate downstream processing by generating waves of spikes with reliable relative times that the downstream neuron can decode. As a result, these neurons can respond selectively to spike patterns and, importantly, learn to respond to these patterns. Together, these findings suggest that oscillatory activity might have a major role in long-term memory encoding.

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ORIGINAL RESEARCH PAPER Masquelier, T., Hugues, E., Deco, G. & Thorpe, S. J. Oscillations, phase-of-firing coding, and spike timing-dependent plasticity: an efficient learning scheme. *J. Neurosci.* **29**, 13484–13493 (2009)