

Synchrony coding of input familiarity

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Neural systems continuously process and transmit information about incoming sensory stimuli, but which aspects of this information are most relevant? Beyond stimulus content, we highlight an important yet underexplored property which captures the relationship between a stimulus and the system itself – meta-information about its familiarity arising from prior experience.

Familiarity plays an implicit role in major computational frameworks, including the attractor dynamics, predictive coding and efficient coding, yet its exact neural implementation remains unclear. In this work, we investigate how familiarity-related meta-information is encoded and transmitted in neural systems from both experimental and computational perspectives.

First, analyzing neural population recordings, we show that ensembles responding to familiar stimuli exhibit increased spike synchrony and reduced firing rates compared to those responding to novel stimuli, consistent with prior observations of repetition suppression [1]. We hypothesize that this synchrony emerges from structured excitatory recurrent connectivity within stimulus-selective ensembles, in line with theories of neuronal assemblies and synchrony [2-3].

Second, we develop a recurrent spiking network model demonstrating that such ensembles naturally form through Hebbian plasticity [4] and exhibit synchronized responses to their preferred stimuli. The degree of synchrony reflects stimulus familiarity, providing a dynamical signature of prior experience.

This suggests a complementary coding dimension to firing rates, enabling neural systems to multiplex stimulus identity and familiarity. Together, our results indicate that recurrent spiking networks encode new versus familiar stimuli through distinct dynamical regimes, with synchrony serving as the primary carrier of meta-information about input familiarity.

[1] K. Grill-Spector et al., *Trends in cognitive sciences*, 10(1), 14-23, 2006.

[2] W. Singer, *Neuron*, 24, 49-65, 1999.

[3] C. Korndörfer et al., *Neural computation*, 29(9), 2491-2510, 2017.

[4] D. Hebb, *The Organization of Behavior: A Neuropsychological Theory*, 1949.