2-064. A functional role of cortical oscillations for probabilistic computation in spiking neural networks

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There is mounting evidence that the brain deals with uncertainty by carrying out probabilistic inference. This adds support to the long-standing idea that the brain employs a generative model to capture regularities in the world in the form of probability distributions, with neural dynamics representing a form of sampling from these distributions. However, real-world distributions are highly complex and pronouncedly multimodal, rendering computations such as sampling difficult in practice. We propose that this problem is overcome through background oscillations, a ubiquitous phenomenon throughout the brain, which we suggest to effectively implement a form of tempering in networks of spiking neurons. We show how the intensity of background input defines a Boltzmann temperature for spiking neurons. This allows oscillating background input to induce a tempering schedule and promote different modes of operation in spiking neural networks, resulting in improved coverage of the relevant state space. High levels of background input lead to periods of high temperature, where the state space is rapidly traversed, while periods with low input result in low temperatures, where the network state converges to a single mode. While the resulting impact on the network's probability distribution can be analytically described for current-based neurons, we show that this tempering effect is also present in conductance-based models across a broad range of physiologically relevant parameter settings. In particular, we demonstrate how background oscillations improve mixing in a stimulus interpretation task with ambiguous input, a scenario highlighting the advantages of sampling models. These networks show the emergence of a phase-based encoding, with coherent interpretations having a high probability at certain parts of the oscillation cycle. Our work thus provides a rigorous framework for the suggested functional role of cortical oscillations as a tempering mechanism and creates a novel link from sampling-based computations in spiking neural networks to neural coding.