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Stimulus Complexity Shapes the Optimal Balance of Cortical Excitation and Inhibition

How cortical networks process sensory inputs encountered in everyday life remains poorly understood. Recent experiments in vestibular cortex reveal marked differences between neuronal responses to natural self-motion and simple artificial stimuli, raising the question of which circuit mechanisms support these distinct coding regimes. In this talk, I will present spiking-network simulations and linear-response analyses that link stimulus complexity, recurrent inhibition, and population information transmission. We compare responses to periodic and natural stimuli while controlling neuronal firing rates and systematically varying excitation and inhibition. For natural stimulation, reconstruction-based information estimates are greatest near excitatory–inhibitory balance, where neurons exhibit diverse temporal response profiles. For periodic stimulation, the information optimum shifts toward excitation-dominated conditions. In reduced models, increasing inhibitory strength can improve information transmission for natural inputs while impairing it for periodic inputs. Approximations help provide a mechanistic explanation for the association between balance and response diversity: when excitatory and inhibitory contributions nearly cancel, small changes in their relative strength can produce large changes in the neural response shape. This local sensitivity peaks near balance. Together, these results suggest that stimulus-dependent recruitment of recurrent inhibition can reconcile distinct cortical responses to artificial and natural sensory inputs. Rather than requiring a single optimal coding regime, cortical networks may optimize information transmission by tuning the balance of excitation and inhibition depending on stimulus complexity.