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Poster presentation

Dynamics of non-linear cortico-cortical interactions during motion integration in early visual cortex: a spiking neural network model of an optical imaging study in the awake monkey

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Introduction

Lateral interactions are crucial mechanisms in contextual modulation of visual processing, including visual motion. We have recently shown, using voltage-sensitive dye imaging (VSDI), that a local static stimulus (Gaussian blob) first activates a restricted cortical area, followed by slow horizontal propagation of activity along the cortex [1]. In a sequence of two local static stimuli, two-stroke apparent motion, the two waves of horizontal activation interact non-linearly in V1, giving rise to a gradual and smooth wave of normalized activity. This signature of non-linear integration was a wave of suppression traveling from the representation of the second stimulus towards the first stimulus. To investigate the cellular and network mechanisms underlying these non-linear lateral interactions, we constructed a two-dimensional cortical network model using spiking neurons with conductance-based synapses. The model represents cortical layer 2/3, the main source of the VSDI signals. The connectivity of the inhibitory neurons was restricted to the local neighborhood, whereas the excitatory neurons could, in addition, also make long-range horizontal connections. The physiology of these horizontal connections was adjusted to induce balanced excitation/inhibition at high activity levels [2]. To compare the model dynamics to the in vivo VSDI signals, we extracted a model VSDI signal by recording the membrane potentials of many neurons arranged on a fine rectangular grid. The model was written in PyNN [3] using NEST [4] as a simulator. Our simulations reproduced the experimental observations of slow horizontal propagation when stimulating the network by a single static stimulus. In the two-stroke apparent motion paradigm, the model reproduced the non-linear integration by a wave of suppression. The origin and dynamics of this suppression were caused by the activity-dependent amount of local inhibition balancing the effect of the excitatory lateral connections. Physiological data shows that similar wave of suppression could be observed with a wide range of spatio-temporal two stroke input, but also with "real motion" stimuli. We therefore generalized our study to conditions during which the stimulus speed varies according to the suppressive spread velocity. Thus, our model suggests that the wave of non-linear integration observed in vivo could be caused by local inhibition balancing the integration of horizontal inputs. Moreover, it highlights the importance of contextual modulation for visual processing.

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