A biologically realistic model of contrast invariant orientation tuning by thalamocortical synaptic depression

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Abstract:

Simple cells in layer 4 of the primary visual cortex of the cat show contrast-invariant orientation tuning, in which the amplitude of the peak response is proportional to the stimulus contrast but the width of the tuning curve hardly changes with contrast. This study uses a detailed model of spiny stellate cells (SSCs) from cat area 17 to explain this property. The model integrates our experimental data, including morphological and intrinsic membrane properties and the number and spatial distribution of four major synaptic input sources of the SSC: the dorsal lateral geniculate nucleus (dLGN) and three cortical sources. The model also includes synaptic properties of these inputs. The cortical input served as sources of background activity, and visual stimuli was modeled as sinusoidal grating. For all contrasts, strong synaptic depression of the dLGN feedforward afferents compresses the firing rates in response to orthogonal stimuli, keeping these rates at practically the same low level. However, at preferred orientations, despite synaptic depression, firing rate changes as a function of contrast. Thus, when embedded in an active network, strong synaptic depression can explain contrast-invariant orientation tuning of simple cells. This is true also when the dLGN inputs are partially depressed as a result of their spontaneous activity and to some extent also when parameters were fitted to a more moderate level of synaptic depression. The model response is in close agreement with experimental results, in terms of both output spikes and membrane voltage (amplitude and fluctuations), with reasonable exceptions given that recurrent connections were not incorporated.

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