Emergence of Orientation Selectivity in Primary Visual Cortex without Functional Map

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Neurons in primary visual cortex (V1) display substantial orientation selectivity even in species where V1 lacks an orientation map, such as in mice and rats. The mechanism underlying orientation selectivity in V1 with such a salt-and-pepper organization is unknown; it is unclear whether a connectivity that depends on feature similarity is required, or a random connectivity suffices. Here we argue for the latter. To this end I will consider the response to a drifting grating of a network model of layer 2/3 with random recurrent connectivity and feedforward input from layer 4 neurons with random preferred orientations. I will show that even though the total feedforward and total recurrent excitatory and inhibitory inputs all have very weak orientation selectivity, strong selectivity emerges in the neuronal spike responses if the network operates in the balanced excitation/inhibition regime. This is because in this regime the (large) untuned components in the excitatory and inhibitory contributions approximately cancel. As a result the untuned part of the input into a neuron as well as its modulation with orientation and time all have a size comparable to the neuronal threshold. However, the tuning of the F0 and F1 components of the input are uncorrelated and the high-frequency fluctuations are not tuned. This is reflected in the subthreshold voltage response. Remarkably, due to the nonlinear voltage-firing rate transfer function, the preferred orientation of the F0 and F1 components of the spike response are highly correlated. Finally, I will show that a similar mechanism can account for the emergence of selectivity in layer 4 of V1 without orientation map.