Stimulus-dependent temporal decorrelation of evoked oscillatory responses in primary visual cortex

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In primary visual cortex, nearby neurons respond preferentially to oriented stimuli, presented within classical receptive fields of similar position, and share similar orientation tuning properties. While monosynaptic inhibition tends to be confined within the columnar scale, the lateral spread of excitatory connections can be as large as several millimeters (2-6 mm). Many studies have reported the existence of patchy horizontal excitatory projections linking preferentially distant neurons that respond to collinear stimuli (see eg. [1]). Thus, an intra-striatal excitatory coupling between neurons in distinct columns is established and the resulting interaction is likely to provide a contribution to context-dependent extra-classical receptive field effects [2].

We study here simple firing-rate and conductance-based models of two V1 hypercolumns interacting via lateral orientation-selective long-range excitation. Each hypercolumn is modeled by a uni-dimensional ring network. The connectivity is random and the probabilities of excitatory and inhibitory connections within the hypercolumn depend on the relative preferred orientations of the interconnected neurons [3]. The excitatory neurons also establish connections toward excitatory or inhibitory neurons in the distant hypercolumn, with a probability that decays quickly with the distance between preferred orientations.

In presence of a weakly tuned input, localized oscillatory responses are generated in each hypercolumn via local mutual inhibitory interactions. Stimuli of different relative orientations are presented in the receptive fields associated to the two hypercolumns. When these stimuli are collinear, the recruitment of long-range excitatory connections is larger, because the active neurons in the two hypercolumns have similar preferred orientations and are more likely to be interconnected. A mismatch of orientation in the stimuli results, on the other hand, in a smaller effective coupling between the hypercolumns. An effect of a stronger excitatory coupling is the emergence of a fast temporal decorrelation of the synchronous oscillatory activity, as a collective dynamical phenomenon [4]. Therefore, we predict that the decorrelation time of the evoked oscillatory responses in simultaneously activated interacting receptive fields will be modulated by the relative orientation of the presented bars. To conclude, we speculate about possible functional implications of the illustrated dynamical mechanisms [5].

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References