Asymmetric Surround Suppression Coincides with Structure of Orientation Preference Map

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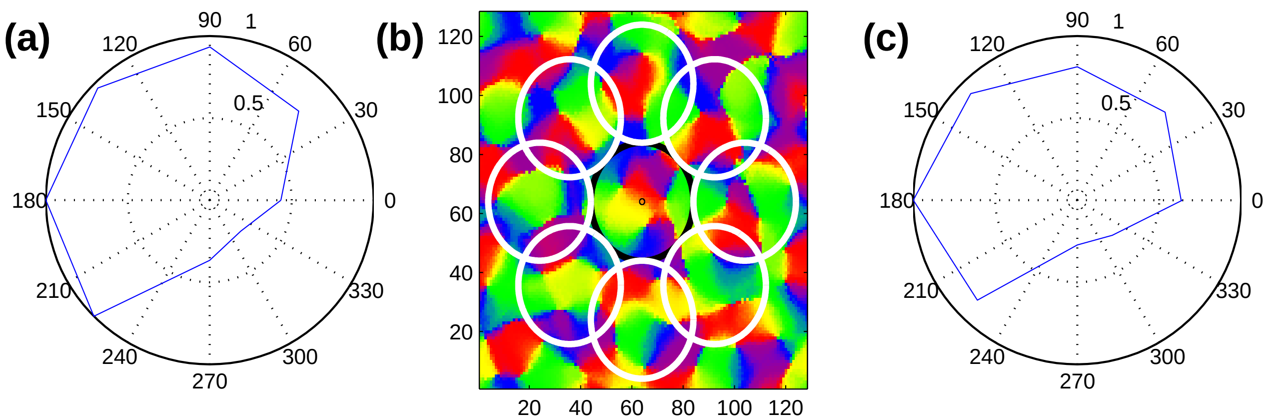
Neurons in the primary visual cortex (V1) respond preferentially to elongated stimuli like moving bars or gratings. While the response is maximal if these stimuli are presented in a specific region of the visual field (the so-called 'classical' receptive field, cRF), stimuli presented outside this region elicit no response. If one presents combinations consisting of stimuli inside and outside the cRF, however, it has been shown that the additional stimulus outside the cRF can modulate strongly the neuron's response to the stimulus inside the cRF (non-classical receptive field, ncRF) [1].

Functionally, it has been suggested that these response properties might underly the phenomena of pop-out, fill-in, and the detection of edges in a visual scene, but the neural mechanisms leading to ncRF properties are still not known. Two promising candidates for this modulatory interaction are long-range excitatory interactions within V1 [2], and top-down influences from higher visual cortical areas.

Within the framework of a simple model of V1, we explore the hypothesis that 'surround suppression', an attenuation of the firing rate resulting from an optimally oriented stimulus outside the cRF presented in addition to the same stimulus inside the cRF, is constrained by the geometry of the orientation preference (OP) map. Hereby, the additional stimulus does not cover the whole region outside the RF as in [1]. Instead, the surround stimulus has the same size as the center patch and is presented within different angles around the cRF center. From this arrangement, we would expect that the modulation will be strong if the surround stimulus activates cortical patches containing numerous cells of the same, preferred orientation; and weak, if patches of cells are stimulated which have predominantly preferred orientations orthogonal or oblique to the surround grating.

If the suppression depends on the angle under which the surround stimulus is presented, this modulation should be independent of the alignment of the stimuli inside and outside the cRF. This result from our simulations is consistent with recent extracellular recordings from cat area 17 [3]. In addition, our paradigma makes specific predictions which could be tested experimentally, namely how these modulatory effects are correlated to the OP map, how the properties of the stimuli (size and relative distance) should be chosen to yield maximal suppression, and in which respect one has to expect differences if the interaction is mediated either by lateral or top-down interactions.



(a) Response of a cortical cell to combined stimuli: the angular position indicates the position of the surround patch, and the radial axes show the response rate normalized to the single patch response (replotted from [3], experimental data). (b) On the OP map underlying our model, the white circles show which cells are stimulated by the surround patches presented at different angles. (c) Response of the model cell in the center of the small black circle in (b). The larger the amount of cells in the white circles in (c) having similar OPs to the OP of the center cell, the weaker is the response.

[1] A. Sillito et al., Nature **378** (1995).
[2] U. Ernst et. al, Neurocomputing **26-27** (1998).
[3] G.A. Walker, I. Ohzawa, and R.D. Freeman **19** (1999).