Contrast-dependent suppression from the “far” surround of V1 neurons: Experiments and data-driven model comparison.

J.M. Ichida¹, L. Schwabe², S. Shushruth¹ and A. Angelucci¹

¹Moran Eye Center, University of Utah, ²EPFL, Brain Mind Institute

V1 cells are tuned to stimulus size and are suppressed by optimally-oriented large stimuli in the receptive field (RF) surround. We previously proposed that modulation arising from the “far” surround (i.e. beyond the extent of monosynaptic horizontal connections) is mediated by highly divergent and fast-conducting feedback connections to V1 [1], and implemented this idea into a recurrent network model [2]. To isolate the modulatory signals from the far surround, V1 cells were stimulated with an optimal grating patch confined to the RF, surrounded by an iso-oriented annular grating of 14° fixed outer radius and an inner radius whose size was decreased from 14° to just outside the cell’s RF size measured at low contrast. A blank annulus was interposed between the center and surround gratings to prevent afferent stimulation of horizontal connection neurons in the “near” surround. Using this visual stimulus, we recently showed that the far surround can be facilitatory or suppressive depending on center stimulus contrast and surround stimulus size [3]. Here we used the same visual stimulus to examine the contrast-dependence of far surround suppression in V1 cells (n=70) recorded from anesthetized and paralyzed macaques. Then, we used these measurements in order to further constrain the parameter regime of our recurrent network model. In particular, we focused on two key parameters (the strength of the intra-areal recurrency and the feedback inhibition), which so far have not been measured directly.

Far surround suppression was induced by gratings up to 14° away from the RF center (mean=5.7°±0.34). We measured suppression strength (SS) as the percent decrease in the response to center-only stimulation induced by the widest annular grating. Mean SS at high contrast was 35%±2.3 and significantly decreased (22.2%±3.9, p<0.05) when the center stimulus contrast was lowered, and decreased even further (9.3%±3.2) when the surround stimulus contrast was also lowered. For 87% of cells suppression was stronger at high than at low center contrast. Far surround stimuli of identical size evoked weaker suppression of low contrast than high contrast center stimuli, so that larger surround stimuli were required to induce suppression of low contrast center stimuli.

We then calculated the probability of the suppression strength predicted by the recurrent network model for different values of the two key model parameters and found that the parameter regime that can best describe the data quantitatively includes stronger feedback excitation of inhibitory neurons than we assumed in the initial version of the model [2]. Additionally or alternatively, stronger inhibition could arise from direct feedforward excitation of inhibitory neurons or from surround suppression of LGN afferents, which are missing in the current version of our model.

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References