Introduction

Human observers are sensitive to "2nd-order" features, e.g., a horizontal edge defined by the change in contrast of a "1st-order" luminance pattern. Given common psychophysical and imaging data, it is reasonable to assume that the first stage operates on the retinal image and responds to luminance variations; the 2nd stage operates on the output of the 1st, and responds to a spatial frequency (SF) and orientation-tuned way to contrast variations (Landy & Graham, 2004). This model can also serve as a physiological model of single-unit responses in primate V1/V2. There, a unit responds at a single cortical site (strabismic amblyope S4, left eye) to drifting sinusoidal gratings of 0.5 Hz, which drifted at 0.5 Hz across the receptive field. The bottom row (SUA) shows a similar representation of the activity of one unit isolated by spike sorting at the same cortical site. The multi-unit and single-unit activity show similar modulator tuning.

Methods, stimuli, and analysis

Stimuli: We presented spatially defined drifting sinusoidal gratings. The temporal frequency of the carrier was 0.5 Hz, and the spatial frequency of the carrier was 0.5 cycles/degree. In the amblyopic eye, we presented a spatially defined drifting sinusoidal grating. The contrast of the carrier with a raised-sinusoidal grating, roughly optimized for the recorded neuron, was 40%.

Methods: We implanted 4 x 4 mm 96-channel multi-electrode arrays in 7 anesthetized, paralyzed macaques (6 amblyopes and 1 control). The experiment was approved by the institutional animal care and use committee. We mapped, in each eye, the retinal location of the vertical meridian of V1 and V2, close to the fovea and a lateral cortical location, posterior to the lunate sulcus. We then mapped the volumes of suppressive and excitatory receptive fields, which can bias surround suppression of cortical responses in amblyopic macaques.

Result: Surround suppression of cortical responses in amblyopic macaques would be weaker than in normals. The reason lies in the consequence of reduced 1st-order sensitivity (Wong et al., 2001). We therefore wondered whether surround suppression and complete surround suppression are present in amblyopic macaques and whether the results from 3 amblyopes and the control are similar to the results from 6 amblyopes and 1 control in the normal eye. Therefore, we tested 5 amblyopes. The bottom row summaries the derived SSIs for all responsive sites in an anisometropic amblyope (black, amblyopic eye; gray, fellow eye). As shown, surround suppression was reduced in the amblyopic eye: approximately two thirds of all sites were unsuppressed; the median SSI was approximately 0.5 in both eyes, and approximately 25% of sites and neurons were strongly surround suppressed (SSI > 0.75). In the control, we tested 5 single units, one of which was responsive to stimulation of the right eye. This unit was not surround suppressed, the triangle shows its derived SSSI (0.0). The bottom row summaries the derived SSIs for all responsive sites in an anisometropic amblyope (black, amblyopic eye; gray, fellow eye). As shown, surround suppression was reduced in the amblyopic eye: approximately two thirds of all sites were unsuppressed (SSI > 0.0). In S3, we tested 17 single units, four of which were responsive to stimulation of the right eye. One of those four units was also responsive to stimulation of the amblyopic eye. The triangles show the derived SSIs for those four units. The two other strabismic amblyopes (S2 and S6) were like S3 in that there was a marked difference in surround suppression between eyes.

Surround suppression index (SSI)

The shapes of these curves give information about the structure of the surround suppressive areas of the receptive field. The magnitude of surround suppression is captured by the strength of the response at the optimal modulator SF and at 0.5 Hz in the amblyopic eye. The effect of surround suppression on luminance SF is in the fellow eye. The three example cortical loci for modulator SF show a representative range of SSI values from no suppression (diagonal, top) to strong suppression (shaded, band-pass, bottom).

Methods: We computed the modulated responses for each modulator SF and orientation modulation that drifted at 0.5 Hz across the receptive field. We then plot response to modulator SF and orientation modulation that drifted at 0.5 Hz across the receptive field. The top row (SUA) shows a similar representation of the activity of one unit isolated by spike sorting at the same cortical site. The multi-unit and single-unit activity show similar modulator tuning.

Conclusion

Surround suppression of cortical responses in amblyopic macaques was reduced as compared to the control. This abnormality may be the neural basis of 2nd-order sensitivity deficits in amblyopes.

Citations

Wong et al. (2001), Vision Research.
Tanaka & Ohzawa (2009), Journal of Neurophysiology.

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