Retinal Ganglion Cell Parameters Predicting Human Performance in a Two-Stage Neural Spiking Model of Luminance Increment Detection

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Background: Clinical perimetry measures non-central vision loss using circular luminance increment stimuli.

Gardiner et al.¹ developed a model of perimetric stimulus detection that used parameters from animal neurophysiology and signal detection based on firing rates in the visual cortex (Figure 1).

Aim: To determine model retinal ganglion cell (RGC) parameters that allow prediction of human psychometric functions for luminance increment detection.

Methods: 2IFC psychometric functions for detection of 0.43° (size III) and 1.70° (size V) diameter circular luminance increments were measured for two observers, at eight spatial locations (±9, ±9 and ±15, ±15). Model psychometric functions were computed for the same. RGC receptive field characteristics, maximum firing rate and centre-to-centre spacing were varied within plausible ranges from the literature²,³ (Figure 2), and model/empirical psychometric functions were compared. Effects of increasing numbers of non-functional RGCs were also modelled.

Results: RGC parameters (orange curves in Figure 2) were found that matched empirical detection thresholds across locations and stimulus sizes (mean difference [95% CI] for smaller stimulus -0.1dB [-0.5 to +0.3], for larger stimulus +0.3dB [0 to +0.6]). Similar to the previous study¹, empirical psychometric functions were steeper than those of the model (mean difference [95% CI] for smaller stimulus 1.0dB [0.9 to 1.1], for larger stimulus 1.9dB [1.7 to 2.1]) (Figure 3). Increasing numbers of non-functional RGCs flattened model psychometric functions and raised thresholds in a manner consistent with the literature on glaucoma patients⁴.

Conclusions: RGC parameters within the range found in primate electrophysiological studies allowed model thresholds but not slope of psychometric functions to match empirical data. Slope differences may be due to unmodelled feedback factors. The model will be useful in predicting the effects of RGC disease on perimetric thresholds.


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