The relationship between spatial resolution and effective retinal ganglion cell separation in macaque monkeys

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Purpose
The purpose of this study was to investigate the relationship between spatial resolution and effective retinal ganglion cell separation in macaque monkeys.

Methods
We used previously published data from the literature of spatial resolution thresholds (mean of 7 monkeys (Macaca nemestrina) obtained using gratings of 90% contrast at eccentricities from 0 to 24 deg and ganglion cell densities from 1 monkey (Macaca fascicularis) at eccentricities from 3 to 25 deg. Ganglion cell densities were transformed to effective ganglion cell separations.

Results
Strong linear relationships through the origin were established between different modalities of effective ganglion cell separation and grating resolution thresholds. There is a good correspondence between measured spatial resolution (Kiørpes & Kiper, 1996) and effective ganglion cell separation (Wade et al., 1990) in the studied eccentricity range (Fig. 1). A linear regression with zero constant yields a regression coefficient of 1.46 (95% CI: 1.21-1.70). Assuming that only midget cells mediate spatial resolution, and that they make up 80% of the ganglion cell population in macaque retina, it is possible to calculate the contribution of ON and OFF midget ganglion cells. A direct proportionality between resolution and effective ganglion cell separation should yield a regression coefficient of one (Fig. 1, black dotted line). To account for an ON/OFF midget population in which the cells act as complementary encoders (ON and OFF), it is necessary to divide the regression coefficient by the whole ganglion cell population by 1/0.8 = 1.25, and for a population in which cells act as individual encoders (ON or OFF) the diverter will be 1/0.8 = 1.25. This yields coefficients of 1.30 (95% CI: 1.17-1.43) for a population of complementary encoders and 0.92 (95% CI: 1.00) for a population of individual encoders.

Discussion
The results indicate that total ganglion cell separation is a poor predictor of experimentally measured spatial resolution (Fig. 1, blue data & Fig. 2). A marginal improvement is achieved by using the midget ganglion cell subpopulation (Fig. 1, red data & Fig. 3). However, a predictor based on a subpopulation of individual encoders (50% ON or OFF cells) yields a considerable improvement (Fig. 1, green data & Fig. 4) with a regression coefficient close to unity (Fig. 1, diagonal dotted line). Comparisons between spatial resolution and ganglion cell separation based on human data yield similar results (Popovic, 2003).

Conclusions
Strong linear relationships through the origin were established between effective ganglion cell separation and grating resolution thresholds in macaque monkeys. Several factors might have affected our results: variation of the visual system, methodological issues relating to the measurements of central spatial resolution performance, and the fact that the ganglion cell density data were obtained from only one macaque. Nonetheless, we present results that are comparable to theoretical limits of resolution.

References

Fig. 1. Plot of spatial resolution thresholds versus effective ON midget ganglion cell separation.

Fig. 2. Plot of spatial resolution thresholds versus eccentricity.

Fig. 3. Plot of spatial resolution thresholds versus effective OFF midget ganglion cell separation versus eccentricity.

Fig. 4. Plot of spatial resolution thresholds versus eccentricity.