Lateral inhibition and spectral opponency in the outer retina of primate

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PURPOSE
Horizontal cells play an important role in gain scaling photoreceptor signals to control for fluctuations in brightness and are often assumed to play a role in color vision. However, the precise footprint of horizontal cells on vision in primates has not been fully resolved. We modeled the outer retina to explore possible influences of horizontal cells on chromatic processing in the midget pathway.

METHODS
The primate fovea was modeled with a trichromatic cone mosaic, two types of horizontal cells and midget bipolar cells. The cone mosaic transformed simulated RGB video into cone activations. HI and HII horizontal cell networks were each modeled as a resistive mesh that was driven by weighted combinations of cone signals. The midget bipolar cells took the difference between cone signals and horizontal cells at each location in the retina. Parameters of the cone mosaic and horizontal cell network that influence the spatial sampling and chromatic opponency of first-order projection neurons, the bipolar cells, were examined. Spatial frequency tuning and cone weights of modeled cells were compared to experimental observations from the literature.

RESULTS
Horizontal cell connectivity, mosaic arrangement and horizontal cell receptive field size were all factors influencing the propagation of cone signals. Surprisingly, modeling with cone isolating stimuli, there were biologically plausible parameters that generated a modest S-cone signal via horizontal cells in 2-10% of midget cells. The weights of S-cone signals were estimated to be between 10-20%, which is sufficient to produce a small population of cells that would be well suited to code for hue percepts. Finally, we noted that the spatial structure of stimuli had a substantial influence on the propagation of S-cone signals.

DISCUSSION
A computational model can explain how a relatively small, but physiologically significant signal from S-cones might plausibly find its way into a subset of midget ganglion cell circuits via HII horizontal cells. The findings that only a small proportion of midget ganglions in the model carried S-cone signals and that the amplitude of such signals was modest may explain why such cells have not been routinely observed. The results of our modeling could implicate HII cells in both blue/yellow and red/green color vision and could explain the preserved color vision in individuals with dysfunctional ON-bipolar glutamate receptors, mGluR6.