Presentation Abstract

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Title: Symmetry breakdown in the ON and OFF pathways of the retina at night: Functional implications

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Authors: *C. PANDARINATH¹, J. D. VICTOR², S. NIRENBERG³;
¹Physiol. and Biophysics, Weill Med. Col. Cornell Univ., New York, NY;
²Neurol. and Neurosci., ³Physiol. and Biophysics, Weill Med. Col. of Cornell, New York, NY

Abstract: The standard view of the visual system holds that visual information is divided into parallel pathways, beginning in the retina. One fundamental example of this division is the split into ON and OFF pathways. Traditionally, these pathways have been thought of as “equal and opposite,” that is, they respond to the same features of the visual scene, just with opposite polarity. However, evidence has begun to accumulate that the two pathways are subtly different, both at the physiological and perceptual levels. The functional relevance of these differences, though, has yet to be determined.

Here we show that the ON and OFF pathways show a substantial difference in their temporal adaptation to day and night, and, further, that this difference has a clear functional advantage. We characterized the temporal response properties of the ON and OFF pathways under day (photopic) and night (scotopic) conditions, using mouse retinal ganglion cells as the model system. The stimuli were sine-wave gratings, white noise, and natural sequences. We found that during the day, the pathways are, in fact, largely symmetric: their responses differ in sign, but their temporal characteristics are nearly identical.

However, at night, the two pathways diverge - ON cells signal better to low temporal frequencies, while OFF cells respond better to high.

We then show how this divergence becomes useful at night, using a simple model of signal detection. At low light levels, the limits placed by quantal fluctuations affect increments and decrements in an asymmetric manner - increments become more difficult to detect than decrements of equal magnitude. Thus, in order to send a reliable signal in the dark, ON cells must integrate their input over a longer period of time than OFF cells, consistent with the observation that ON cells selectively shift toward low temporal frequencies.
In sum, we show that the assumption of complementary, symmetric ON and OFF pathways breaks down with the shift from day to night vision. This is important for two main reasons: first, since retinal outputs serve as building blocks for circuits in higher brain areas, characterizing this breakdown of symmetry allows one to put constraints on models for downstream processing (e.g., our findings suggest that models of cortical receptive fields that rely on complementarity of ON and OFF input would fail at night, when the two pathways are out of sync). Second, these differences provide clues about the stages of processing that act on the separate pathways. Specifically, our results suggest that the two pathways have separate mechanisms to regulate integration time.

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