

EFFICIENT RETINAL GANGLION CELL CODING
AND THE STATISTICS OF NATURAL SCENES

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ABSTRACT

The structure of the early stages of the visual system is thought to be well-matched to the particular statistics that characterize the visual environment. Retinal ganglion cells in vertebrates and analogous retinal units in invertebrates show center-surround receptive field organization. Given that center-surround organization is observed across species (in multiple modalities as well), we seek a general explanation of the purpose of this unit, specifically in terms of spatial visual coding. Ganglion cell coding has been assumed to be well-matched to only the most rudimentary statistical regularities of natural scenes, namely the pairwise correlational structure of images. It has been proposed that ganglion cell receptive fields, when convolved with natural images, are theorized to produce a flat or whitened power spectrum for a range of frequencies. If the visual system were performing a spatial decorrelation of ganglion cell outputs (presumably through lateral inhibition), it would give this type of whitened response (Atick and Redlich, 1992). But ganglion cell outputs are found to be highly correlated and furthermore, decorrelation is insufficient to predict center-surround receptive fields. In this thesis, we present a coding strategy that employs phase-randomized receptive fields that produce the same degree of whitening as those modeled after real ganglion cells, with center-surround organization. The phase-randomized receptive fields do not resemble real ganglion cell receptive fields suggesting that there are other goals to ganglion cell processing. Results indicate that the sparseness of the responses could be another goal of retinal coding since the center-surround receptive fields give a

more sparse response than do the phase-randomized ones. The flat (whitened) response power spectra could be related to what has been called *response equalization* (Field and Brady, 1997), which refers to the notion that cells sensitive to different frequencies should have uniform response magnitudes. Using a vector-length sensitivity measure, we find that data recorded from single ganglion cells across the macaque retina (Croner and Kaplan, 1995) show a degree of response equalization (at least for parvocellular ganglion cells). Nonlinearities in the retina may also be related to efficient coding goals.