A Learning Model for L/M Specificity in Ganglion Cells

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Abstract. An unsupervised learning model for developing L/M specific wiring at the ganglion cell level would support the research indicating L/M specific wiring at the ganglion cell level (Reid and Shapley, 2002). Removing the contributions to the surround from cells of the same cone type improves the signal-to-noise ratio of the chromatic signals. The unsupervised learning model used is Hebbian associative learning, which strengthens the surround input connections according to the correlation of the output with the input. Since the surround units of the same cone type as the center are redundant with the center, their weights end up disappearing. This process can be thought of as a general mechanism for eliminating unnecessary cells in the nervous system.

Unsupervised learning models have been proposed for the generation of L/M specific color opponent cortical receptive fields based on visual experience (Ahumada & Mulligan, 1990; Wachtler, Doi, Lee & Sejnowski, 2007). The inputs for these cortical models are ganglion cells with L/M indiscriminate wiring, but their single cone centers make them color opponent (Paulus & Kroeger-Paulus , 1983). Here we show that unsupervised learning at the ganglion cell level could generate ganglion cell with the pure surrounds suggested by the results of Reid and Shapley (2002). We assume that at the time that learning occurs the optics are so blurry that the cones in the immediately surrounding units are seeing the same stimulus as the center cone.

Simple linear single-cone center, c(0,t), model of the ganglion cell with initially indiscriminate weighting over N surround cones, c(i,t).

$$g(t) = c(0,t) - \mathrm{Sum}(i,1,N,w(i,t)\, c(i,t)),$$

$$w(i,0) = 1/N\ .$$

The associative learning rule with learning rate a(t) is

$$w(i,t+1) - w(i,t) = a(t)\, g(t)\, c(i,t)$$

with the normalization

$$\mathrm{sum}(i,\ 1,\ N,\ w(t+1)) = 1.$$

This model with an appropriate learning rate leads to weights which are zero for the surrounds that have the same response as the center.

This mechanism does not obviate the need for the unsupervised cortical learning mechanisms to construct plausible cortical receptive fields, and something like the translation-invariance learning mechanism of Maloney and Ahumada () is still needed to organize the outputs of receptive fields at different locations.

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