The Relationship Between Subthreshold and Superthreshold Ocular Dominance in Cat Visual Cortex

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Primary visual cortex (V1) is the site at which three dramatic changes in receptive field properties are known to occur. It is the site where orientation and motion selectivity first emerge, as well as where information from the right and left eyes is integrated. This integration of ocular information in V1 is the first step in a cortical pathway that creates a representation for object depth.

The ocularity of individual neurons has previously been measured by comparing the firing rate responses elicited by stimuli presented separately to each eye. Hubel and Wiesel used this ocular dominance metric to demonstrate the columnar organization found in cat V1. Neurons within the same column exhibit similar ocular dominance. Across V1 ocular dominance changes from neurons preferring only right-eye input to neurons equally responsive to both eyes to neurons preferring only left-eye input. Hubel and Wiesel also showed that ocular dominance depends on visual experience during the developmental critical period. During this critical period, disrupting ocular alignment increases the monocularity of neurons [1] and closing one eye causes a shift in ocular dominance toward the open eye [2]. Measuring ocular dominance using firing rate responses has thus been useful in observing changes in V1 brought on by changes in the visual environment.

Ocular dominance has been used to describe the degree of right and left eye input onto a neuron, but is based on the neurons output, firing rate, instead of the subthreshold membrane potential. Membrane potential is more closely related to the synaptic inputs onto neurons, since firing rate must pass through the spike threshold nonlinearity. Spike threshold has been shown to increase direction selectivity, narrow orientation selectivity, and enhances the differences between simple and complex cells (for review see [3]). To determine how spike threshold alters ocular dominance, we recorded membrane potential and firing rate responses to the preferred stimulus in the right and left eye. Ocular dominance based on firing rate systematically overestimates the degree of monocularity relative to that based on membrane potential. All neurons in the database depolarized to both the right and left eye, yet not all neurons increased firing rate to both the right and left eye. A simple model of spike threshold accounts for the discrepancy between membrane potential and firing rate ocular dominance. This work raises the question of whether the shifts in firing rate ocular dominance induced by the changes in the visual environment, overestimate the amount of changes in the inputs to cortical neurons.

Acknowledgments
This work was supported by NEI grant R01 EY04726

References