Neural Basis of Fine Visual Discrimination

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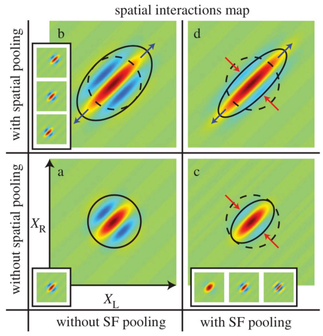

Our visual system is capable of discriminating small differences in visual stimuli, e.g., stereoscopic depth discrimination, where the discrimination threshold can reach down to several seconds of arc, as demonstrated by Westheimer & McKee and others. This is in spite of limitations imposed by intrinsic variability of neural responses, and limited dynamic range of neural signals where signal strength must be encoded by spike discharge that cannot exceed a few hundred spikes per second. Typically, a fine discrimination ability for a given stimulus dimension is closely related to the sharpness of neural tuning for that dimension. For example, for achieving a fine depth discrimination ability, a sharp binocular disparity tuning must be realized at some point in the visual system. We analyzed neurons in V1 if any mechanisms exist that enhance sharpness of neural tuning. Surprisingly, it turns out, a sharp disparity tuning is achieved by pooling of output of multiple neurons in the spatial frequency domain. The converse is also true. A sharp matching requirement for left-right spatial frequencies is achieved by pooling of output of multiple neurons in the space domain. Therefore, pooling generally broadens a tuning in the domain where pooling is done, but sharpens the tuning in the counterpart domain related via Fourier transform. Visual discrimination ability may also be enhanced by an appropriate form of adaptation that allows optimal use of the limited dynamic range of neural firing. A well-known example of such optimization is light adaptation for allowing the visual system to operate over ten log units of changes in ambient luminance from star-less night to illumination under bright sun light. There is also a mechanism for contrast gain control for cortical neurons. Both of these are based on gain changes. Distinct from gain adaptations, we have also found a novel mechanism for optimal use of the limited dynamic range in the form of offset adjustments, as observed in responses of V1 neurons.

Reference:

Kato D, Baba M, Sasaki KS, Ohzawa I, Effects of generalized pooling on binocular disparity selectivity of neurons in the early visual cortex. Phil. Trans. R. Soc. B 371: 20150266, (2016), doi: 10.1098/rstb.2015.0266

Biography:

Izumi Ohzawa received his BS degree in Electronics Engineering from Nagoya University in 1978, and Ph.D. in Physiological Optics (Vision Science) from University of California, Berkeley in 1986. After working as a postdoctoral associate, assistant and associate research physiologist at Berkeley from 1986 to 2000, he joined the Graduate School of Engineering Science, Osaka University as a professor in 2000. Since 2002, he is a professor in the Graduate School of Frontier Bioscieces, Osaka University. He is also a member of CiNet since 2013. His primary research interests are in neurophysiology of the visual system with emphases on binocular vision and stereopsis, texture, and shape perception.
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