A neural computation for visual acuity in the presence of eye movements

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Abstract:

Humans can distinguish visual stimuli that differ by features the size of only a few photoreceptors. This is possible despite the incessant image motion due to fixational eye movements, which can be many times larger than the features to be distinguished. To perform well, the brain must identify the retinal firing patterns induced by the stimulus while discounting similar patterns caused by spontaneous retinal activity. This is a challenge since the trajectory of the eye movements, and consequently, the stimulus position, are unknown. We derive a decision rule for using retinal spike trains to discriminate between two stimuli, given that their retinal image moves with an unknown random walk trajectory. This algorithm dynamically estimates the probability of the stimulus at different retinal locations, and uses this to modulate the influence of retinal spikes acquired later. Applied to a simple orientation-discrimination task, the algorithm performance is consistent with human acuity, whereas naive strategies that neglect eye movements perform much worse. We then show how a simple, biologically plausible neural network could implement this algorithm using a local, activity-dependent gain and lateral interactions approximately matched to the statistics of eye movements. Finally, we discuss evidence that such a network could be operating in the primary visual cortex.

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