Implications of neuronal interactions on disparity tuning in V1

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In the primary visual cortex, disparity tuning can be modeled by a combination of Gabor weighted inputs from the left and right eyes, followed by a nonlinear rectification due to the spiking mechanism. Although this feedforward "disparity energy model" can predict quite well the disparity tuning curves of V1 neurons, actual measurements of V1 neurons' responses to varying disparities in dynamic random dot stereograms (DRDSs) revealed some subtle but notable deviations. First, valleys tended to be wider than peaks creating a sharper disparity tuning curve than one predicted by the model. Second, when cortical neurons were presented anti-correlated DRDSs (a-DRDSs), the inverted disparity tuning function was of lesser magnitude than predicted by the disparity energy model. These deviations can be understood in terms of local competitive and non-local cooperative interactions that we have recently demonstrated among disparity-tuned neurons in primary visual cortex. Our data show that early in responses, neurons of antagonistic disparity tuning at the same spatial location mutually inhibited each other, while later in responses, neurons of similar disparity tuning across spatial locations mutually facilitated each other. These interactions are consistent with the uniqueness and smoothness constraints common in computational algorithms for stereopsis. These constraints allow the use of global contextual information to resolve ambiguity in local depth estimates by suppressing false matches and enhancing correct matches. Interestingly, because these interactions were delayed, we found that the deviation from a Gabor function became more pronounced for DRDSs with slower refresh rates. The greater time between random dot patterns allowed neuronal interactions to sharpen disparity tuning. When we presented a-DRDSs, we no longer observed cooperative interactions, but local competitive interactions did persist. The lack of cooperation was expected, since there was no consistent global stereo context and might explain why the observed inverted disparity tuning curve matched the predicted feedforward model. The tendency for a weaker response magnitude relative to the prediction of the model might be attributed to the persistent competitive interactions. Overall, these findings suggest that disparity tuning in V1 is not only a result of feedforward computations, but is likely the outcome of a depth inference process that also involves lateral and recurrent interactions.

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