Spatiotemporal integration properties in MT neurons affect motion discrimination

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Perception requires integrating noisy dynamic visual information across the visual field to identify relevant stimuli and guide decisions. While temporal integration has been studied extensively in experiments with highly controlled visual stimuli and reverse-correlation techniques, the nonlinear mechanisms underlying spatial integration are often neglected. More concretely, neurons in the Middle Temporal area (MT) show antagonistic motion-direction selectivity within their receptive fields (RFs) [1-3], and these neurophysiological properties could mediate the spatial suppression effects observed in perceptual motion discrimination tasks [4]. However, such a link between neural dynamics and behavioral responses is yet to be established. Here, we show that the spatial structure of the stimulus modulates MT responses in monkeys performing a decision making experiment with rich spatiotemporal motion stimuli. Further, we propose a model to generate global motion perception from local direction-selective neurons and find that spatial integration impacts perceptual choices.

In particular, we found that monkeys integrate spatial evidence sublinearly in a motion discrimination task due to (i) weaker impact of motion further away from the fovea, and (ii) surround suppression effects causing an attenuation of the responses to motion in the center of the stimulus. To investigate the neural basis of these effects, we used nonlinear regression models and show that the instantaneous firing rates of MT neurons can be predicted from both excitatory and suppressive contributions of the motion fields within the neurons' RFs.

We propose to link the findings on the neural and behavioral level in a hierarchical model of spatiotemporal decision making in which spatial context effects modulate spatial stimulus integration in neurons of sensory areas, and a decision area supports temporal integration to give rise to perception [5]. In the input layer, two populations of sensory neurons respond preferentially to motion in opposite directions but the structure of the connectivity generates heterogeneous spatial modulation of the responses, and nonlinear spatial integration of the motion stimuli. A second layer consisting of two decision-encoding populations, each associated with a possible choice, integrates sensory evidence across time until the network reaches the attractor state due to winner-take-all dynamics. This model reproduced the spatial effects found in monkey's choices, evidencing that contextual modulation mechanisms at the level of sensory neurons could be responsible for the perception of spatially distributed motion signals.

Taken together, our results provide a deeper understanding of how the brain processes dynamic visual information, and how specific nonlinear properties of sensory perception in sensory neurons shape perceptual choices.

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