Heterogeneous spatial encoding in area MT shapes motion perception

Interacting with the world often requires integrating noisy dynamic information across the visual field to discriminate stimuli and guide behavior. Studies using highly controlled visual stimuli have provided a comprehensive description of how the instantaneous responses of sensory neurons are integrated across time to make decisions. Nonlinear mechanisms underlying spatial integration have been described at the single neuron and perceptual levels, but these effects have not yet been linked in a unified model of perception. Here, we explore spatiotemporal motion representations in visual area MT and relate contextual effects in single neurons to perceptual responses.

We find that monkeys integrate spatial evidence sublinearly in a motion discrimination task due to (i) surround suppression effects causing an attenuation of the responses to motion in the center of the stimulus, and (ii) weaker impact of peripheral motion. To test whether these effects originate in MT, we estimate and validate the spatiotemporal direction sensitivity kernels of MT neurons using nonlinear regression models. Our results reveal reliable nonuniform spatial modulation effects in MT units that point towards visual spatial integration taking place in sensory areas.

Finally, we summarize these finding 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. By simulating pseudo-populations of MT neurons with different spatial weighting profiles, we demonstrate how spatial effects at the behavioral level are directly shaped from sensory representations of motion. By simulating models with a variety of neuronal receptive field structures, we demonstrate how spatial effects at the behavioral level emerge from these instantaneous sensory representations of motion. Taken together, our results provide a deeper understanding of how the brain processes dynamic visual information, and how specific nonlinear properties of sensory neurons shape our perception of spatially distributed motion signals.