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Human Visual Speed Change Detection in Foveal and Peripheral Vision – Thresholds, Reaction Times, Apparent Speed, and Implications for Neurophysiological Experiments

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Visual motion perception has always been a key model to explore the relationship between our sensory experience and its underlying neuronal processes, and extensive psychophysical and neurophysiological research has turned it into one of the best understood functions of the human visual system today. However, in contrast to the perception of uniform motion, it is still unknown how rapid changes of speed are detected by the brain.

This thesis explored the ability of human observers to detect instantaneous positive and negative speed changes in different parts of the visual field. In the four main experiments, grating stimuli were shown foveally and at 5°, 10° and 15° eccentricity. For ten subjects, response rates and reaction times (RTs) were measured for accelerations and decelerations of different amplitude, occurring after 750ms of motion at a reference speed of 3.3deg/s. Psychometric functions were fitted to the response rates to extract detection thresholds. The main findings are: (1) Detection is better for accelerations than for decelerations within 5° eccentricity. Lower thresholds (+21% vs. -27%) and significantly shorter RTs were found for the former as compared to the latter. (2) With increasing eccentricity, detection performance deteriorates for acceleration detection and improves for deceleration detection. At 10° and 15° eccentricity, detection thresholds were higher for accelerations than for decelerations (+30% vs. -20%). (3) Peripheral detection performance depends on speed change amplitude. Whereas response rates were higher and RTs were shorter for decelerations than for accelerations at small and moderate speed changes around threshold, they were lower and longer, respectively, at large speed change amplitudes of 100% and 200%. (4) Peripheral speed change detection is biased towards decelerations. Lowest response rates were not found for constant speed, but for small positive speed changes. (5) RTs for both accelerations and decelerations follow a power-law function with an exponent of -0.4 when speed changes are defined by their difference instead of their ratio.

For a full characterization of peripheral speed change detection, it was shown that a rapid form of motion adaptation has to be considered. Using the same stimuli as in the main experiments, one additional experiment at 10° eccentricity was conducted, in which speed changes occurred randomly after 250, 500, 750, 1000 or 1250ms. The following aspects were found: (1) Adaptation causes a reduction of perceived speed which subtracts from stimulus

accelerations, and adds to stimulus decelerations. , biasing detection towards decelerations. As in the main experiments, lower thresholds were found for deceleration detection after more than 500ms reference speed duration, and response rates became lowest for small positive speed changes, indicating that accelerated motion was perceived most uniform. (2) Adaptation causes improvements of differential sensitivity. Thresholds for acceleration detection, and even more so for deceleration detection were found to drop markedly within 1250ms, especially between 250 and 500ms reference speed duration. (3) Motion adaptation can account for the conflicting detection performance observed for small and large amplitudes of change. Based on previous psychophysical and electrophysiological studies, a model is being proposed which assumes that adaptation selectively affects the neuronal representation of speed within a limited range around the adapting reference speed level. According to this model, reductions of perceived speed induce a bias towards deceleration detection within ±25% speed change, while detection performance remains unaffected and is superior for accelerations beyond ±50% speed change.

The obtained findings are discussed with respect to their implications for neurophysiological experiments and models on cortical motion processing in the non-human primate: (1) Psychophysical and electrophysiological evidence is presented that argue for a rapid motion adaptation mechanism at the stage of the primary visual cortex (V1). (2) Speed, spatial frequency and grating size are discussed as possible stimulus factors that cause adaptation in V1 neurons to be stronger in the periphery of the visual field. (3) Results are related to the current knowledge of adaptation and the neuronal code for speed in the middle temporal area (MT), a central brain region for perceptual decisions regarding motion.

This thesis is the first to examine speed change detection systematically across a range of eccentricities. It contributes to the still controversial question of whether accelerations or decelerations are easier to detect, and stresses the need to consider interferences by perceptual speed changes in order to fully account for psychophysical performance. Moreover, it raises specific questions for future electrophysiological experiments, and serves as a psychophysical reference for parallel experiments exploring the neuronal representation of instantaneous speed changes in area MT of the macaque monkey. Finally, the present findings call for a closer investigation of adaptation on timescales as short as a few hundred milliseconds, both psychophysically and physiologically.