A central goal of sensation and perception is to direct our interactions with the environment. During most voluntary motor actions that are driven by sensory input we consciously experience an internal representation of the visual world. This leads to the question how faithful this internal representation is, and how precise our actions are compared to this reference. To answer that question, we studied the relationship between the perceived speed, which is the experiential representation of the stimulus, and the speed of smooth-pursuit eye movements, the motor action.

We determined psychophysical thresholds for detecting small perturbations in the speed of Gabor patterns (1 cycle deg⁻¹) moving at a base speed of 4 deg s⁻¹. At the same time we recorded eye movement traces and used an ideal-observer analysis to compute analogous "oculometric" thresholds.

Our results show a remarkable agreement between perceptual judgments for speed discrimination and the fine gradations in eye-motion speed, with psychophysical and oculometric functions exhibiting the same slope. However, there was no correlation between perceptual errors and eye-motion errors on a trial-by-trial basis. We conclude that the motor system and perception share the same constraints in their analysis of motion signals, but they act independently and have different sources of noise.

Comparison of pursuit eye movement and perceptual performance in speed discrimination did not depend on the analysis interval. The red curve shows how the correlation of eye speed with subjective speed emerges when the physical perturbation speed is cancelled out.

These results show that the fidelity of the motor system can perfectly match that of a sensory system. This agreement in absolute thresholds is actually difficult to reconcile with a model of perceptual and motor control, where initially the visual system analyzes the speed of moving stimuli, and that speed estimate is then supplied to the motor system to control behavior. Neural computations at all levels are prone to noise. Our results rule out the possibility that simple measurement noise of the eye movements may give rise to differences in the fidelity. Another source of noise, motor noise from the oculomotor plant, might manifest itself as a reduction in pursuit fidelity compared to the perceptual fidelity. In our experiments this does not seem to be the case.

Results suggest that the magnitude of the noise common to both processes, presumably introduced by the analysis of visual motion, is so large that the separate noise sources are negligible. Alternatively, the amount of noise added separately to the two systems could, incidentally or not, be of the same magnitude.

A much more powerful way to investigate the relationship between the circuits driving perception and action is to look at the correlation between the perceptual and pursuit errors made on individual trials. If faster perceived speed goes along with faster eye movements on individual trials, this would support the notion that both subsystems are driven by the same circuitry and signals. A lack of correlation would suggest that independent subsystems are responsible for perception and action.