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Optimal Performance in Sensorimotor Behavior

LESLIE OSBORNE, Department of Neurobiology, University of Chicago

Suppose that the variability in our movements is caused not by noise in muscle contraction, nor by fluctuations in our intentions or plans, but rather by errors in our sensory estimates of the external parameters that define the appropriate action. For tasks where precision is at a premium, performance would be optimal if no noise were added in movement planning and execution: motor output would be as accurate as possible given the quality of sensory inputs. We have used visually-guided smooth pursuit eye movements in primates as a testing ground for this notion of optimality. In response to repeated presentations of identical target motions, nearly 92% of the variance in eye trajectory can be accounted for as a consequence of errors in sensory estimates of the speed, direction and timing of target motion, plus a small background noise that is observed both during eye movements and during fixations. The magnitudes of the inferred sensory errors agree with the observed thresholds for sensory discrimination by perceptual systems, suggesting that these very different neural processes are limited by the same noise sources. Computing the signal to noise ratio of pursuit movements allows us to estimate a "behavioral threshold" akin to a threshold for reliable perceptual discrimination of a change in target motion. We find that pursuit thresholds agree quite well with perceptual thresholds throughout the sensory-driven period of movement initiation. These results suggest that pursuit can be a reliable read-out of the evolving sensory estimate of target motion.