Noise improves sensitivity during optimized decision-making.

Adam Morris[1,2], Bart Krekelberg[1]
[1]Center for Molecular and Bahavioral Neuroscience, Rutgers University, Newark, NJ, USA
[2]National Vision Research Institute, Australian College of Optometry, Carlton, Victoria, Australia

Perception of visual features is thought to arise from noisy population codes in the brain. For most tasks, not all members of a population are equally suited to the task at hand. For example, for fine discrimination, the most informative neurons are those that have the steepest part of their tuning curve on the decision-boundary. Choice probability analysis suggests that primates assign higher weights to these maximally informative neurons to optimize decision-making. Under more natural conditions, however, such optimization could be difficult because tuning curves (and their derivatives) depend critically on the stimulus set used for their definition. Accordingly, sub-optimal inference is inevitable for real-world perceptual decision-making. We examined effects of optimal and sub-optimal inference on discrimination using a combination of computational modeling and psychophysics in humans and monkeys. We simulated a population of direction-selective neurons and mapped tuning curves for translational motion in random dot patterns. Even though model parameters were fixed, empirical tuning widths could be adjusted (and therefore, which neurons were the most informative) by varying the width of the distribution from which dot-directions were drawn ("external noise"). Discrimination thresholds were measured at different levels of external noise and with two different states of optimization. When optimized for narrow-distribution ("clean") stimuli, thresholds increased monotonically with external noise. When optimized for broad-distribution ("noisy") stimuli, however, thresholds for moderate levels of external noise were actually lower than those for low levels of external noise – even though the latter objectively carried more information about direction. We confirmed this unexpected result psychophysically in humans and monkeys using comparable methods (the two optimization-states were encouraged by presenting different proportions of high and low external-noise trials across blocks). Our results suggest that the visual system can optimize decision-making for expected noisy stimuli at the expense of reduced sensitivity to unexpected high-fidelity signals.