The neural basis of optimal cue combination

Wei Ji Ma

Department of Brain and Cognitive Sciences, University of Rochester
Meliora Hall, Box 270268, Rochester, NY, 14627,USA

Combining multiple pieces of sensory information about a stimulus can greatly improve perceptual performance. Despite the ubiquity of this phenomenon, its neural basis is still poorly understood. Psychophysical studies have shown that integration of two sensory cues is, in many cases, optimal in a Bayesian sense. Optimality requires that the cues are weighed by their reliabilities when being integrated into a single percept. A crucial implication of these findings is that the brain must encode sensory reliability, and the question is how. We observe that because neuronal population activity is variable from trial to trial, the population pattern of activity on a single trial, through Bayes' rule, automatically encodes a probability distribution over the stimulus, and therefore also the reliability of a cue. This form of neural coding is known as probabilistic population coding and has received increasing attention in recent years. We show that using such a code, optimality of cue integration can be achieved through simple linear operations on population patterns of activity, provided that neural variability belongs to a broad family of distributions which we call Poisson-like. We do not need to assume independent neurons, a specific type of tuning curve, or Gaussian probability distributions. Simulations confirm that a network of biologically realistic neurons can implement the proposed operations. A physiological prediction of this model is that neurons involved in optimal cue integration will exhibit (near) additivity in their cue interactions. Finally, we will outline a roadmap towards a complete neural theory of cue combination.