Neuronal network dynamics underlying stimulus categorization and estimation

M. Donderis[1], J. Esnaola-Acebes[1], B. Talluri[2], T. Donner[3], A. Roxin[1], and K. Wimmer[1]

[1]Centre de Recerca Matemàtica, Computational Neuroscience Group, Bellaterra, Spain
[2]National Institutes of Health, Laboratory for Sensorimotor Research, Bethesda, MD, United States of America
[3]University Medical Center Hamburg-Eppendorf, Dept. of Neurophysiology, Hamburg, Germany

Perception is influenced by past choices. In combined discrimination-estimation experiments a categorical choice leads to two biases:

(i) a choice-dependent confirmation bias in the continuous estimate of the stimulus average,

(ii) an overall decrease in the sensitivity to subsequent sensory evidence.

It remains unknown what neural mechanisms give rise to these post-decision biases and whether continuous estimates and categorical choices are computed in a common cortical circuit. Here, we develop a neural network model that addresses these questions. We leverage our recent results on the integration of continuous sensory evidence in a bump attractor network. By modulating the bump amplitude through a change in the global excitatory input to the network, we have observed qualitatively distinct temporal integration regimes, including early, uniform and late temporal weighting. We embed this integration circuit in a hierarchical three-area network such that it receives stimulus information through a low-level sensory circuit and sends integrated stimulus evidence to a top-level decision circuit that signals the categorical choice. Both the categorical choice as well as the stimulus estimate rely on the accumulated evidence in the integration circuit. To model post-decision biases, we include top-down feedback signals from the decision circuit. The feedback to the integration circuit is non-specific and reduces the sensitivity to subsequent stimuli by increasing the bump amplitude as described above. The feedback to the sensory circuit is selective, akin to feature-based attention, and gives rise to a confirmation bias through a choice-dependent modulation of the sensory inputs. Our network model provides a comprehensive and experimentally testable computational framework to study the neural mechanisms underlying stimulus estimation and perceptual categorization and their interaction.