A Line-Attractor Network Model of Multiple Choice Decisions

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Decision making with multiple alternatives has been subject of many psychological studies and mathematical modeling (e.g. Usher & McClelland, 2001). It is generally observed that a decision is harder, and its reaction time is longer, when there are more choice options to consider. Recently, to investigate the neural basis of multiple-choice decisions, Churchland et al. (2005a, 2005b) trained monkeys to perform a visual motion direction discrimination task with multiple choice targets. They collected behavioral data and recorded from the lateral-intraparietal (LIP) area, and found that changing the number of choices affected both behavior and neural activity in several ways. For nontrivial discriminations (when the motion coherence is not too high), an increase in the number of choices resulted in lower monkey’s performance (the rate of correct responses), longer reaction times, and reduced LIP neural activity during the early stages of decision formation.

Here we propose a spiking network model for decision making in the multiple-choice motion discrimination task, using a continuous line-attractor circuit (Compte et al., 2000) which is capable of representing all possible directions of a motion stimulus. We extended the model to a ‘double-ring’ structure with two interconnected neural circuits. One module represents the cortical area LIP in which accumulation of information takes place; and the other represents the superior-colliculus (SC) where burst neurons are capable of triggering saccadic responses. Our simulation protocol incorporates visual inputs to LIP that represent both the targets and the motion stimulus, presumably coming from different visual pathways. The LIP units accumulate sensory information, while SC bursts indicate threshold-crossing of LIP activity and termination of the decision process (Lo & Wang, 2006). Simulation results show that the model accounts for a wide-range of behavioral and physiological data for 2, 4, and 8 choices. Specifically, the model reproduces the performance and reaction-times as a function of motion coherence; longer reaction times in error trials than in correct trials; and reduced neural responses during targets presentation with an increased number of choices. We analyzed the synaptic currents to LIP model neurons and found that the reduction in the early neural response for a larger number of choices results from a larger recruitment of the inhibitory neurons in the network. Interestingly, the model shows a higher probability of erroneous choices for a target if the latter is closer to the correct target, thereby predicting a specific dependence of error rate on the similarity between the chosen target and the correct one. This prediction is specific to a continuous network model in contrast to a discrete network model (Wang, 2002) and experimentally testable.

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References