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Research Article

A Two-Layered Diffusion Model Traces the Dynamics of Information Processing in the Valuation-and-Choice Circuit of Decision Making

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A circuit of evaluation and selection of the alternatives is considered a reliable model in neurobiology. The prominent contributions of the literature to this topic are reported. In this study, valuation and choice of a decisional process during Two-Alternative Forced-Choice (TAFC) task are represented as a two-layered network of computational cells, where information accrual and processing progress in nonlinear diffusion dynamics. The evolution of the response-to-stimulus map is thus modeled by two linked diffusive modules (2LDM) representing the neuronal populations involved in the valuation-and-decision circuit of decision making. Diffusion models are naturally appropriate for describing accumulation of evidence over the time. This allows the computation of the response times (RTs) in valuation and choice, under the hypothesis of ex-Wald distribution. A nonlinear transfer function integrates the activities of the two layers. The input-output map based on the infomax principle makes the 2LDM consistent with the reinforcement learning approach. Results from simulated likelihood time series indicate that 2LDM may account for the activity-dependent modulatory component of effective connectivity between the neuronal populations. Rhythmic fluctuations of the estimate gain functions in the delta-beta bands also support the compatibility of 2LDM with the neurobiology of DM.

1. Introduction

Even simple decisions imply higher cognitive functions that integrate noisy sensory stimuli, prior knowledge, and the costs-and-benefits related to possible actions in function of their time of occurrence. Accumulation of noisy information is a reliable pattern performed by neural pools in cortical circuitry during decision making (DM) process. This process is time absorbing, especially when the quality of information is poor and there exist many possible alternatives that may be evaluated and compared. There exists large consensus in the studies of DM toward the conformation of a phase of accumulation of evidence until a decision is made [1–11]; that is, the decision maker is expected to keep on gathering information until the evidence in favor of one of the alternatives suffices. Thus, the stochastic integration of information up to a certain threshold gives rise to a speed-accuracy tradeoff (the performance of the responses increases for slower response times) that is bounded by the costs associated with obtaining more information. In this context the responses times (RTs) to the stimuli characterize the speed-accuracy tradeoff because they allow the identification of the time when a decision is made (although not yet completed by the motor action) [12]. RT studies have addressed the implementation of diffusive models for describing decisional behaviors and the identification of the neuronal areas related to the decisional activity. DM is a process that involves different areas of the brain. These regions include the cortical areas that are supposed to integrate evidence supporting alternative actions and the basal ganglia (BG) that are hypothesized to act as a central switch in gating behavioral requests [9–15]. Neurons in the middle temporal area (MT) are known to encode motion stimulus [13], while the decision process itself occurs in other areas including