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Analysis of stochastic integration with a network of bistable units

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The ability to integrate over time and to keep a memory of the result of this computation is thought to be important for several operations performed by the nervous system. Several models have been proposed for the biological implementation of the integration of inputs. Some of these models consist of a set of units which have two stable states in the absence of noise: an activated state, characterized by high activity and a spontaneous state, characterized by low activity. In these models the value of the integral is approximated by the number of bistable units that will reach and stay in the activated state given a certain input. Using such a network both deterministic [1] and stochastic mechanisms [2] have been proposed for integration of inputs. Further, experimental observations were found to be consistent with this type of models [2]. In this work we analyze theoretically how a network of stochastic bistable units performs integration of an external input. We use a simple probabilistic model to study how the number of activated units evolves with time, given a certain input. We consider both unconnected and connected units. For the unconnected model we derive analytical expressions for the ability of a system to discriminate between inputs with different durations or strengths. The difference between two inputs needed to assure that they can be discriminated depends on the absolute strengths of the inputs. We show that the connected system can, on average, perform an almost perfect integration, but that the performance on single trials is strongly dependent on the specifications of the model and inputs. Finally, we relate the probabilistic model with more biologically plausible systems, where the bistable units are neuronal populations or neurons which can be described by their average firing rates or by their spiking activities.

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