Rapid memory encoding in a recurrent network model with behavioral time scale synaptic plasticity

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Episodic memories are formed after a single exposure to novel stimuli. The plasticity mechanisms underlying such fast learning still remain largely unknown. Recently, it was shown that cells in area CA1 of the hippocampus of mice could form or shift their place fields after a single traversal of a virtual linear track. In-vivo intracellular recordings in CA1 cells revealed that previously silent inputs from CA3 could be switched on when they occurred within a few seconds of a dendritic plateau potential (PP) in the post-synaptic cell, a phenomenon dubbed Behavioral Time-scale Plasticity (BTSP). A recently developed computational framework for BTSP in which the dynamics of synaptic traces related to the pre-synaptic activity and post-synaptic PP are explicitly modelled, can account for experimental findings. Here we show that this model of plasticity can be further simplified to simple map which describes changes to the synaptic weights after a single trial. The map can be solved analytically and provides a quantitative fit to experimental data from CA1. We use this map to study the storage of a large number of spatial memories in a recurrent network, such as CA3. Specifically, the simplicity of the map allows us to calculate the correlation of the synaptic weight matrix with any given past environment analytically. We show that the calculated memory trace can be used to predict the emergence and stability of bump attractors in a high dimensional neural network model endowed with BTSP.