Transfer of Spike Timing Patterns by Theta Phase Synchrony

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Abstract
Auto-associative neural network models represent an established computational framework for the study of mammalian learning and declarative memory function. Biological correlates of these models – consisting of recurrently connected networks which exhibit extensive synaptic plasticity – have been proposed to exist in the CA3 region of the hippocampus and layers 2/3 of the neo-cortex. Both of these brain regions are modulated by inhibitory theta oscillations during mnemonic processing, and the magnitude and direction of changes in synaptic strength induced by standard protocols in the hippocampus has been shown to vary significantly within each theta cycle. Furthermore, phase synchrony between neocortical and hippocampal networks increases with mnemonic load, which suggests that one function of theta may be to mediate a dynamic link between the distributed network of pre-frontal, mediotemporal and visual cortices during learning, recall and decision making.

Here, we present an abstract model of cortico-hippocampal interaction that consists of two bi-directionally connected auto-associative networks, the neural and synaptic dynamics of which are modulated by independent theta frequency oscillations in a biologically realistic manner. This configuration allows externally applied patterns of temporally-coded activity to be learned by either network, and subsequently transferred between the networks at will by manipulating the synchrony of respective theta oscillations. This model therefore provides a biologically inspired mechanism for the selective copying of established cell assemblies between disparate neural networks. This research is particularly relevant to the neuronal replicator hypothesis, which posits that a process akin to Darwinian evolution may operate within the brain; and theories of declarative memory consolidation, which posit that mnemonic traces are transferred between complementary learning systems in the hippocampus and cortex.