A model for structural plasticity in neocortical associative networks trained by the hippocampus.

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The hippocampal formation plays a crucial role in organizing cortical long-term memory. It is believed that the hippocampus is able of fast (one-shot) learning of new episodic information followed by extensive time periods where corresponding neocortical representations are trained and "compressed" [1]. Here "compression" usually refers to processes such as chunking spatially and temporally distributed activity patterns. We take the complementary approach and optimize the synaptic network by structural plasticity, e.g., replacing unused synapses, thereby making full use of the potential connectivity [2].

We apply the frameworks of structural plasticity and hippocampus-induced learning to the training of neocortical associative networks [3]. Associative networks such as the Hopfield or Willshaw model are at the heart of many cortex theories and have been analyzed for a long time with respect to information storage capacity and plausible retrieval strategies [3,4]. For example, it is well known that a completely connected network can store about 0.7 bits per synapse. However, for incompletely connected networks the capacity per synapse can be massively reduced or even vanish, depending on the retrieval algorithm [4].

In this work we analyze how structural processes combined with hippocampal training and synaptic consolidation [5] can restore high capacity for neocortical associative networks by emulating full (or increased) synaptic connectivity. We assume that a set of activity patterns can be stored in the hippocampus by one-shot learning. Then the hippocampus trains the neocortex by repeatedly replaying the patterns in a sequence. Synapses of the neocortical network are consolidated depending on Hebbian learning. In each time step a fraction of the unconsolidated synapses are removed and replaced by the same number of new synapses at random locations thereby maintaining total connectivity. We show that this procedure can improve the synaptic capacity of a cortical macrocolumn massively (factor 10-20 or even up to factor 200 for pattern capacity). In a second step we analyze the model with respect to the time (or number of repetitions) necessary to increase effective connectivity from base level to a desired level. The analysis shows that acceptable training time requires a certain fraction of unconsolidated synapses to keep the network plastic.

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