Predictive Coding Light with Different Spike Timing-Dependent Learning Rules

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Learning in biological brains is thought to rely on diverse synaptic plasticity mechanisms. While many plasticity rules have been observed experimentally, it is still unclear how the combination of various plasticity rules at different synapse types supports learning at the network level. Here, we want to shed light on this issue by systematically investigating the effects of combining different kinds of STDP [1, 4] rules in an established model of unsupervised visual representation learning. Our starting point is the recently proposed Predictive Coding Light (PCL) model [2], a recurrent spiking neural network model for unsupervised learning of visual representations (see Fig. 1a). We chose this model, because it reproduces many properties of primary visual cortex (V1), including simple and complex cell receptive fields and different non-classical receptive field effects (surround suppression, orientation-tuned suppression, cross-orientation suppression), which are considered a hallmark of predictive coding theories [3]. Furthermore, it only uses a single biologically plausible local STDP rule, establishing a link between STDP and classic theories of predictive coding.

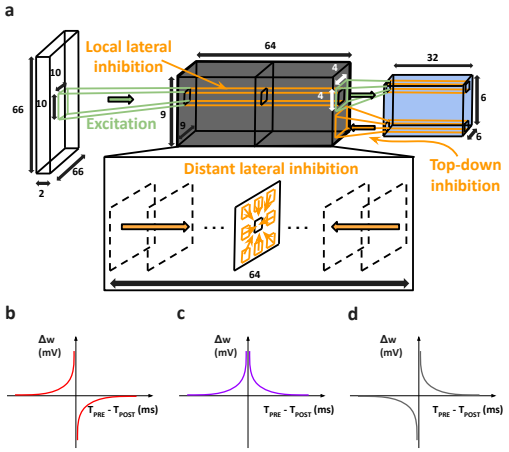

Figure 1: **The Predictive Coding Light network and different spike timing-dependent plasticity rules considered in this work. a,** PCL's network architecture adapted from [2]. **b,** Causal STDP. **c,** Symmetric STDP. **d,** Acausal STDP.

We wondered how critical these achievements of PCL depend on the choice of STDP rule for the different connection types within the network. To answer this question, we considered three different STDP rules: the original "causal" rule where a pre-before-post pairing induces long-term potentiation (LTP), an "acausal" rule where the same kind of pairing induces long-term depression (LTD), and a "symmetric" STDP rule (see Fig. 1b-d). We systematically studied various combinations of these rules for excitatory and inhibitory synapses in the network. As expected, we found that successful learning hinges on the type of STDP rule used for the excitatory synapses, with the acausal rule preventing learning. Surprisingly, however, we found learning to be very robust to changes in the STDP rule for inhibitory synapses, with all rules supporting successful learning. Overall, our work sheds new light on how combinations of plasticity rules shape learning at the network level.

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