

## Detecting transitions: A probabilistic description of short-term plasticity

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Many experiments have shown that synapses, instead of being static, take part actively and over a wide range of time scales in processing and transmitting information in the brain. Moreover, sensitivity to fast changing stimuli is a ubiquitous feature in the brain and is believed to be one of the roles supported by short-term depression. Here, we use a probabilistic approach and derive the dynamics of short-term plasticity one would expect for detecting, as reliably and quickly as possible, a sudden change in the environment.

In this study, we consider that the input to a synapse is a sample spike train generated by a Hidden Markov Model describing the temporal dynamics of a binary variable  $x$  representing the presence ( $x=1$ ) or absence ( $x=0$ ) of a feature in the neuron's receptive field. Meanwhile, the firing rate of the pre-synaptic neuron is higher when  $x$  is 1. We require, then, the synapse compute the probability that a stimulus appeared within a short temporal window, given the spikes observed. Using a procedure developed in a previous work for learning the dynamic parameters of the generative model, we compute this probability online and found that, depending on the parameters set chosen, the underlying synaptic computation is an integration of EPSPs which exhibits either/both short-term *facilitation* or/and *depression*.

An isolated spike received by the synapse increases temporarily the probability of a switch having occurred (an EPSP); whereas successive spikes are integrated if they are sufficiently close. This integration, however, is not a simple sum. Initially, the amplitude of the EPSP increases (*facilitation*) to reflect accumulating evidence that  $x$  switched to 1. While the synapse responds strongly to the spikes immediately following the state transition, the subsequent responses decay in amplitude (*depression*). Eventually, future spikes provide no contribution to the probability and bring it below its resting level. This resembles a phenomenon in synaptic plasticity known as *Desensitization* (Fig. A response to a regular input burst). In fig.B2, we show an example of detecting transitions on a hidden variable (Fig.B1). As observed experimentally, depression is stronger for smaller ISI's (right most transition).

This result suggests that membrane potential of a post-synaptic sensory neuron may reflect transitions probabilities of hidden variables to which they are tuned. These transition probabilities would be represented by the instantaneous membrane potential deviations from resting potential. Furthermore, the amplitude of an EPSP, its duration, the presence and strength of depression, facilitation and desensitization, their time constants, and frequency dependence are all constrained by the statistics of the input to the synapse. As we have shown in a previous work, these parameters could be learned by long-term spike-time dependant plasticity rules, suggesting that short-term and long-term plasticity might collaborate to make a synapse an efficient detector of changes.

