Encoding variable cortical states with short-term spike patterns

Abstract

Neurons in the primary somatosensory cortex (S1) respond to peripheral stimulation with synchronised bursts of spikes, which lock to the macroscopic 600 Hz EEG wavelets. The mechanism of burst generation and synchronisation in S1 is not yet understood. We fitted unit recordings from macaque monkeys with a Poisson-like model including the refractory period (spike-train probability model, STPM). The model combines high-amplitude synaptic inputs with absolute and relative refractoriness. We show that these two properties can reproduce synchronised bursts observed in S1 neurons. The probabilistic nature of the model introduces trial-to-trial response variability. Similar to the experimental data, the variability can be decomposed into stereotypical spike patterns consisting of short bursts of spikes with variable number of spikes and length of within-burst intervals. Next, we extend the model to a population of uncoupled neurons, which receive common inputs fluctuating in amplitude across trials. We demonstrate that these fluctuations introduce correlations between neurons and between the single-neuron spike patterns and population activity (high-frequency EEG wavelets) as observed experimentally. To further study the biophysical mechanism behind S1 burst responses, we develop a single-compartment model (leaky integrate-and-fire, LIF) receiving intracortical and feedforward thalamic inputs. The intracortical inputs are assumed to be in a balanced state, where excitatory and inhibitory currents nearly cancel each other out yielding the neuron in the high-conductance state. This model can reproduce many features of experimental data, in particular the burst statistics and the presence of spike patterns. We conclude that neural systems could use refractoriness to encode variable cortical states into stereotypical short-term spike patterns amenable to processing at neuronal time scales (tens of milliseconds).

Keywords: somatosensory cortex, non, human primates, modelling, bursts