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Title: Exploring the dynamics of up and down states in cortical networks undergoing short term synaptic plasticity

Abstract:
Cortical neuronal circuits undergo transitions between periods of sustained neural activity (UP state) and periods of silence (DOWN state) alternating in a rhythmic pattern. This UP and DOWN dynamics has been widely observed in cortical activity and the mechanisms that generate this alternation have been extensively studied in literature (see [1], among others). However, when the network is subjected to short-term synaptic plasticity (STP), either depression (STD) or facilitation (STF) the alternating behavior can be changed depending on the level of STP. Although numerous mathematical models have been proposed to elucidate the mechanisms underlying these changes caused by plasticity, the functional role it plays in network dynamics remains less clearly understood.

In this project, we build upon a bio-inspired computational model for an Excitatory-Inhibitory (EI) network of spiking neurons, introduced in [2], that simulates V1 cortical activity under the effects of STP. When STP is not taken into account, the network presents synchronized alternations between UP and DOWN states. However, diverse network dynamics emerge based on the type and strength of STP involved. We introduce a minimal rate model that reproduces the firing-rate dynamics of both Excitatory and Inhibitory populations observed in the network of spiking neurons in [2]. Our focus lies in understanding the underlying mechanisms driving the transitions between different states induced by STP. Namely, the transition from Up and Down states to asynchronous activity due to depression dynamics, and the transition from a silent state to UP and DOWN states observed when facilitating the network. We further deepen our study by integrating the interplay between STD and STF into the rate model. Our simulations reveal the existence of 3 distinct activity states: (1) UP and DOWN states, (2) an asynchronous activity regime, and (3) a silent state. These states depend both on the level of depression and facilitation experienced by the network and the steady-state of the probability of release of the facilitation.

References

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