Pyramidal Interneuron Next-Generation Neural Mass Model: Synaptic Properties and Stimulation Response

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Neural mass models (NMM) seek to unveil the fundamental principles governing macroscopic neural activity, which emerges from complex interactions within and between populations of neurons. The advent of an exact mean-field theory for networks of quadratic integrate-and-fire (QIF) neurons represents a significant leap forward in our comprehension of the link between microscale neural mechanisms and mesoscopic brain activity [1]. This formalism establishes a robust coupling between two biophysically relevant macroscopic quantities: the firing rate and the mean membrane potential, which collectively drive the evolution of the neuronal network. These features allow this type of NMM variant to provide a deeper understanding of synaptic dynamics [2, 3].

In this study, we analyze a next-generation neural mass model derived from the exact mean-field theory for QIF neurons.

The model is composed of two coupled populations: pyramidal neurons and interneurons (PING). We begin with an extensive bifurcation analysis of the model's parameter space, aimed at better understanding its inherent properties. Furthermore, we study the response of neural populations to periodic stimulation, inspired by therapies such as transcranial Alternating Current Stimulation (tACS). In this part, we focus on the entrainment of the neural populations, examining how it impacts the average firing rates of each population and its relationship to the Arnold tongues displayed by the system.

Finally, we compare the results obtained with our model, like the decrease in firing rates and increase in phase locking values with experimental data, where we find that our model is able to qualitatively capture the effects of tACS in mice. Our findings shed light on how brain circuits respond to tACS and could help develop more effective brain stimulation techniques.