Inhibition stabilized cortical network models contrast dependence of cortical rhythms in the visual cortex

Monika Jadi JADI@SALK.EDU
Terrence Sejnowski TERRY@SALK.EDU
Salk Institute of Biological Studies

Cortical functions arise from excitatory recurrent connections and strong interactions between the principal excitatory and local inhibitory interneurons. What is the dynamic behavior of these networks and in what regime do they operate? Experiments in the hippocampus (Tsodyks et al, 1997) as well as the visual cortex (Ozeki et al, 2009) point to an inhibition stabilized regime of the E-I network (ISN). Ozeki et al show that the paradoxical observation of suppression in the firing of not only the excitatory, but also the inhibitory interneurons in the primary visual cortex, due to surround suppression can be explained with a model of cortical columns operating in the ISN regime. In this study, we seek to validate if the ISN is indeed an appropriate regime to capture another important cortical behavior: cortical rhythms, the oscillations detected in the LFP as well as firing rates in a narrow frequency range over an extended period. Recent work by Ray & Maunsell has shown that the frequencies of stimulus-induced gamma oscillations (30-80 Hz) in the primary visual cortex depend on the stimulus contrast.
Based on available physiological data, we started with a simple E-I model of cortical column operating in ISN regime that demonstrates the paradoxical reduction in mean firing rates during surround suppression. Next we tuned it to generate stimulus-triggered gamma rhythms. We show that the frequency of gamma rhythms in this regime is a function of the stimulus contrast, in agreement with the experimental data. We further show that the contrast-dependence of gamma rhythms is not significant for smaller fluctuations in contrast, which is more likely the case in natural scenes (compared to the 25%-100% contrast tested experimentally). Our analysis further reinforces the ISN behavior of cortical network in stimulus-driven state, which can be used to predict and explain.

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