A Nonlinear Dynamical Model of Excitatory-Inhibitory Interactions in the Vibrissa System

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Intracellular and extracellular studies of cortical and thalamic neurons of the rat vibrissa system reveal a stereotyped biphasic response to an isolated punctate deflection of the peripheral vibrissa. A brief excitatory response is followed by a prolonged inhibitory tail that can persist over time-scales greater than 100msec, which can have profound impact on how more complex tactile patterns are encoded. A number of studies within- and across vibrissa have shown that the corresponding response to a second stimulus can be strongly attenuated when the second stimulus follows the first within the time-frame of the inhibitory tail. We have previously shown that a simple characterization of these dynamics can lead to a prediction of a number of experimentally observed neuronal responses to more complex stimulus patterns. A key finding was that in addition to the suppression of the excitatory response to the second stimulus, the subsequent suppression normally following the second stimulus is also strongly reduced, which we termed “suppression of suppression”. In the present work, we show that many of the phenomena that we observe experimentally can be qualitatively observed in a simple excitatory-inhibitory network that embodies the “push-pull” interplay at various stages of the thalamocortical loop. Specifically, reciprocally connected model inhibitory and excitatory neuronal populations driven by a common source give rise to the “suppression of suppression” and many of the other complex transient patterns observed experimentally in response to periodic vibrissa stimulation. The fundamental dynamics captured by the simple model are likely to be important in the representation and eventual percept of textural features in the vibrissa system.

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