Post-excitatory Suppression Dictates the Dynamics of Adaptation in Barrel Cortex

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Adaptation is a feature of encoding observed at multiple levels of processing across all sensory systems. Although it has been implicated in shifting the sensitivity of the system and priming the system for response to a novel stimulus, little is currently known about its full role in sensory coding. Previous studies have focused primarily on steady-state responses to periodic stimuli. However, under more naturalistic conditions in which stimulus statistics are continuously changing, there may be no true steady-state. Characterization of the transient nature of adaptation is therefore critical in fully understanding the encoding process.

Here, the rat vibrissa system was used as a model system to study the transient and steady state nature of adaptation, as well as to determine the role of temporal tuning properties in the dynamic response. Neurons in the barrel cortex show significant adaptation at stimulus frequencies above 4 Hz. In this study, adaptation was investigated at frequencies between 2 and 16 Hz in the barrel cortex. The primary whisker of anesthetized rats was deflected with alternating periodic patterns in the rostral-caudal plane, and single unit cortical activity was measured. Because of the alternating directions of the stimulus, the adaptation response of the neuron could be characterized in two directions. Three types of responses to the periodic stimulus were observed. Neurons either adapted to the same steady-state value for both deflection directions or they adapted more to one of the directions than to the other. An important tuning property that affected the adaptation response of a neuron was the amount of post-excitatory suppression following a single deflection in each direction of the stimulus. The relative symmetry of the suppression in the two directions determined the type of response trajectory that was observed.

Changing the initial portion of the periodic stimulus altered the state of the neuron at the beginning of the stimulus. This altered the transient portion of the adaptation response, but the neuron still converged to the same steady-state response. Not only was the steady-state response the same, the average firing rate per cycle was conserved regardless of the difference in the transient responses for the standard stimulus and the modified stimulus. These observations were confirmed by simulations of neuronal response using idealized response suppression curves with various time courses of suppression. The important property for conservation of firing rate per cycle was the average time course of suppression in the two directions. Therefore, in this study the adaptation properties of barrel neurons were shown to be directly related to their functional tuning properties, namely the amount of post-excitatory suppression, and these properties could predict the trajectory of the transient and steady-state adaptation as well as the conservation of average firing rate per cycle.

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