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Poster presentation

Effects of passive dendritic properties on the dynamics of an oscillating neuron

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Introduction

Dendritic properties can have substantial effects on the dynamics of single neurons and the activity in neuronal networks. For instance, the architecture of the dendritic tree can alter the firing pattern of a neuronal oscillator [1], and dendritic filtering can change the phase-locking behavior in networks of neuronal oscillators [2]. From a more basic standpoint, dendritic properties can affect the firing rates of neuronal oscillators in response to constant input. Even when considering passive dendrites, these effects are not as easy to understand as it might seem. That is, the dendritic "load" can have surprising effects on a neuron's firing frequency. Kepler et al. [3] found that coupling a somatic oscillator to a passive neuronal compartment can sometimes increase or decrease the firing frequency. However, their explanation was specific to a two variable piecewise linear relaxation oscillator. Thus, the general mechanisms by which dendritic properties affect frequency remain to be clarified.

To probe this issue further, we model a neuron as a thin passive dendritic cable attached to an isopotential somatic oscillator, i.e. a "ball and stick" model. We then use the theory of weakly perturbed oscillators to derive an equation for the change in frequency of the oscillator due to the perturbation resulting from the presence of the dendrite. Intuitively, if the reversal potential of the dendrite is lower (higher) than the average voltage of the somatic oscillations, then the firing frequency of the somatic oscillator will decrease (increase) as the radius of the dendrite increases. We show that this is indeed the case when the phase response curve of the somatic oscillator has a positive average value. However, when the average value of the phase response curve is negative, our equation shows that the intuitive prediction described above would be reversed: the firing frequency of the oscillator increases as the radius of the dendrite increases (at least initially). Curiously, for values of the dendritic reversal potential close to the average voltage of the somatic oscillations, there is a non-monotonic dependence of the firing frequency on the dendritic radius. We confirm these results using direct numerical simulations.

Our results show that the addition of a passive dendrite to a neuronal oscillator can sometimes have counter-intuitive effects on firing frequency. Furthermore, we show that these results can be understood in terms of the somatic oscillator's phase response curve.

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