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How slow K$^+$ currents impact on spike generation mechanism?

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Neuronal adaptation is the change in the responsiveness of a neuron over time, and may improve coding information from an environment. Adaptation originates from various factors, including single neurons, synapses, and network dynamics. Here we investigate adaptation in a responsiveness of a neuron. When a neuron received prolonged stimulation, it initially responds with a high firing rate, and the firing rate decrease. This is called spike-frequency adaptation, which is observed in most pyramidal neurons in various animals. Spike-frequency adaptation is usually accounted for by slow K$^+$ currents, for example, the M-type K$^+$ current (I_M) and the Ca^{2+}-activated K$^+$ current (I_{AHP}), and the conductance-based (Hodgkin–Huxley type) models including the slow K$^+$ currents have succeeded to reproduce the electro-physiological properties of a neuron [1].

The detailed biophysical mechanism underlying spike-frequency adaptation may impact on the coding property of a neuron [2,3]. For example, it was suggested that I_M facilitates the spike-timing coding, whereas I_{AHP} improves the spike rate-coding [2] and I_M increases the response to low-frequency input signals, whereas I_{AHP} decreases the response to low-frequency signals [3].

Due to the complexity of the conductance-based models, it is not clear how the slow K$^+$ currents impact on spike generation mechanism, more specifically, how the parameters of the slow K$^+$ currents regulate spike generation. For understanding the impact of slow K$^+$ currents, we have developed a framework to reduce a detailed conductance-based model with slow K$^+$ currents to an adaptive threshold model [4]. We have deduced a formula that links the slow K$^+$ parameters to the parameters of the reduced model. The formula was validated with the

simulation of the detailed model. This formula clarifies how I_M and I_{AHP} impact on spike generation mechanism differently and the parameters of I_M and I_{AHP} influence spike generation.

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