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Coregulation of ionic currents maintaining the duty cycle of bursting

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Central pattern generators (CPGs) are the oscillatory neuronal networks which control rhythmic movements of animals. Some CPGs keep the phase relationships between the neurons' oscillatory activities over a wide range of the cycle periods. Maintenance of the duty cycle of the bursting activity could be a key feature for a variety of dynamical mechanisms supporting phase constancy in oscillatory neuronal networks. It is a form of cellular homeostasis of neuronal activity. Among other currents, hyperpolarization-activated currents and potassium currents have been shown to be a ubiquitous target for modulation and homeostasis [1,2].

Here we present a novel mechanism of coregulation of currents which preserves duty cycle of bursting activity over a range of cycle periods. We develop a generic low-dimensional Hodgkin-Huxley type model stemming from a model of the leech heart interneuron under certain pharmacological conditions [3]. Application of Co^{2+} and 4-AP blocks Ca^{2+} currents, the synaptic currents and most of the K^+ currents. The model contains the slow potassium current (I_{K2}), the fast sodium current (I_{Na}). Our new model also includes the hyperpolarization activated current (I_h). Bifurcation theory allows us to make predictions concerning the temporal characteristics of the dynamics of bursting nearby the critical transitions between activities.

Shilnikov & Cymblayuk showed that the transition from bursting into tonic spiking (blue sky catastrophe) determines the dependence of the burst duration on the voltage of half-activation of I_{K2} (θ_{K2}) as one over square root of the parameter value [4]. Here we show that the half-activation potential of I_h (θ_h) controls the interburst interval as one over square root of the parameter value. We investigate the activity of the model to identify mechanisms of coregulation of I_{K2} and I_h maintaining the duty cycle. Bifurcation analysis of the model was performed using θ_{K2} and θ_h, as controlling parameters. We investigated the temporal characteristics of bursting activity. We identified a saddle node bifurcation for periodic orbits determining the blue sky catastrophe [4] and a saddle node bifurcation for stationary states (SNIC) [5]. We showed the temporal characteristics of bursting depend on the location of the bifurcation curves. By coordinating the two parameters, we were able to increase the period such that the burst duration and interburst interval maintained constant proportion. The coregulation consists of a negative correlation of θ_{K2} and θ_h, which is steeper for the higher duty cycles.

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