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Interaction of membrane dynamics with network structure and its effects on spatio-temporal network patterning

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Introduction

Modulations of cellular and network properties are known to be associated with changes in spatio-temporal patterning in neural networks, which may have significant effects in neurological disorders such as epilepsy. Both types of properties have cumulative effects that can lead to different network activity. We set out to study the interaction between different neural membrane dynamics and different network structures to learn how this relationship affects spatio-temporal patterning in the network as a whole. Using the simulation environment NEURON, we constructed a large network of multicompartmental model cells based on CA1 hippocampal pyramidal neurons. The model neurons consist of a dendritic cable with a soma compartment containing Hodgkin-Huxley Na+ and K+-delayed rectifier currents as well as the K+ A-type current and the hyperpolarization-activated, non-specific cation current Ih that are known to occur in these cells. The cells were coupled locally with dendritic excitatory synaptic connections and we varied the network structure as per the Small World paradigm. As an example of possible cellular changes that can occur in the brain, we compared network dynamics when model cells exhibited a transition from Type I-like to Type II-like membrane dynamics. We simulated effects of network rewiring, due to cell death and activity related mechanisms, by varying network topology using the rules of Small World Network architecture. Simulation results showed that networks of different cell composition displayed different network behaviors at the same network parameters for a wide range of network topologies and connectivity levels. When network structure allowed the influence of cellular properties, Type I-like membrane dynamics resisted global synchrony, while Type II-like cells favored global synchrony and bursting. Furthermore, complimentary cell interaction in networks of heterogeneous cell composition resulted in emergent behavior not exhibited by homogeneous networks. Thus modification of membrane currents and network cell composition could have particular and significant implications for network activity patterns.

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