A Biomimetic Neural-Astrocytic Network: Adding a Slow Layer for Fast Information Processing

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INTRODUCTION

Astrocytes connect via gap junctions to form functional networks which transmit information using intercellular \( \mathrm{Ca}^{2+} \) waves. By simulating these waves, as well as their effect on nearby neurons, we show that the ‘slow’ activity of astrocytes is sufficient to modulate the ‘fast’ spiking activity of neurons in easily controllable ways.

MODEL

The biomimetic model consisted of LIF neurons organized into all-to-all feedforward synaptic islands (Fig 1b) [1], defined by the territory of a single astrocyte. The astrocyte-network propagated calcium waves with speed and shape taken from the literature [2]. By controlling at most two parameters—the gating function, \( f \), and the slow-inward-current amplitude, \( I_{\text{astro}} \) (Fig 2), we were able to produce a wide range of easily tunable neural firing patterns.

Conclusion

The theoretical benefit of parallel processing on different temporal and spatial scales is an open question in computational brain science: Our model aims to tackle this problem by combining the fast spiking of neurons with the comparatively slow calcium activity of astrocytes. Although our understanding of neural-astrocyte dynamics is still in its infancy, translating the new “bottom-up” knowledge of astrocytic function into artificial intelligence is a promising research area [3].

Table 1. Equations describing the interaction between a pre- and a post-synaptic neuron, under the influence of an astrocyte.

REFERENCES