ROLE OF SYNAPTIC CONNECTION TOPOLOGY IN ASTROCYTE-NEURON COMMUNICATION

Kirsanov A.V.[1a], Brazhe A.R.[1b], Verveyko D.V.[2a], Verisokin A.Yu.[2b],

[1]Lomonosov Moscow State University, Biological faculty,
Leninskie Gory, 1/24, Moscow, 119192, Russia
[a]ArtemKirsanov2606@gmail.com, [b]brazhe@gmail.com

[2] Department of Theoretical Physics, Kursk State University,
Radishcheva st., 33, 305000, Kursk, Russia
[a]allegroform@mail.ru, [b]ffalconn@mail.ru

Astrocytes are cells of the nervous tissue that have long been considered to be only auxiliary units. However, experiments have shown, that astrocytes play a variety of important functions, including regulation of synaptic plasticity through gliotransmitter release. Such modulation of neural activity is affected to a large extent by the shape of single astrocytes (cell morphology) and their arrangement in networks (topology).

We base on the model of astrocyte calcium dynamics [1] which describes the interaction between astrocytes and neurons in a simplified way: every region of the astrocyte is assumed to interact with a neuron. This is a serious simplification of the real biophysical phenomenon. We suggest a technique for generating synaptic locations along the astrocyte membrane based on experimental data [2]. In accordance to these studies, we scatter discrete synapses along the cell, assuming they are localized predominantly near thin processes and, to some extent, leaflets, while being almost absent from regions corresponding to the cell body and thick processes.

Numerical simulation allowed us to determine that localization of synapses along the astrocyte surface is responsible for the formation of patterns of calcium dynamics. The analysis of the model behavior has led to the following results:

1) Spatial and temporal patterns of calcium dynamics are determined by the interplay between astrocytes intrinsic morphology and the particular spatial distribution of synapses.
2) Localization of synapses as well-defined sources of glutamate leads to the decrease of baseline calcium levels in the peripheral regions of the astrocyte, while the dynamics of thick branches and cell body does not change significantly.
3) Introduction of synapses leads to the emergence of “microdomains” – regions of the astrocyte with the highest average activity.

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References

1. *Verisokin, A. Yu., Verveyko, D. V., Postnov, D. E. & Brazhe, A. R.* Modeling of Astrocyte Networks: Toward Realistic Topology and Dynamics. Front. Cell. Neurosci. 15, 645068 (2021).
2. *Héja, L., Szabó, Z., Péter, M. & Kardos, J.* Spontaneous Ca2+ Fluctuations Arise in Thin Astrocytic Processes With Real 3D Geometry. Front. Cell. Neurosci. 15, 617989 (2021).