Computational Study: Dynamic Reversal Potentials in a Conductance-based Synaptic Model

Publication Status:
Published (in print/issue): 12/07/2020

DOI:
10.13140/RG.2.2.36285.69601

Document Version
Author Accepted version

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Neuronal chemical synapses are important and complex areas of information transfer which operate on a micrometre scale. Due to the obvious experimental limitations of studying synapses at such a small scale, computational modelling has become an important tool for simulating and predicting synaptic behaviour. Traditional computational models of synapses assume an infinite extracellular space surrounding the synaptic complex, however, recent evidence suggests most synapses in the hippocampus are wrapped by astroglial cells, effectively creating a finite area for synaptic events to occur.

Using the assumption that neurons are enwrapped tightly at chemical synapses, we simulate a standard conductance-based neuronal synapse model that is surrounded by a finite extracellular space. A consequence of a finite extracellular space is that ionic flux across the cell membrane has the potential to change the extracellular ionic concentrations drastically, which in turn will change the ionic reversal potentials. We use the standard Hodgkin-Huxley formulism to simulate a hippocampal synapse, with active and passive ion channels. The reversal potentials are calculated over time using the Nernst equation. Our main aim is to investigate whether a finite extracellular space can impact the behaviour of reversal potentials or the membrane potential in a single compartment conductance-based synaptic model.

Our results show that a finite extracellular space around the synapse does affect the reversal potentials, however, the effect is not drastic enough to change the overall behaviour of the membrane potential. Therefore, we conclude the assumption reversal potentials stay constant is a good approximation even at synaptic scales.