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Studying the effect of oscillating electric field in time and space on neuronal activity using the extended point neuron model

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Abstract

According to the electrical-chemical structure of nerve cells, it is expected that applying electrical stimulation affects the dynamics of neural networks, and strengthens or weakens brain activity. On this basis, in the last two decades, the use of electrical stimulation to treat neurological disorders such as depression, epilepsy, Parkinson's, etc. has gained wide acceptance.But the response of nerve tissue to external stimulation is not linear, that is, empirical studies on animal models as well as computational modeling show that changes in the amplitude and pattern of changes in electrical stimulation can lead to completely different results. However, in most stimulation methods, the electric field resulting from direct injection of current to the head (and brain) is relatively low in intensity. But the incomplete understanding of the mechanism and complexities of electrical stimulation sometimes forces physicians to adopt a trial-and-error approach**.** It means that it actually puts the patient at risk. Using computational modeling, we have analytically calculated the response of the single neuron membrane to the extracellular current stimulation that oscillates in space and time, and investigated the effect of different characteristics of the extracellular stimulation on the neuronal response. In particular, we have for the first time fully considered the spatial non-homogeneity of the electric field, and its effect on neuron activity, using the extended point model, which is simple but contains the geometrical information of the neuron. The obtained results show that the time-frequency-dependent response of neurons strongly depends on the spatial frequency and phase of stimulation. In fact, the intensity of field non-homogeneity in space can affect the frequency behavior of the neuron. The results of this study help to design optimal methods for nerve tissue stimulation, as well as to estimate the amount of risks caused by unwanted exposure to electric fields.

Keywords: brain electrical stimulation, nonhomogeneous electric field, ball and stick model, extended point neuron, frequency behavior

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