Electrical activities and magnetic stimulation effects in a CBGT neural network

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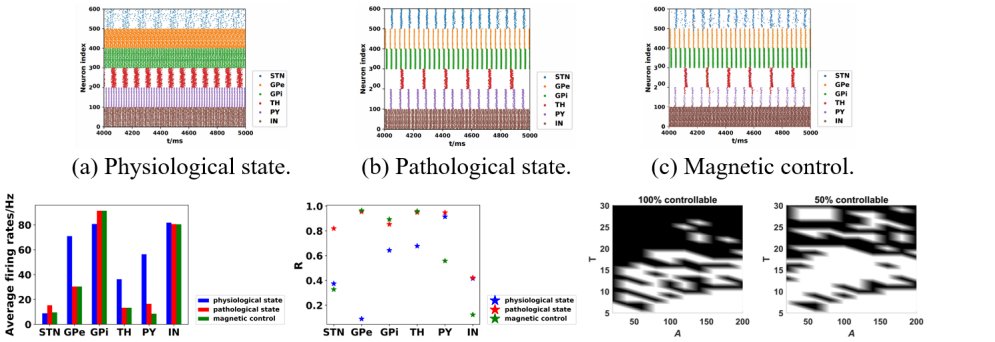
Abstract. Changes of firing and pathological oscillations in basal ganglia (BG) have been confirmed as the main feature in Parkinson's disease (PD). Noninvasive magnetic stimulation has been used in the treatment of PD. In order to understand its therapeutic effect, we employed Izhikevich neuron model as the basic node to study the electrical activity and controllability of magnetic stimulation in a Cortico-Basal Ganglia-Thalamus (CBGT) network. Results show that stronger synapse connection in hyperdirect pathway caused abnormal oscillations and excessive synchrony in Subthamala Nucleus (STN). The pathological firing properties of STN can be efficiently suppressed with magnetic stimulation. The statistical results show that parameter region for the controllability of STN can be divided into three parts and the fitted boundary curve are given. The work helps to understand the dynamics response in PD-related nucleus and provide insights into mechanisms of the therapeutic of magnetic stimulation.

Introduction

Parkinson's disease (PD) is a common neurodegenerative disease. The significant pathological features of PD is the degeneration of dopaminergic neurons in the substantia nigra compacta (SNc), which leads to abnormal β band oscillations (13-30Hz) and excessive synchrony in BG. The motor cortex also plays an input role to STN through hyperdirect pathway. It has confirmed in animal model and clinic that electromagnetic therapy such as TMS is effective in the treatment of PD. However, the underlying mechanism is still unclear. In the perspective of dynamics, magnetic field could change ion concentration inside and outside the membrane, which could further influence the electrical activity of nervous system. Ma J et al. establish the magnetic flow model on neuron by model the magnetic effect as memristor to transfer the magnetic energy to current. In order to better understand the therapeutic effect of magnetic stimulation, we employed Izhikevich neuron model under Ma's model as the basic node to study the electrical activity and the controllability of magnetic stimulation in a CBGT network.



(a) Physiological state. (b) Pathological state. (c) Magnetic control.

(d) Average firing rates and synchrony in three states. (e) Controllable region of 100% and 50%.

Figure 1: Main results.

Results

Magnetic effect in a CBGT neural network is investigated in this paper. The computational model can be used to exploring the magnetic effects of biophysical neural activity and study the control strategy. Firstly, the CBGT network in physiological and pathological condition is proposed and analysed (Fig.1(a), (b), and (d)). Secondly, it has found that frequency of STN grows in accordance with $g_{PY\to STN}$, while synchronize shows a nonlinear trend. We further applied magnetic stimulation on PY (Fig.1(c)). The result implied magnetic stimulation mainly affects the activity of PY directly and further influence the firing properties of STN through the hyperdirect pathway. Finally, we analysis the statics result under different magnetic stimulation conditions (Fig.1(e)). The control area can be divided into three subregions and the fitted boundary curve are given.

References

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