MODELING THE SYNCHRONIZATION OF HUMAN BRAIN NEURAL NETWORK

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We used Hodgkin-Huxley, a four dimensional model, to reproduce the neural dynamics of two cortical sensorimotor networks: during cortical breathing and hand motion. Our model was guided by high density electroencephalogram (eeg) in human. The model is based on three main components: the neuronal scheme, the connectivity map and the synaptic model. Altogether, they are responsible for the dynamics of the neural network. (i) The neuronal dynamics is described by the Hodgkin Huxley conductance-based model, a mathematical model that describes how action potentials in neurons are initiated and propagated. It is a set of nonlinear differential equations that approximates the electrical characteristics of excitable cells, such as neurons, and hence is a continuous time model. The firing pattern of each neuron is a tonic spiking regime. (ii) The connectivity map represents the way neurons are connected with one another. We consider neurons that are placed in a two dimensional Cartesian grid. Connectivity between neurons is governed probabilistically based on their Euclidian distance. (iii) The synaptic model is the way connected neurons communicate. The neurons are chemically connected, either excitatory or inhibitory.

Synchronization of the simulated neural network (400 neurons) is studied depending on model parameters, and is guided by the wavelet analysis (time-frequency) of the cortical sources (high density EEG source reconstruction). Modeling the activity of two synchronized regions of interest is depending on a stimulus (synaptic coupling strength) and the ratio of excitatory vs inhibitory neurons. The different frequencies (alpha, beta, gamma) are reproduced depending on the distribution of the natural frequencies of the neurons in the model and on their connectivity.

The next step consists of the analysis of neuronal cross-frequency coupling (CFC), the phase-locked modulation in frequency ranges alpha, beta and gamma. The functional role of CFC has been highlighted in many sensorimotor (cortical breathing, hand motion, visual) and cognitive tasks. Phase –amplitude coupling, i.e. the relationship between the phase in low-frequency rhythm in one region of the brain with the amplitude in high frequency in another region of the brain, is the hallmark of brain synchronization. We propose to analyze with the network model how two regions of interest activation shape the relationships between low and high neuronal frequency rhythms.