

Synchronization for real-time computation in the brain

Yoko Yamaguchi¹, David Coliaux^{1,2}

1 Lab for Dynamics of Emergent Intelligence, RIKEN Brain Science Institute, Japan

2 Ecole Polytechnique, France

Recent neurophysiological studies in animal and human suggest ubiquitous importance of synchronization in the brain computation. Stimulus dependent synchronous firing in gamma rhythm (30~80 Hz) was discovered in cat visual cortex. The synchronization is considered to concern with dynamical linking of visual features in pattern recognition. Theta rhythm (4~8 Hz in human, 4~12 Hz in rodents) appears in rat hippocampus during running and is considered to concern with on-line memory formation (Yamaguchi 2003). In human EEG, theta rhythm was first reported at frontal midline during cognitive tasks (Ishihara 1971). Theta rhythm is also observed to distribute in the frontal cortex, amygdala, striatum etc. under various behavioral conditions.

Our study of simultaneous fMRI/EEG measurement (Mizuhara et al., 2004, 2005, 2006) enlightened that scalp EEG synchronization/desynchronization is associated with appearance/disappearance of distant cortical-subcortical regional networks. Beta synchronization (14Hz) at the parietal region indexes linking of cortico-striatal working memory network. Theta synchronization (7Hz) among frontal and posterior regions indexes linking of central execution network are alternatively activated.

Neural entities of working memory are known to have flip-flop transition between up- and down-states, while oscillation mechanism in the working memory is little known. We here provide a phenomenological flip-flop oscillation network model for working memory. Input-dependent transition from down to up state activate oscillation network according to recurrent connections. Up-down transition in this network is autonomously regulated by oscillation dynamics around Milnor attractor. Together with theta phase coding obtained in rat hippocampus, real-time computation in the central execution and working memory are discussed based on synchronization of flip-flop oscillation.