Psychobiophysics of Transcranial Magnetic Stimulation

by

Yukiyasu Kamitani (Advisor: Prof. Shinsuke Shimojo)
Computation and Neural Systems
California Institute of Technology

Abstract

Transcranial magnetic stimulation (TMS) is a technique that stimulates the brain using a magnetic coil placed on the scalp. Since it is applicable to humans non-invasively, directly interfering with neural electrical activity, it is potentially a good tool to study the direct relationship between perceptual experience and neural activity. However, it has been difficult to produce a clear perceptible phenomenon with TMS of sensory areas, especially using a single magnetic pulse. Also, the biophysical mechanisms of magnetic stimulation of single neurons have been poorly understood.

In the psychophysical part of this thesis, perceptual phenomena induced by TMS of the human visual cortex are demonstrated as results of the interactions with visual inputs. We first introduce a method to create a hole, or a scotoma, in a flashed, large-field visual pattern using single-pulse TMS. Spatial aspects of the interactions are explored using the distortion effect of the scotoma depending on the visual pattern, which can be luminance-defined or illusory. Its similarity to the distortion of afterimages is also discussed. Temporal interactions are demonstrated in the filling-in of the scotoma with temporally adjacent visual features, as well as in the effective suppression of transient visual features. Also, paired-pulse TMS is shown to lead to different brightness modulations in transient and sustained visual stimuli.

In the biophysical part, we first develop a biophysical theory to simulate the effect of magnetic stimulation on arbitrary neuronal structure. Computer simulations are performed on cortical neuron models with realistic structure and channels, combined with the current injection that simulates magnetic stimulation. The simulation results account for general and basic characteristics of the macroscopic effects of TMS including our psychophysical findings, such as a long inhibitory effect, dependence on the background activity, and dependence on the direction of the induced electric field.

The perceptual effects and the cortical neuron model presented here provide foundations for the study of the relationship between perception and neural activity. Further insights would be obtained from extension of our model to neuronal networks and psychophysical studies based on predictions of the biophysical model.