Reorganization of the brain

Hirokazu Takahashi
The University of Tokyo, Tokyo 113-8656, Japan
takahashi@i.u-tokyo.ac.jp

The neural system inherently has a plasticity that causes dynamic remodeling of representation according to the experience, and in this framework, the brain sometimes self-repairs malfunctions by reorganizing the neural networks and optimizing the system. Understanding of the plasticity in the brain will therefore have great implications for rehabilitation of disorders in the central nervous system. In addition, microstimulation and behavioral training that can assist the reorganization of the brain will have a potential to provide a powerful platform for the future neurorehabilitation. In the present work, we investigate how microstimulation and behavioral training can induce plasticity in the rat auditory cortex, and how we can reorganize the cortical representation as desired.

We first attempted to reorganize the auditory cortex by intracortical microstimulation (ICMS) with paired and anti-paired tone stimuli on the basis of the spike time-dependent plasticity rule. Two kinds of ICMS were applied; a pairing ICMS following tone-induced excitatory post-synaptic potentials (EPSPs) and an anti-paring ICMS preceding the tone-induced EPSPs. The pairing and anti-pairing ICMS produced potentiation and depression, respectively, in responses to the paired tones with a particular test frequency. In addition, the combination of pairing and anti-pairing ICMS could modify the neural properties more precisely and drastically. The comparison between the pre- and post-ICMS frequency tuning properties suggested that the pairing and anti-pairing ICMS could reorganize the auditory cortex as desired.

Second, we proposed a novel fear conditioning experiment and investigated context-dependent plastic changes in the auditory cortex. Only when background white noise was presented, rats received an electric shock as an unconditioned stimulus (US), which was associated with a tone as a conditioned stimulus (CS). In contrast, rats never received US in silence. After the conditioning, freezing time tended to be longer when CS was presented under noise, suggesting that rats were successfully conditioned in a context-dependent form. Electrophysiological study revealed the neural activities in the primary auditory field (A1) had temporal differences between “in silence” and “under noise” conditions, while the ventral auditory field (VAF) showed spatial differences in the tonotopic representation.

These results suggest that desired reorganization of the brain by external stimuli is possible, and thereby can be considered the first step for the neurorehabilitation of auditory functions. The next step is to elucidate how the microstimulation-induced plastic changes in the auditory cortex affect the recognition of sound. We are also in desperate need of more physiological data that show how the neural representation and plasticity in the auditory cortex are associated with recognition.

Keywords: Brain, Plasticity, Rehabilitation, Auditory cortex, Prosthesis