The science behind brain-machine interface

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Control and learning in physical motor behavior is the best subject to understand who we ourselves are, how we percept the outer world, and how we create the cultural aspects of living, such as sports, music, dance, and handcraft. Through the studies of motor control and learning, we are aware of the medium of memes, commonly shared with us inside the brain, beyond sexual, generational, and social boundaries.

Brain-Machine Interface (BMI) is a technology that decodes natural neural information from a targeted brain area, and translates it into machine control signals. It has achieved *telepathy-like* machine control (BMC Neurosci 2010) or *cyborg-like* limb control, but also it achieves manipulation of the targeted neural activities via visual/somatosensory feedback (Front Neuroeng 2014; Clin Neurophysiol 2013; see Fig. 1). Neural decoding identifies the spatio-temporal feature of the processing of motor information in a computational fashion (Brain Topogr 2015), and manipulation of brain activity represents a way of investigating the causal relationship between brain activity and behavior (J Rehabil Med 2015; J Rehabil Med 2014). Retention of improved brain activity and motor behavior through BMI-based therapeutic intervention is feasible as medical application (Restor Neurol Neurosci 2016; J Rehabil Med 2011), as reorganizing damaged brain function and underlying neural circuits to promote functional motor recovery from pathoneurological conditions, such as post-stroke hemiplegia (Prog Brain Res 2016), incomplete spinal cord injury, and dystonic writer's cramp (BMC Neurosci 2014). Ethical, legal, and social issues on BMI for an outside laboratory is also discussing (Science 2017).

A grand challenge in this field is to solidify neurobiological evidences of motor control, learning, and recovery through BMI. We have recently been taking an optogenetic approach of large-scale neural recordings from primary motor cortex (M1). So far, we confirmed stable recording of naturally activating ~100 cortical neurons in the M1 Layer 5 from freely behaving non-human primates, Common Marmoset. What we surprised here was that M1 cortical neurons started to encode movement direction a few seconds preceding actual arm reaching movement. The result suggests that M1 is not a simple final path of motor signal output to the muscles, but is an important node of computation in motor planning. Successful decoding of movement direction (~90%) will also achieve volitional control of machine devices via BMI, without presence of actual movement. A neurobiological nature of motor learning and motor recovery will be discussed deeply with this advanced BMI technology in the near future, and clinical application of BMI in humans will be driven by such neurobiological evidence.

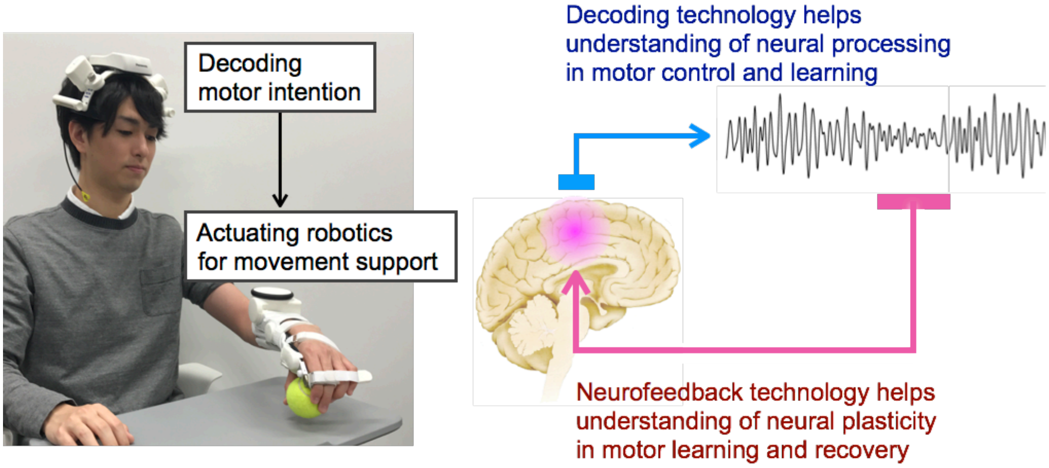

Figure 1 Brain-Machine Interface

(left) A non-invasive brain-machine interface device, developed with Panasonic.

(right) A schematic drawing of brain-machine interface and its impact on the science of motor control, learning, and recovery from pathophysiological conditions.

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Keyword:

Brain-Machine Interface, post-stroke hemiplegia, neurorehabilitation, neural plasticity, motor recovery