Moving EEG Monitoring Out of the Clinical Environment

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Abstract—The present paper discussed a possible use of electroencephalography (EEG) for neurorehabilitation and neuromuscular control. We have so far tested a real-time EEG monitoring system to detect participant’s voluntary motor preparation of the limbs, and trigger actions of computer or robotic agents in a brain-computer interface (BCI) fashion. A total of 44 stroke survivors who are suffering with chronic hemiplegia had participated in this study, and 38 out of them increased their Fugl-Meyer clinical assessment scores of upper limb function. A single A-B-A-B study introduced this paper also proved the importance of the closed-loop frame of participant’s voluntary motor preparation and accompanying peripheral somatosensory feedback by electrically and motor driven muscle actuation. Ongoing project in EEG electrode development has been helping us to promote such BCI rehabilitation not only in a limited electrically shielded environment, but also in an ordinary training room, bedsides, and home.

I. CLINICAL TRIAL OF BRAIN-COMPUTER INTERFACE

Brain-Computer Interface (BCI) can bypass motor output neural pathways by directly translating motor-related brain signals into commands for control of neuromuscular electrical stimulation [1]. Since extrinsic feedback is expected to promote motor learning, approaches using BCI might facilitate neural plasticity and restore lost function after stroke. Here the present study using a single case ABAB design tested the importance of closed-loop system in BCI.

A participant with hemiplegia due to subcortical stroke was recruited in this study. In Period A for open-loop condition, the participant was asked to practice finger opening repeatedly. Neuromuscular electrical stimulation was simultaneously applied to the paretic finger extensor. In Period B for actual BCI condition, the sensorimotor rhythm (SMR) in electroencephalogram was recorded over the affected sensorimotor cortex. Paretic finger extensor was electrically stimulated only if sustained decrease of SMR was observed. In both periods, one-hour daily training was given for two weeks. Event-related desynchronization of SMR by motor intention became larger from 12% to 40% throughout the experiment, and its increment was larger in Period B. BOLD MRI initially identified activations in bilateral sensorimotor and supplementary motor cortices. The ratio of the signal intensity in the affected hemisphere to the intact side was increased in Period B, and decreased in Period A. Voluntary EMG in the paretic finger muscle was appeared in Period B. These results indicate that closed-loop system of BCI facilitates functional reorganization, at least in part, in the affected corticospinal tract. This implies that (1) SMR could be a real-time marker of corticospinal excitability, (2) extrinsic feedback of the corticospinal excitability may facilitate motor relearning, and also (3) neuromuscular electrical stimulation following the increase of corticospinal excitability may form Hebbian-like manner to enhance further excitability. Such a neurophysiological assessment of BCI with actual stroke survivors opened a possibility to use EEG as a signal source of neurorehabilitation.

II. DEVELOPMENT OF EASY EEG MONITORING

We should note here that the BCI device was originally designed to monitor EEG outside the electrically shielded environment for practical use. Both semi-dry and dry type electrodes with a brush-shaped Ag/AgCl architecture successfully reduced in time for preparation and settlement since the scalp was able to be significantly abraded by the tip of the electrodes, as well as combing the participant’s hair. In situ histological assessment with a confocal laser scanning microscope and impedance measurement (~30 kohm/10 Hz) quantitatively confirmed the validity of the electrodes. A portable EEG amplifier was combined with a touch panel display, and a user-friendly GUI supported to use BMI without engineers. Four occupational therapists assessed this portable prototype using a standardized questionnaire called “QUEST, Quebec User Evaluation of Satisfaction with Assistive Technology”, and confirmed its usefulness.

III. CONCLUSION

From these trials, we confirmed that BCI is of great use for persons with severe motor disorder. The system development for EEG monitoring outside a specific environment is promised to enlarge a possibility to apply BCI for every situation including training rooms, bedsides, and home.

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REFERENCES