 DOI: 10.3217/978-3-85125-467-9-82

Classifying force levels of hand grasping and opening using electroencephalography cortical currents

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Introduction: For people suffering from extremity-paralysis due to a stroke, assistive robots that can be an alternative for their hand will dramatically improve their quality of life. This study aims to develop a brain-machine interface (BMI) for controlling a robot hand using electroencephalography (EEG) signals. Especially, we attempt to add functions not only to control opening and grasping its hand but also to change its grip force levels according to users' intension. However, it has been considered that EEG signals do not have spatial resolution enough to extract such detailed information. To overcome the issue, instead using EEG signals as they are, we estimated EEG cortical current signals from EEG sensor signals by a variational Bayesian method with hierarchical priors [1]. EEG cortical current signals are time series signals of vertices that were spatially randomly assigned onto cortical surface. Since they might be theoretically equivalent to electrocorticography signals, we expect grip-force levels can be discriminated from EEG cortical current signals.

Material, Methods and Results: A T1-weighted 3D anatomical magnetic resonance imaging (MRI) image, 32-channel EEG sensor signals, and EEG sensor coordinate position data were used to calculate an inverse filter for estimating EEG cortical current signals by Variational Bayesian Multimodal Encephalography (VBMEG) toolbox [2]. During EEG signal acquisition, five participants performed five isometric hand-movement tasks (i.e., opening or grasping with high or low force, and no-motion) for 1 sec according to visual stimuli. Two-channel electromyography (EMG) signals were recorded simultaneously with EEG signals from electrodes placed over common digital extensor muscle and flexor digitorum superficialis muscle. EEG epochs were extracted in reference to EMG onset defined by Teager-Kaiser Energy Operation method [3], ranged from 1 sec before to 0.5 sec after the onset. EEG cortical current estimation and task-classification analyses using power specter density signals through a sparse logistic regression [4] were conducted by 10-fold cross validation method. As shown in Fig. 1, EEG cortical current showed significantly higher classification accuracies for force levels as well as movement difference than EEG sensor signals.

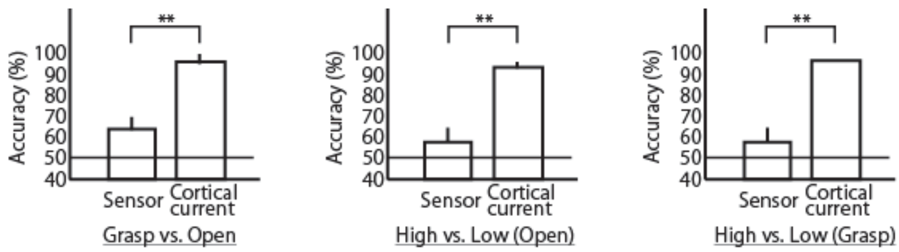

Figure 1. *Comparison of mean binary classification accuracies across participants between EEG sensor and EEG cortical current signals. Left: Grasping vs. opening. Middle: High vs. low forces in opening movement. Right: High vs. low forces in grasping movement. Error bars are standard errors and statistical significances were calculated using paired t-test **p<0.001.*

Discussion: Vertices with high weight values were located in slightly different positions for grasping vs. opening from high vs. low forces classification. Furthermore, when calculating accuracies for different time windows, it was found that accuracies surged just before the EMG onset from around chance level to high values, which were reasonable considering that we used vertices in the primary motor cortex for the analysis.

Significance: This work showed the usability of EEG cortical currents to overcome a drawback of EEG that has been considered not to have enough spatial resolution for extracting force differences. Our findings will expand the possibility of EEG-based BMI.

Acknowledgements: This work was supported in part by JSPS KAKENHI 26112004 and 15H01659.

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