Anatomical structure correlated with control performance for an electroencephalography-based brain-computer interface: A voxel-based morphometry study

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Introduction

The potential of brain-computer interfaces (BCIs) to replace lost functions has been widely studied. Moreover, BCIs have gained recent attention as a possible means to induce beneficial neuroplastic changes via neurofeedback training. However, BCI performance varies considerably among individuals, and the factors affecting BCI performance are poorly understood. Therefore, we investigated the relationship between performance of an electroencephalographic (EEG) mu rhythm-based BCI (EEG-BCI) and brain structure.

Methods

Thirty healthy participants (14 male, 16 female; mean age 22.3 years ± 3.1) were instructed to control a computer cursor using left- and right-hand motor imagery via the EEG-BCI. EEG data were recorded using an 11-channel head cap and amplifier. Left- and right-hemispheric mu band powers were then calculated from the EEG data stream, and differences of imagery-induced desynchronizations between the two central electrodes (C3 and C4) were converted into a control signal for cursor movement. EEG data showed that subjects were able to modulate their mu band powers and control the BCI with accuracies significantly above the chance level. Following this experiment, subjects underwent T1-weighted three-dimensional structural imaging and diffusion tensor imaging, using a 3 Tesla MRI scanner (Trio, Siemens, Germany). T1 weighted imaging; 3D-MPRAGE, TR: 2000 ms, TE: 4.38 ms, IT: 990 ms, Voxel size: 1×1×1 mm, Flip angle: 8, Bandwidth: 130 Hz/Px, FOV: 192×176. The MRI data were subjected to voxel-based morphometric analysis using BCI control performance as an independent variable.

Results and Discussions

We identified significant positive correlations between EEG-BCI performance and gray matter volumes of the dorsal premotor cortex (PMd, Small volume correction, $P < 0.05$, FWE), supplementary somatosensory area (Area 5, $P < 0.05$, FWE), and supplementary motor area (SMA, $P < 0.05$, FWE). On the other hand, these regions did not correlate with mu amplitude in resting-state and motor imagery questionnaire. This finding indicates that control performance for the EEG-BCI was higher in participants with greater gray matter volumes in specific parts of the brain. High performers were better able to elicit event-related desynchronizations in the task-relevant side that were distinct from those of the contralateral side, suggesting higher ability in switching between motor imageries of the right and left hands. We presume that it was necessary for the participants to switch quickly between left- and right-hand motor imagery to achieve maximal performance. Therefore, the PMd may be the hub where switching between left- and right-hand motor imagery occurs.

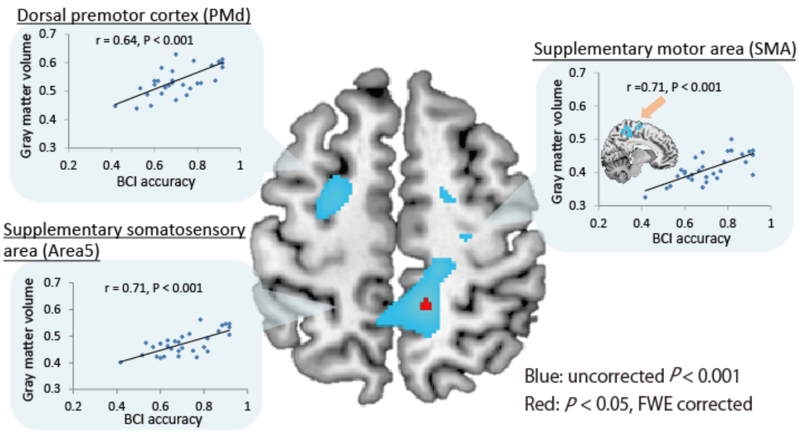

Fig 1. Voxel-based morphometric analysis using BCI control performance as an independent variable. EEG-BCI performance showed correlations with gray matter volume of PMd, Area 5, and SMA.

Conclusion

We found for the first time correlations between EEG-BCI performance and gray matter volume of PMd, Area 5, and SMA. These findings demonstrate the importance in developing BCIs better suited to individual variability in performance and may also provide insight into how to design such BCIs.

References [1] DaSalla et al., *The annual meeting of Society for Neuroscience*, 2011; [2] Blankertz et al., *Neuroimage 51*: 1303-1309, 2009; [3] Caminiti et al., *European Journal of Neuroscience* 31: 12, 2320-2340, 2010; [4] Laich et al., *Brain* 120: 855-864, 1997; [5] Rizolatti et al., *Annu. Rev Neuroscience* 27: 169-92, 2004; [6] Kalaska et al., *Experimental brain research*, 51(2): 247-260, 1983. [Kasahara and DaSalla contributed equally to this work.]