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An EEG Source Imaging BCI for Movement Decoding in Youth with Brain Lesions

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Introduction: Traditional brain-computer interfaces (BCIs) based on electroencephalography (EEG) typically make no accommodations for users with brain lesions. EEG source imaging (ESI) is a neuroimaging technique to estimate cortical potentials based on scalp EEG signals [1]. By constructing anatomical models of the head using magnetic resonance imaging (MRI), ESI may help compensate for variability in head tissue morphology and cortical geometry in BCI users, potentially improving classification performance [2-5]. For this reason, we investigated the feasibility of an ESI BCI for classifying hand movement and imagery tasks in youth with brain lesions.

Material Methods and Results: T1-, T2-, and diffusion-weighted anatomical MRI scans were acquired from 9 pediatric participants (16 ± 2.5 years old) with brain lesions. Subsequently, EEG activity from 64 channels were recorded with a Brain Products actiCAP wet system while each participant completed hand movement and imagery tasks over two sessions. The anatomical MRI images were used to segment the head into different tissue types including white matter, gray matter, cerebrospinal fluid, skull, and scalp. The conductivity characteristics for each tissue type were used to construct a volume conduction model that describes how electrical signals propagate through different brain regions. The resulting model was used to compute a lead field matrix that projects the scalp EEG signals into approximately 1000 cortical sources located over an evenly distributed grid sampled over the cortex with 10 mm resolution. The EEG signals were pre-processed and spatially co-registered with the MRI before time-frequency features were extracted for the classification of left versus right-hand motor execution and imagery tasks. The classification performance of the scalp EEG approach was compared to that of the ESI approach. Generally, the classification accuracies of ESI BCIs were comparable to those of corresponding EEG BCIs. When compared to the EEG BCI, the ESI approach showed an improvement of $8.68 \pm 7.84\%$ ($p < 0.001$) in one participant for the motor execution task and $10.91 \pm 16.85\%$ ($p < 0.05$) in another participant for the motor imagery task.

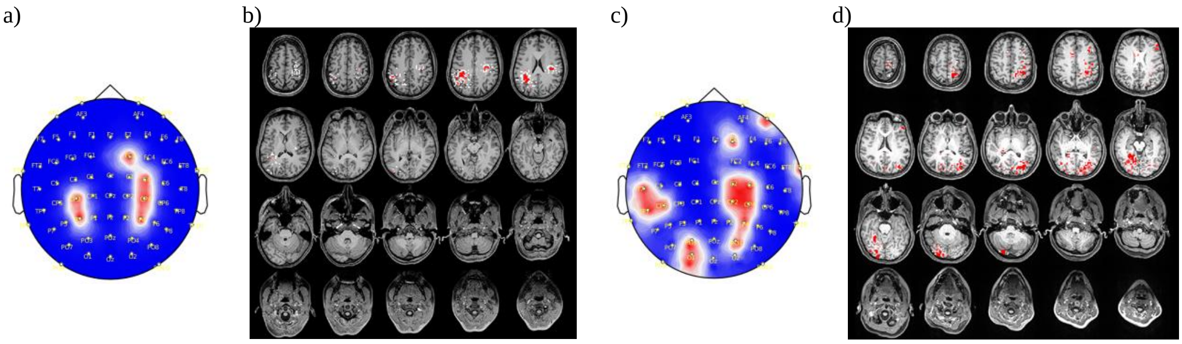

Figure 1: Topographical maps for participants and tasks with the maximum improvement in classification accuracy for the ESI BCI; a) and b) present the EEG scalp maps and ESI source distribution maps for the hand movement task; c) and d) present the EEG scalp maps and ESI source distribution maps for the hand imagery task

Discussion: Overall, ESI shows potential in improving the classification performance of BCIs. However, substantial research is still needed to validate its feasibility in a larger population of users with different brain lesion types and locations, motor ability, and age. In addition, given that the MRI is needed for anatomical modeling, ESI BCIs need to substantially improve over EEG BCIs in decoding multiple complex tasks to justify the associated costs in practice. Finally, considering the additional computational cost required for ESI processing, future research would also need to demonstrate the feasibility of ESI BCIs for users with brain lesions in an online setting outside of the laboratory setting.

Significance: To the author's knowledge, this is the first study to investigate the feasibility of an ESI BCI for decoding motor execution and imagery tasks in youth with brain lesions.

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