Accelerating Human Motor Response Using Single-Trial EEG Classification of Event-Related Potentials

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ELECTROENCEPHALOGRAM (EEG)-based brain-computer interfaces (BCI) provide a new tool to people with severe motor disabilities to communicate with their environments [1]. Although BCI researchers mainly focus on clinical research and practices, they are now expanding their attention to include the use of neural information for improving human-system performance, human cognition and action [2-5]. Recently, the motor action paradigm, which aimed to replace human behavioral response with brain response, has become an increasingly popular topic. Because a BCI establishes a direct link between the brain and the output device, the conventional pathway of peripheral nerves and muscles in motor control can be bypassed. Furthermore, delays between early stages of sensory information processing and the late stage of motor control could also be eliminated. Therefore, theoretically, the BCI technology might predict motor behavior faster than the actual motor reaction time (RT).

This study proposes a machine learning-based framework of using single-trial EEG classification of event-related potentials (ERP) to accelerate human motor response. The system paradigm consisted of two major components: feature extraction and classification. To rapidly detect the event-related brain response, the ERP signals occurring before the actual motor response were used as features. The ERP segments from multiple electrodes were concatenated, and then inputted to a support vector machine (SVM)-based classifier to predict the upcoming motor behavior. This study used a 10x10-fold cross validation to access the prediction accuracy.

To validate the BCI framework, this study analyzed EEG datasets from three types of RT experiments: (I) visual target detection, (II) Go/NoGo decision making, and (III) directional reaching movement. Experiment I aimed to use visual-evoked potentials (VEP) from the visual cortex to detect the appearance of a visual target. The dataset consisted of nine-channel EEG data recorded from nine subjects (240 trials from each subject). Experiment II focused on using the N2 ERP component from the medial frontal cortex (MFC) to predict a Go/NoGo decision. Thirty-two channels of EEG were recorded from 15 subjects (1000 trials from each subject). Experiment III investigated the feasibility of using ERPs in the posterior parietal cortex (PPC) to predict directions of reaching movements (i.e., *reach to left* vs. *reach to right*) [3]. One hundred and twenty-eight channels of EEG were recorded from 20 subjects (200 trials from each subject).

In all datasets, the accuracy of single-trial classification, based solely on unaveraged ERP signals prior to the motor RT, was significantly higher than the chance level (50%). The classification performance corresponded with the amplitude and the signal-to-noise ratio (SNR) of the ERP signals used as features in each experimental paradigm. Experiment I reached high accuracy of 82.1±6.3% and 90.1±4.3% at 120 ms and 250 ms after the target onset, which were much earlier than the mean RT (332±98 ms). The classification accuracy of Experiment II increased from 61.2±4.1% to 74.4±6.3% as the length of time window increased from 200 ms to 350 ms (mean RT: 377±48 ms). Experiment III achieved prediction accuracy of 64.7±6.7% at 350 ms after the cue onset (mean RT: 464±62 ms). These results suggested that human motor behavior can be rapidly and reliably predicted by single-trial EEG classification. The proposed system framework might lead to practical assistive systems for accelerating human motor response in real-world environments.

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