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Single-trial prediction of discrete hand movements with electroencephalography

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Introduction. Single-trial analysis of EEG data has encouraged development of brain computer interfaces (BCI). Many available BCI's use the underlying functional and anatomical structure of motor cortical areas, but only grossly, as for example, by exploiting EEG frequency bands recorded separately from the two hemispheres to control devices. Here, we explored the predictive power of EEG in the context of leftward and rightward directed hand movements performed only with the right hand.

Methods. We studied the dynamics of cortical electrical activity obtained from 14 right-handed adult volunteers. Participants moved a joystick using only the right hand to align a position cursor with one of three targets arrayed horizontally on a video monitor, one target at central gaze and the other two approximately ±10° of visual angle from central gaze. Participants maintained the head stable in a normal position. The target sequence presentation occurred randomly to cue center-to-right and center-to-left movement trial. Participants maintained the 'out' location until cued to return to the initial central location with a right-to-center or a left-to-center movement trial. In all cases, trial onsets varied from 1.5-5.5 s in 0.5 s increments. EEG data were recorded from 64 scalp electrodes applied in a modified 10-20 system, digitally sampled at 512 Hz, 0.02-100 Hz analog band pass filtered, with an additional 40 Hz digital low-pass filter. Ocular movement was recorded with EOG, and these records were used to 'clean' the EEG channels of ocular artifact. After data cleaning, we submitted the time-domain EEG data to a classification scheme that employed a leave-one-out, cross-validation method, with a support vector machine, on EEG and independent components (IC's), to classify left from right movements.

Results. The data analysis revealed that broad-band EEG data in the time-domain did not provide above-chance classification of rightward from leftward joystick movements performed with the right hand. Across participants, fewer than five EEG channels (of more than 850 EEG channels) yielded above chance classification. All participants exhibited strongly weighted IC's over the presumed contralateral primary motor cortex. Using this IC (within participants), we found classification rates significantly above chance (mean 74% correct, range 63-83% correct, across participants, $p \leq 0.0001$).

Conclusions. We found that IC analysis of EEG data can discriminate between leftward and rightward movements performed by one hand. These results indicate that IC analysis of EEG data, which has been demonstrated to transform sensor data into meaningful neuroanatomical and neurophysiological components, can be utilized to extract predictive cortical motor activation that is associated with fine movement and therefore suggests a source of additional information for BCI control.

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