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Development of an EEG-EMG processing pipeline and Graphical User Interface for analysis, recognition, and peak-negativity detection of movement-related cortical potentials

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Introduction. The rehabilitative Brain Computer Interface (BCI) system looks for restoring brain functions through signal-features that are related to the neurophysiological activity. One critical step in the development of BCI for rehabilitation is feature analysis and selection, because based on these it is possible to detect when the subject's intention occurs, therefore improving rehabilitation success. One of the most known and reliable features is the movement-related cortical potential (MRCP) which reflects voluntary movements, in its stages of preparation or execution. One property of great interest in the MRCP is the peak negativity (PN), the most negative point associated with movement execution. When a subject is performing a cue-based movement, it is possible to observe PN arriving 0.5 milliseconds after or even before the cue. Recognizing this time difference respective to the cue is important, because it makes possible to stimulate the target muscle to induce a systematic relationship between the physiologically generated wave during the intention of the movement, and the sensory signal that arrives in the target muscle [1,2,3]. The aim was to develop a processing pipeline and a Graphical User Interface (GUI) for analyzing electroencephalography (EEG) and electromyography (EMG) data, to extract the MRCP in different trials performed by a subject, identifying the PN and the delay based on a certain onset, to calculate the best time to send the stimulus.

Materials, Methods, and Results. EEG signals from 10 channels (FP1, Fz, FC1, FC2, C3, Cz, C4, CP1, CP2 und Pz) and EMG signal from tibialis anterior muscle were recorded from two healthy volunteers (1 female and 1 male, 25 ± 1 years old) during a simple motor tasks (30 dorsiflexions - DF) guided by a visual ramp-cue. The participant performs the movement when the cue was shown in the screen. Each trial was conformed by three phases; Rest (3-4 s), Focus (1-2 s) and Task-execution (4.1 s). During the Task-execution phase there is a triangle cursor moving, after 2 seconds this cursor indicates the moment when the subject has to perform and hold the dorsiflexion until the Task-execution phase finishes.

The EEG and EMG signals were subsequently analyzed offline with a GUI. The EEG data was bandpass filtered between 0.05 to 3 Hz using a 4th order Butterwortth bandpass filter, then segmented into epochs from 2 s before to 3 s after task onset, next the mean was subtracted, optionally, in channel Cz the Laplacian could be also applied, and finally the PN was localized.

The EMG data was rectified, then high-pass filtered with a 4th order Butterworth at 20 Hz [1] and segmented into epochs from 2 s before to 3 s after task onset.

The PN could be localized manually and automatically. Once it is localized in all the trials the delay is measured based on an onset and finally the average is calculated.

Significance. The goal of the GUI is to online analyze trial-wise, and the whole session, to compute the PN delay so to make possible to identify the optimal time to send a stimulus, so to enhance the BCI-based rehabilitation.