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Discriminating goal-directed from nongoal-directed movements and its potential impact for BCI control

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Introduction: Differences in the electroencephalographic (EEG) recordings between the execution of goal-directed and nongoal-directed movements have been recently shown in [1]. Such differences can be of interest for brain-computer interfaces (BCIs) control, when combined with information on the kinematic level (e.g. velocity decoding), since this combination mirrors the hierarchic way one plans a movement. In this study, we show that the time-domain differences between these movements are discriminable in a single-trial classification.

Material, Methods and Results: Ten healthy, right-handed subjects participated in the experiment. Subjects were presented a small red ball on the monitor (*Goal*) or a red screen (*No-Goal*). After 2 seconds and only when the stimuli color changed from red to purple, subjects were instructed to reach-and-touch the ball (*Goal Movement*) or to decide on their own where to touch (*No-Goal Movement*). 72 trials per condition were recorded. EEG signals were recorded using 60 passive electrodes and sampled at 512 Hz.

Independent component analysis (ICA) was performed for artefact removal: components representing eye movements and muscle activity were rejected. To extract relevant low-frequency time-domain features, data were down sampled to 16 Hz, common average referenced and band-pass filtered from 0.3 to 3 Hz with a zero-phase 4^{th} order Butterworth filter. Classification was done using a random forest binary classifier; accuracies were calculated for each time-point and validated using 10x5-fold cross-validation. To score significantly above the chance level, 64.7% had to be reached (p=0.01, Bonferroni corrected for multiple tests over the trial length). Fig. 1 shows the time-course of the classification accuracies when discriminating *Goal Movement* and *No-Goal Movement*. Accuracies rise above the chance level after both first and second cues. After the GO cue (second cue), the average accuracy peaks immediately after movement onset with 67%. Here, 4 out of 10 subjects show accuracies above 80%, and all subjects are above the chance level. Also interestingly, 3 of the subjects show high accuracies even 2 seconds after movement onset.

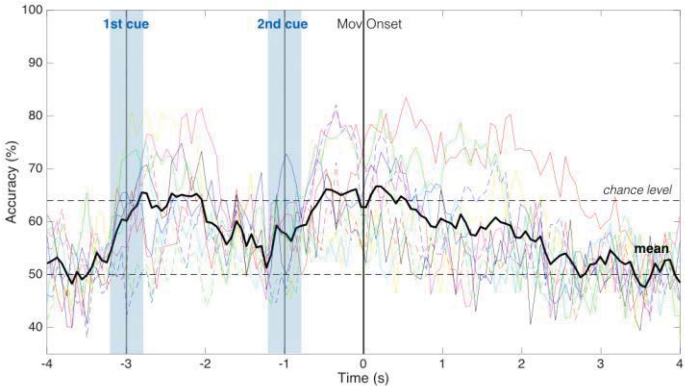

Figure 1. *Classification accuracies when discriminating Goal and No-Goal Movements, time-locked at movement onset (t=0s). The first 2 vertical lines correspond to the average time-points when the 1st and the 2nd cue appeared, in respect to movement onset. The thick black line corresponds to the grand-average accuracy.*

Discussion: Our results show that there are differences between goal-directed and nongoal-directed movements when time-locking at movement onset. Namely, the motor-related cortical potentials – after the second cue- show different amplitudes between conditions. These differences are discriminable in a single-trial classification. Future work will be to investigate whether similar results are obtained with neuroprostheses end-users and movement imagination (MI). If so, this information could be useful to establish activation thresholds, or even by instructing the subjects to imagine the kinesthetic MI associated with a target. We hypothesize that this instruction, combined with movement decoding at the kinematic level, could additionally improve classification accuracies.

Significance: The results contribute to the goal of our research: a naturally-controlled BCI neuroprostheses. Furthermore, we encourage the BCI community to explore the neural correlates behind goal-directed movements and how recent neurophysiological findings in action planning (e.g. [2]) can be of practical interest for BCIs.

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