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EMG modulation evoked by classical BCI tasks as a potential control signal for movement augmentation

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Introduction: Spinal motor neurons receive a wide range of input frequencies via the common drive. However, only frequencies below ca. 10 Hz translate directly into motor output. Frequency components above 10 Hz could represent oscillations leaking down from supraspinal sources like motor cortex that do not affect motor output or only indirectly affect movement. Common drive oscillations can be marginally volitionally modulated in the beta band by neurofeedback [1]. We hypothesized that these oscillations can also be modulated by mental tasks classically used in BCI research, as these tasks induce oscillations in cortical areas, potentially leaking downstream. Oscillations of the common drive can be derived from electrical muscle activity and could serve as a control signal in movement augmentation applications. Screening for various discriminable mental tasks could offer here an alternative to a neurofeedback approach.

Methods and Results: We recruited 8 non-disabled subjects between 21 and 47 years. Subjects sat in a chair with their right leg fixated in a foot dynamometer. Subjects executed 336 trials of isometric dorsiflexion with their right foot with 8% of their maximum force. A trial lasted 10s; from 5s to 10s, subjects were asked to perform a mental task additionally. The possible mental tasks were: foot motor imagery (MI), hand MI, mental arithmetic, or rest. We recorded 64 high-density (HD) surface EMG channels from the tibialis anterior muscle, a 1-channel force signal, and 61 electroencephalography channels (the latter was not analyzed here). The reference and ground electrodes were placed on the right and left ankle, respectively. Noisy channels and artefact-contaminated trials were excluded. We calibrated a motor-unit (MU) decoder [2] using HD-EMG data from force ramps recorded at the beginning and end of a session. Subsequently, we used the MU decoder to obtain spike trains of MUs. To get an estimation of the common drive, we superimposed all MU spike trains yielding the cumulative spike train (CST). As an alternative for estimating the common drive, we additionally averaged all HD-EMG channels (avg. EMG). We then applied a filter bank with 4 Hz wide bands between 10 and 60 Hz. Eventually, we classified the four mental tasks from the average power of the frequency bands during mental task execution. We employed a shrinkage linear discriminant analysis classifier. We also classified the force in the time domain to assess possible task-dependent behaviour. The classification accuracies for the subjects are shown in Table 1. Especially, the channel-averaged EMG contained discriminative information and yielded classification accuracies considerably larger than for CST or force for S3, S5 and S8.

Table 1. Classification accuracies in [%] when discriminating the 4 mental tasks based on CST, channel-averaged EMG, or force.

feature type	*S1*	*S2*	***S3***	*S4*	***S5***	*S6*	***S7***	*S8*	***average***
CST	29	23	34	23	39	31	31	23	29
avg. EMG	29	26	**38**	27	**50**	30	**39**	30	34
force	32	31	31	33	32	26	29	24	30
sig. level.	29	29	29	29	29	30	29	29	26

Discussion: We could clearly differentiate the mental task in 3 out of 8 subjects from the channel-averaged HD-EMG. The classification is probably not due to a class-dependent behaviour, as the force signal contains only little discriminative information in relation. Our results also indicate that the channel-averaged HD-EMG contains more discriminative information than the CST, possibly related to the fact that only a fraction of the active MUs can be decoded from surface HD-EMG signals. If the classification accuracies can be further improved by user training, EMG oscillations evoked by mental tasks could serve as a potential control signal for movement augmentation.

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