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Fast and reliable hand motor imagery decoding based on beta burst rate modulations

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Our understanding of motor-related processes has been significantly influenced by the description of the event-related desynchronization and synchronization phenomena in the mu (~8-13 Hz) and beta (~13-30 Hz) frequency bands [1,2,3]. Accordingly, non-invasive brain-computer interface (BCI) applications exploiting motor imagery (MI) usually depend on spatially- and band-limited power changes as the brain markers of interest. Yet, numerous studies have questioned the role of signal power as the best descriptor of movement-related brain activity modulations. On a single-trial level, beta band activity is characterized by short, transient, and heterogeneous events termed bursts rather than sustained oscillations [4,5,6].

In a recent study we analyzed the activity of channels C3 and C4 from multiple, open EEG datasets [7] with participants performing MI tasks. We demonstrated that a beta burst analysis of hand MI binary classification tasks (i.e. “left” vs “right”) is often superior to beta power in terms of classification score [8].

Here we expand upon this approach. We introduce an algorithm that constructs convolution kernels based on beta burst waveforms and creates classification features that are comparable to those of state-of-the-art methods. By independently transforming the EEG recordings with each kernel we compute a proxy of the waveform-resolved burst rate that is then spatially filtered using the common spatial pattern algorithm (CSP) [9]. Then, all spatial features are combined and used for classification. We adopt a time-resolved decoding strategy and show that, when compared to CSP-based signal power in the beta and mu bands, the waveform-resolved burst rate often yields superior decoding results only needing a short amount of data points, likely because it captures slow (mu-like) signal changes.

This analysis shows that BCI applications could benefit from utilizing such features and paves the way for a real-time implementation of the proposed methodology.

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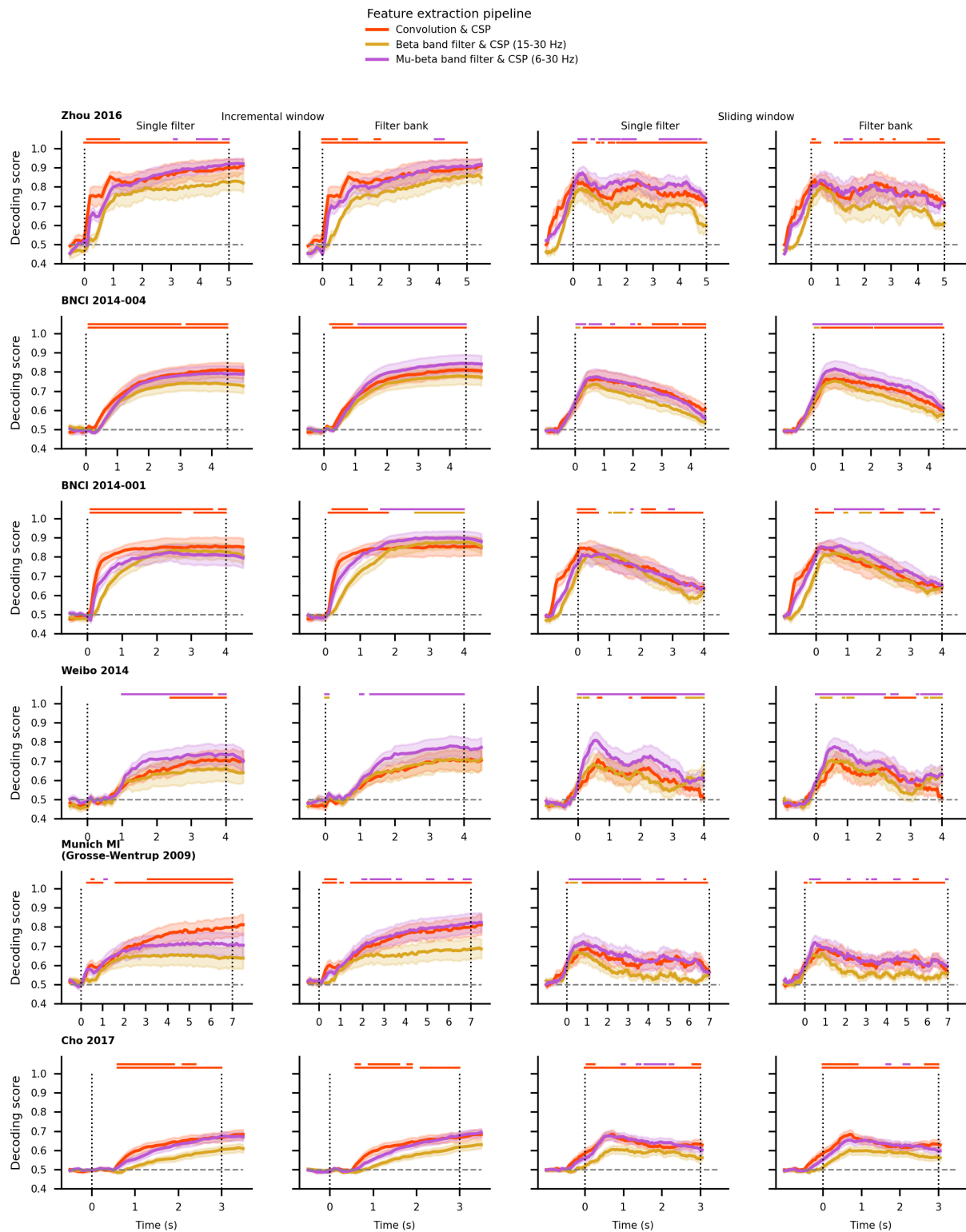


Figure 1. Time-resolved pseudo-online decoding results in “left” versus “right” hand motor imagery classification. Three feature creation techniques are assessed: convolution of raw signals with a selection of burst waveforms (red), beta band (yellow) and mu-beta (purple) band filtering. Each row corresponds to across-subjects average decoding accuracies of a different EEG dataset. The first two columns correspond to a paradigm based on the incremental window approach. Using steps of 100ms duration, a classifier is trained on all available data up to each time point. The last two columns correspond to a paradigm based on the sliding window approach. Using overlapping 1s-long windows (50ms step) a classifier is trained on all data of each window. For either approach, both a single filter and a filter bank are compared to the convolution technique. Above each subplot, colored lines depict permutation test results that indicate the feature extraction technique that yields superior decoding results.