Stimulus-informed spatial filtering for joint noise and dimensionality reduction in high-density EEG[1]

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Multi-channel systems like electroencephalography (EEG) and magnetoencephalography (MEG) are useful tools to record a person's neural responses to, e.g., an auditory stimulus. It has already been established that these responses can be used to study how our brain functions, as well as estimate speech intelligibility, auditory attention, motor imagery etc. Research on neural responses also have promising applications in brain-computer interfaces (BCIs). For example, auditory attention information decoded from the EEG signals of the listener in a competing talker scenario can assist the acoustic noise suppression algorithm of a hearing aid by identifying which speaker is the attended speaker. However, a common problem with MEG or EEG recordings is the low signal to noise ratio (SNR) which makes it challenging to estimate task related neural responses or temporal response functions (TRFs) describing the linear relationship between the stimulus and the neural response, particularly over short data windows. To counter this, experimental designs often include repeated trials, which are then averaged to directly improve the SNR or to inform the design of a spatial filter that projects the data onto high-SNR directions. However, collecting repeated trials is often impractical and even impossible in some paradigms, particularly for EEG where a large number of such repetitions are required.

Objective. A data-driven spatial filter design that takes advantage of the knowledge of the presented stimulus, to achieve a joint noise reduction and dimensionality reduction, without requiring repeated trials.

Methods. Forward modeling, using the method of least squares, is used to project the stimulus into the electrode space. The second-order statistics of this estimated 'desired' signal (stimulus following response) as well as the raw neural data are used to estimate a set of spatial filters that maximize the SNR of the neural response in the output, based on a generalized eigenvalue decomposition (GEVD). We compared the performance of our method to that of denoising source separation (DSS) and averaging over channels, in the context of auditory attention decoding (AAD).

Main Results. On a dataset of 16 subjects attending to 1 speaker in a two-speaker scenario, our method resulted in higher attention decoding accuracies compared to existing TRF-based decoding methods. Our method also resulted in better short-term TRF estimates compared to those estimated from the raw neural recordings.

Significance. As the method is fully data-driven, the dimensionality reduction enables researchers to perform their analyses without having to rely on their knowledge of brain regions of interest, thus eliminating to an extent, the human factor in the results. The method also does not require repeated trials, thus relieving experiment design from the necessity of presenting repeated stimuli to the subjects.

[1] This work is based on the submitted paper 'Stimulus-aware spatial filtering for single-trial neural response and temporal response function estimation in high-density EEG with applications in auditory research' which can be found at: https://www.biorxiv.org/content/biorxiv/early/2019/02/05/541318.full.pdf