Predicting Single-Trial Motor Performance from Oscillatory EEG in Chronic Stroke Patients

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Introduction: Machine learning methods allow for the decoding of ongoing brain states that provides valuable information about trial-by-trial behavioral performance variations of subjects. As a possible field of application, we analyze ongoing brain activity in a hand motor paradigm to predict motor performance on single-trial basis. The online prediction of motor performance can be utilized as an assistive technology for rehabilitation in order to enhance and speed up motor learning by causally influencing the training performance.

Material, Methods and Results:
Within the framework of a sequential repetitive hand force rehabilitation task for stroke patients (SVIPT, [1]), we studied the users brain activity by EEG (64 passive channels, BrainAmp DC). Pre-trial oscillatory power of the EEG was analyzed in terms of its correlation with a motor performance score of the upcoming trial, using a data-driven spatial filtering method called Source Power Comodulation (SPoC, [2]). The algorithm derives an oscillatory subspace (given by a spatial filter) whose bandpower activity is predictive for the motor performance of the upcoming trial. The method requires the data to be filtered to a narrow frequency band of interest. In our offline analysis, SPoC was trained within a 5-fold chronological cross-validation. The resulting filters were applied to unseen data in order to gain an estimate of the motor performance z_{est} for each trial entering the analysis. Since supervised spatial filtering methods are prone to over-fit the data, the meaningfulness and stability of any SPoC component needs to be verified by additional validation procedures [3]. Here, we report on results from a single session (about 200-240 trials) of three chronic stroke patients. The exemplary predictors shown in Fig. 1 were obtained by data of two subjects. They are based on a pre-go interval 800 ms before the *go-cue.* As performance metric, we chose the reaction time upon the go cue of the SVIPT task.

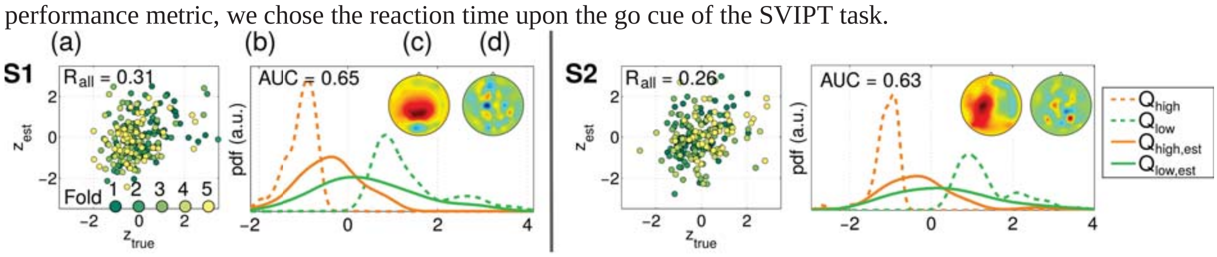

Figure 1. *Probing the predictive strength of two oscillatory components for subjects S1 and S2. The example given for S1 lives in the alpha-band (f=[10,12] Hz), the one for S2 is extracted from the beta range (f=[27,31] Hz) (a) Scatter plot of single trial performance prediction z_{est} as a function of the measured value z_{true} color coded by the temporal structure of the session. (b) Separability of the predictor by contrasting the upper and lower quartiles of z (dashed) with the corresponding quartiles according to z_{est} projected back to the z domain. In addition, the AUC value for a 50 percentile split is reported. Activity pattern (c) and spatial filter (d) extracted from SPoC.*

Discussion and Significance: In healthy subjects, the extraction of motor performance predictors delivers single-trial predictors which explain up to 25% of the variance [4],[5]. Our case study on three chronic stroke patients proposes that the same approach also allows to extract robust motor performance predictors under more severe conditions (less training trials, more artifacts). The resulting subspace features were derived from different frequency ranges (e.g. alpha and beta band) which corresponds to previous findings in healthy subjects. The subject-specific subspace components extracted for stroke patients may be used for brain-state dependent closed-loop experimentation in order to enhance rehabilitation training performance.

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