 DOI: 10.3217/978-3-85125-467-9-229

Prediction of Difficulty Levels in Video Games from EEG

L. Naumann[1*], M. Schultze-Kraft[2], S. Dähne[3], B. Blankertz[2]

[1]*Bernstein Center for Computational Neuroscience, Berlin, Germany;*
[2]*Neurotechnology Group, TU Berlin, Germany;* [3]*Machine Learning Group, TU Berlin, Germany;*

* BCCN, Unter den Linden 6, 10099 Berlin, Germany. E-mail: laura-bella.naumann@bccn-berlin.de

Introduction: Changes in workload have been shown to be accompanied by power modulations in EEG frequency bands such as theta (4-7 Hz) and alpha (8-12 Hz)[1]. In a typical video game that requires continuous mental and visuomotor effort, an increase of difficulty is expected to increase the player's workload. In this contribution, we tested whether it is possible to predict the current difficulty level of a video game by using only the ongoing EEG activity of the player. The game we chose is a modified version of the classical Tetris, in which the current difficulty level can be set by the experimenter.

Methods and Results: Six subjects participated in the experiments during which they played nine Tetris games, with each game lasting ten minutes. Every 60 seconds during gaming, the difficulty level was changed at random to one of 10 predefined levels. EEG data was recorded from 32 channels. Preprocessing included removal of eye artifacts via regression from EOG signals and rejection of single levels or channels based on excess variance.
For the regression of multiple difficulty levels based on neural bandpower dynamics, we applied the Source Power Co-Modulation (SPoC) analysis[2]. SPoC optimizes spatial filters such that their corresponding spectral power dynamics of a given frequency band maximally covary with the given difficulty levels. The frequency band of interest is a parameter of the method.

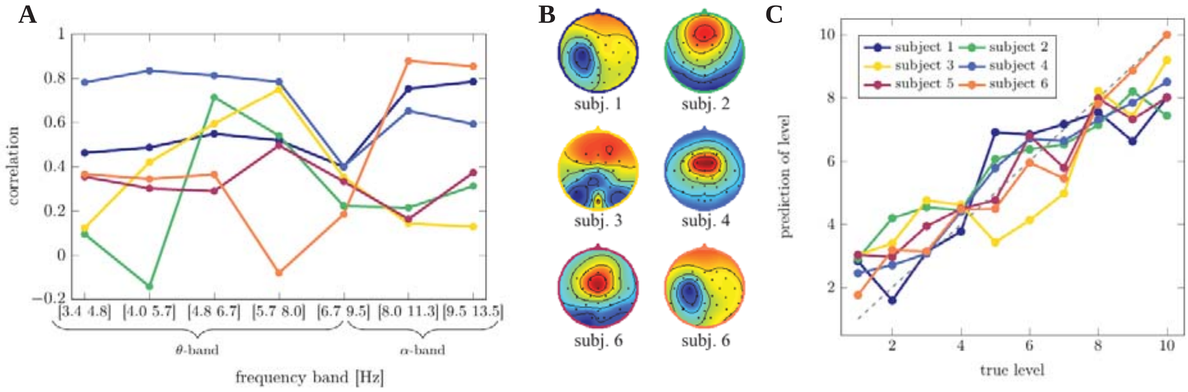

Figure 1. ***A:*** *Correlation between predicted and target levels as a function of frequency band used for SPoC analysis.* ***B:*** *Activation patterns of the first SPoC components for each subject.* ***C:*** *Mean predicted level versus true level for single subjects using the subject-specific optimal frequency band. Gray dashed line indicates a perfect prediction. Single subjects are color-coded equally in all three panels.*

To determine the optimal frequency band for each subject, a crossvalidated SPoC analysis was performed for different frequency bands (Fig. 1A). In each fold, one game was left out during the training of SPoC components. Performance of the prediction on the test dataset was measured as correlation between the regression output and the true levels. While for subjects 1 and 6 the frequency band that yields the best prediction is in the alpha range, for subjects 2-5 the best prediction is achieved in the theta range. The spatial patterns of the corresponding SPoC components are representative for the frequency bands and physiologically plausible (Fig. 1B). We found that for all subjects, one SPoC component is sufficient to yield high levels of prediction accuracy. The predictions roughly cover the levels from 1 to 10 (Fig. 1C), the mean correlation between predicted and true difficulty level across subjects was 0.802±0.036 SEM.

Discussion: Inspecting the optimal frequency band and the resulting spatial pattern indicates that for subjects 1 and 6 the best prediction was based on the sensorimotor rhythm (SMR), while workload related mid-frontal theta activity was the optimal predictor for the remaining subjects. However, even for subjects 1 and 6 the correlations obtained from theta activity (r=0.55 and r=0.36, respectively) are statistically significant as revealed by a permutation analysis. Our findings demonstrate that difficulty levels of a video game can be predicted with high accuracy solely from ongoing brain signals by employing a state-of-the-art EEG spatial filtering method. Finally, our approach can be extended to an online application, e.g. for adaptive gaming.

References

[1] Holm A, Lukander K, Korpela J, Sallinen M, Müller KMI. Estimating Brain Load from the EEG. *TheScientificWorldJOURNAL 9: 639-651, 2009.*

[2] Dähne S, Meinecke FC, Haufe S, Höhne J, Tangermann M, Müller K-R, Nikulin VV. SPoC: A novel framework for relating the amplitude of neuronal oscillations to behaviorally relevant parameters. *NeuroImage 86: 111-122, 2014.*