Defining brain excitability states from EEG by data-driven spatio-temporal filtering

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ConnectToBrain

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Background

- We aim to uncover cortical excitability states using M1-targeted single-pulse TMS-EEG.
- It is known from previous studies that brain excitability varies according to the phase of the mu rythm [1].
- Data-driven brain state decoding may provide to more accurate results and new neurophysiological findings.

Results

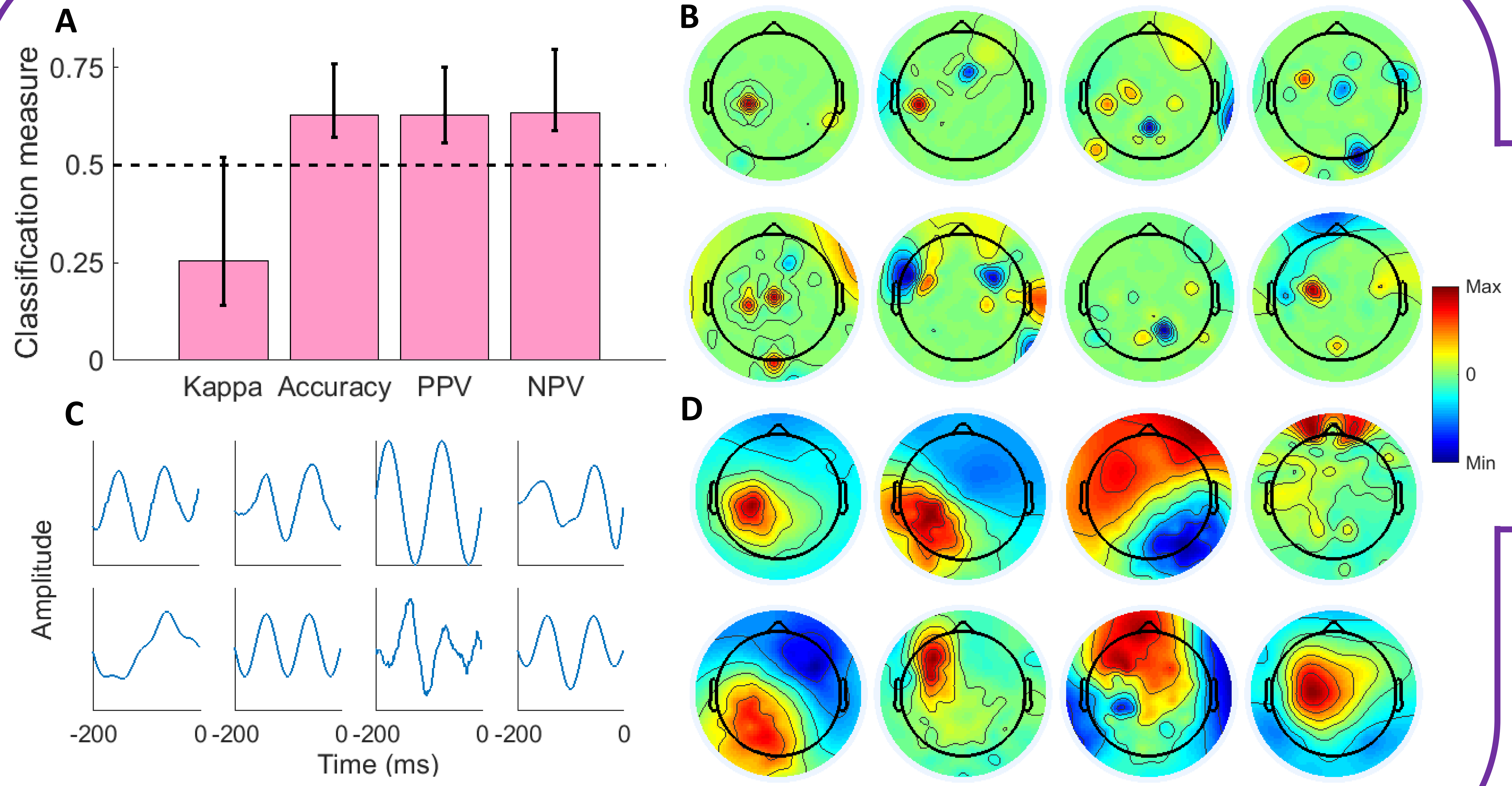

Figure 1. The results for eight healthy subjects. **A** The classification measures over subjects when predicting states of 100 test trials (each subject). Bar indicates the mean and the error bars the range of all values. PPV/NPV is positive /negative predictive value, respectively. The p-value of the accuracy was < 0.05 for each subject. **B** The spatial filters for all 8 sujbects. **C** Temporal filters. **D** The topographies corresponding to the filters in **B** [2].

Methods

- The EEG epochs ($\boldsymbol{X}$) were labelled according to the recorded MEP amplitudes to either low (*y=0*) or high (*y=1*) excitability states
- Logistic regression model was used for training a classifier:

$$p(y=1|\boldsymbol{w}_{\text{spat}}, \boldsymbol{w}_{\text{temp}}, \boldsymbol{X}) = \frac{1}{1+e^{-\boldsymbol{w}_{\text{spat}}^{\text{T}}\boldsymbol{X}\boldsymbol{w}_{\text{temp}}}}$$

$$p(y=0|\boldsymbol{w}_{\text{spat}}, \boldsymbol{w}_{\text{temp}}, \boldsymbol{X}) = \frac{1}{1+e^{\boldsymbol{w}_{\text{spat}}^{\text{T}}\boldsymbol{X}\boldsymbol{w}_{\text{temp}}}}$$

- The filters ($\boldsymbol{w}_{\text{spat}}, \boldsymbol{w}_{\text{temp}}$) are optimized by maximizing the likelihood of the model with the training data. Regularization term is added to prevent overfitting of the filters.

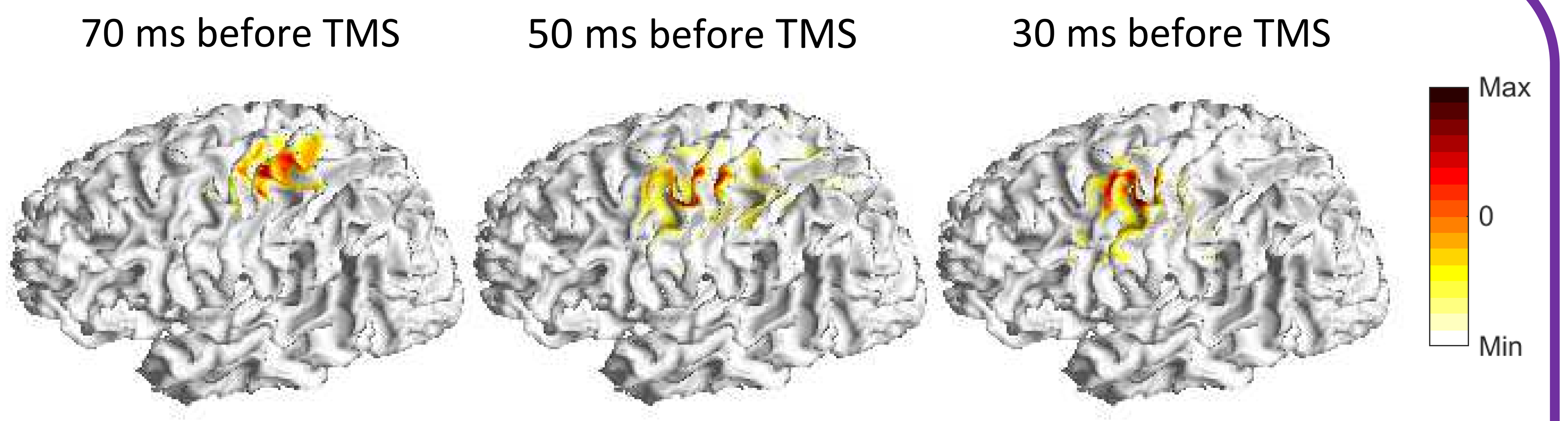

Figure 2. It is further possible to apply source localization to the topographies and flexible spatiotemporal classification on the data. This example shows beamforming estimates from the spatio-temporal pattern predicting high exitability state from subject 1.

Conclusion

- Brain state prediction is possible by applying machine learning to resting state EEG.
- The filters may be used in closed-loop EEG-TMS experiments or TMS therapy.
- The filters may be analyzed further in order to interpret the underlying neurophysiological phenomena.

References

[1] Zrenner, C., Desideri, D., Belardinelli, P., & Ziemann, U. (2018). Real-time EEG-defined excitability states determine efficacy of TMS-induced plasticity in human motor cortex. *Brain stimulation*, *11*(2), 374-389.
[2] Haufe, S., Meinecke, F., Görgen, K., Dähne, S., Haynes, J. D., Blankertz, B., & Bießmann, F. (2014). On the interpretation of weight vectors of linear models in multivariate neuroimaging. *Neuroimage*, *87*, 96-110.