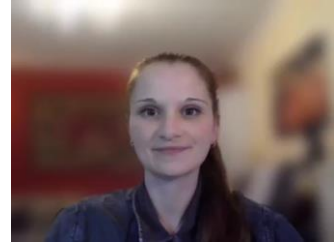


Investigating Feature Set Decisions for Mental State Decoding in Virtual Reality based Learning Environments

Katharina Lingelbach

Brain-Computer Interfaces

Decoding Working Memory Load with Functional Near-infrared Spectroscopy

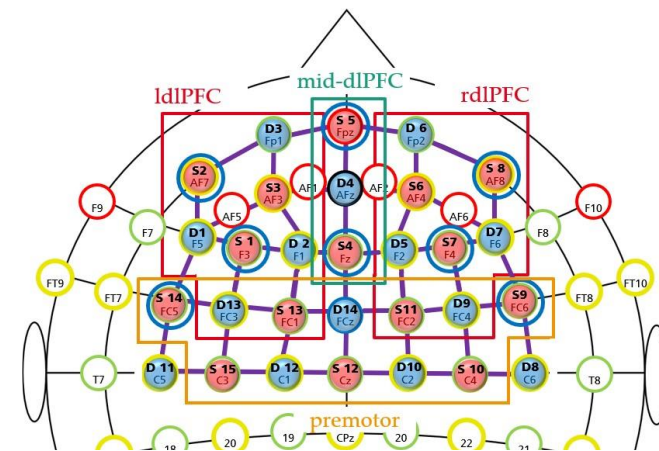
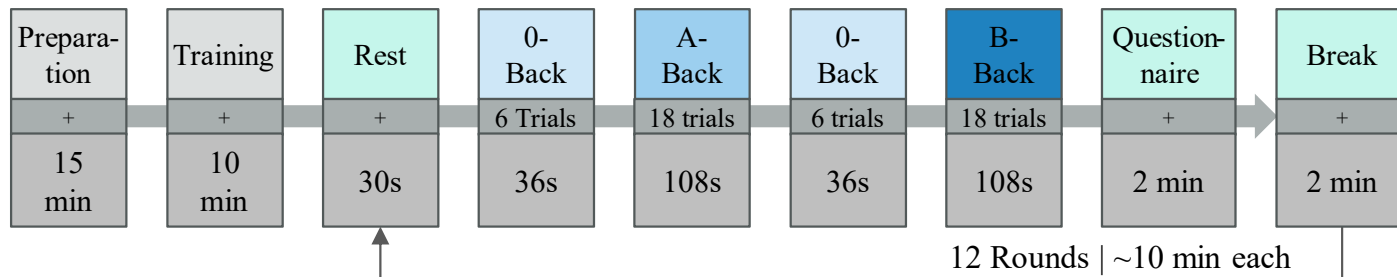
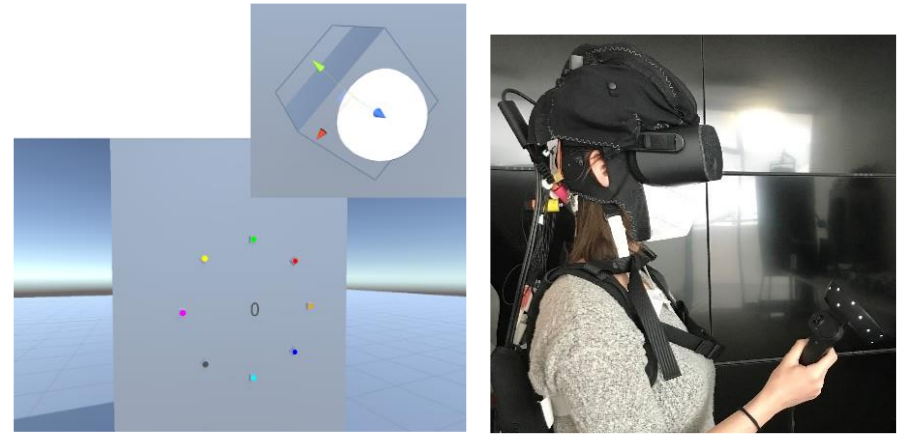


■ Motivation

- investigate different statistical feature sets for working memory load decoding
- spatial distribution of informative channels

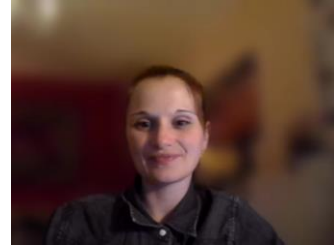
■ Methods

- functional near-infrared spectroscopy (fNIRS) to measure brain activity
- 11 volunteers (four female, mean age of 23.73 ± 1.42 years)
- colour-based visuo-spatial n-back paradigm in VR (von Lühmann, 2018¹)
- low (1-back) and high working memory load (3-back)



Machine Learning Pipeline for Working Memory Load Decoding

HbO and HbR Statistical Features and Classifiers



■ Preprocessing Pipeline

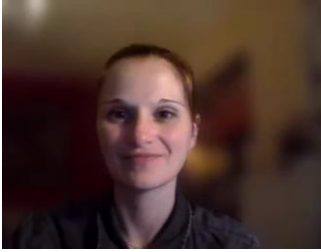
- Converted to optical density
- Channel pruning
- Transformed to HbO and HbR concentration changes (modified Beer-Lambert law)
- Filtering and amplitude rejection
- Extraction of epochs of interest (4 sec)

■ Machine Learning Pipeline

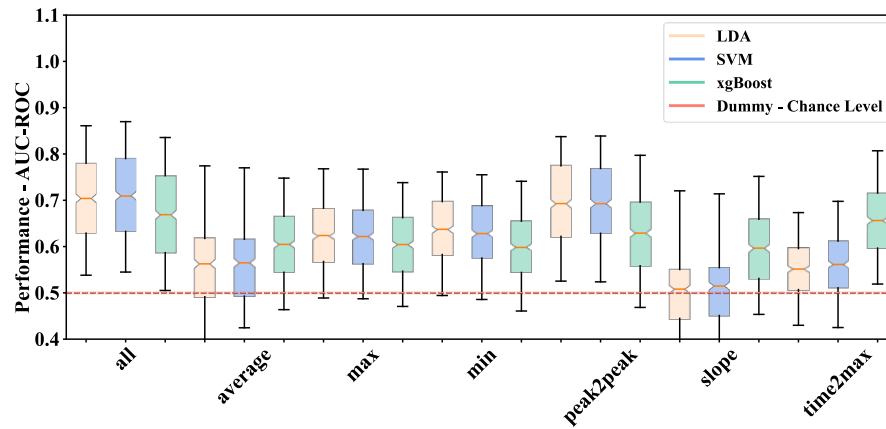
- Subject and HbO/HbR-wise classification model
- Nested cross-validation with hyperparameter optimization (5 folds à 20 repetitions)
- Metric AUC-ROC
- Empirical chance level estimated with a Dummy Classifier
- Classifier: Linear Discriminant Analysis (LDA), Support Vector Machine (SVM) and Gradient boosting tree (xgBOOST)
- Feature Sets: Average, Max, Min, Peak2Peak, Slope, Time2Peak
- Evaluation: Bootstrapping over the cross-validation folds to estimate the mean and its confidence interval

Performance of Working Memory Load Decoding

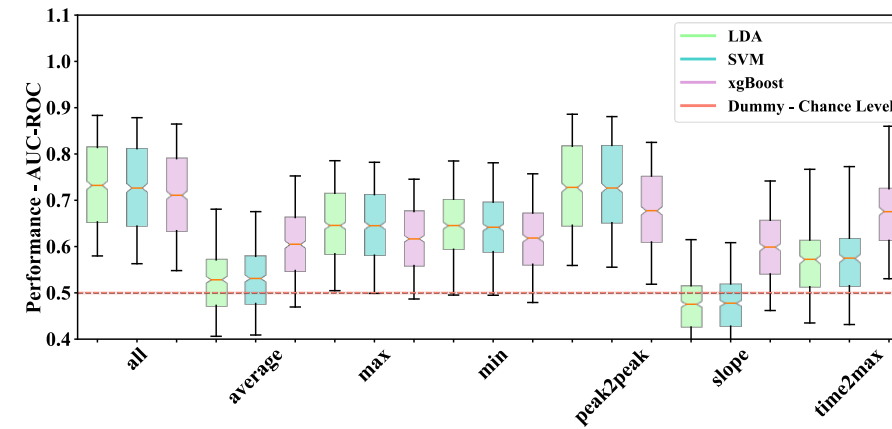
HBO and HBR Statistical Features



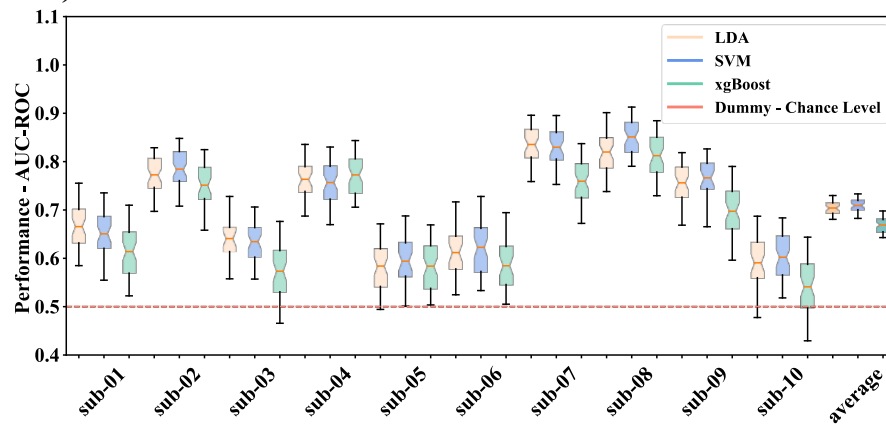
A) Performance per Classifier and Feature - HBO



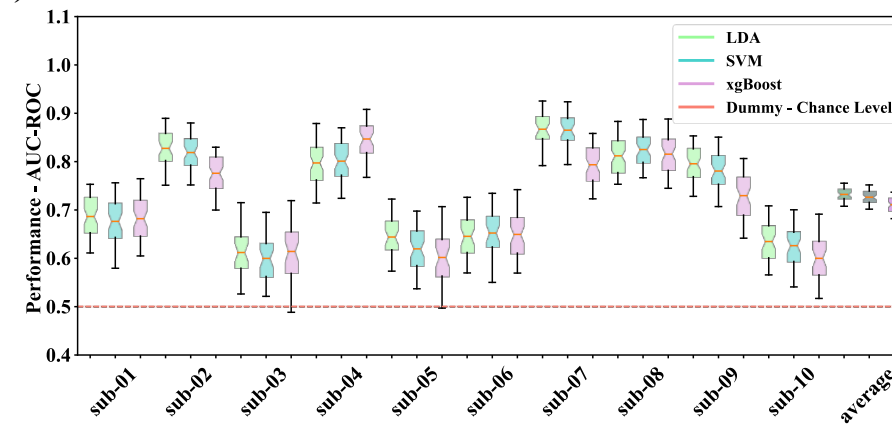
B) Performance per Classifier and Feature - HBR



C) Classifier Performance per Participant Using All Features - HBO

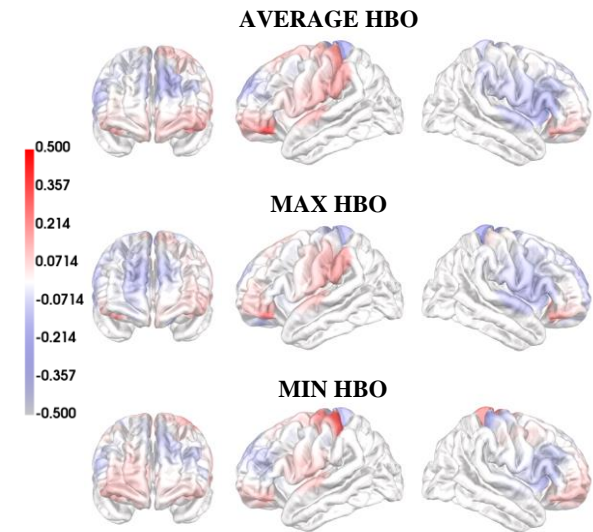
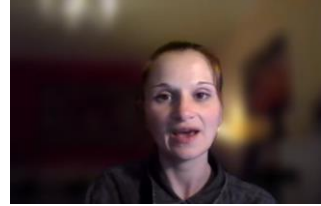


D) Classifier Performance per Participant Using All Features - HBR

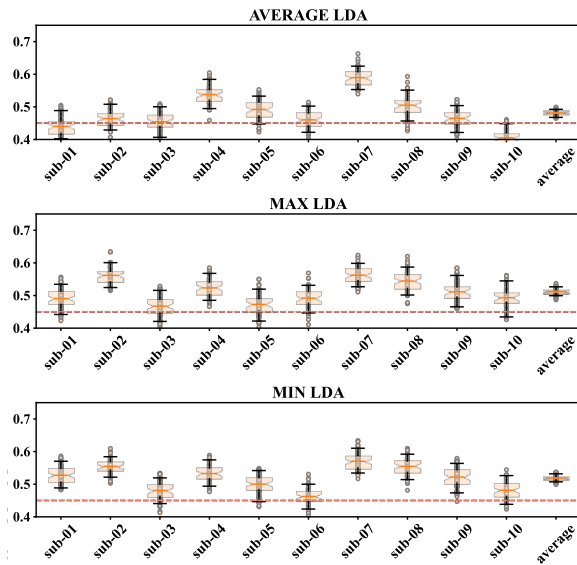


Performance of Working Memory Load Decoding

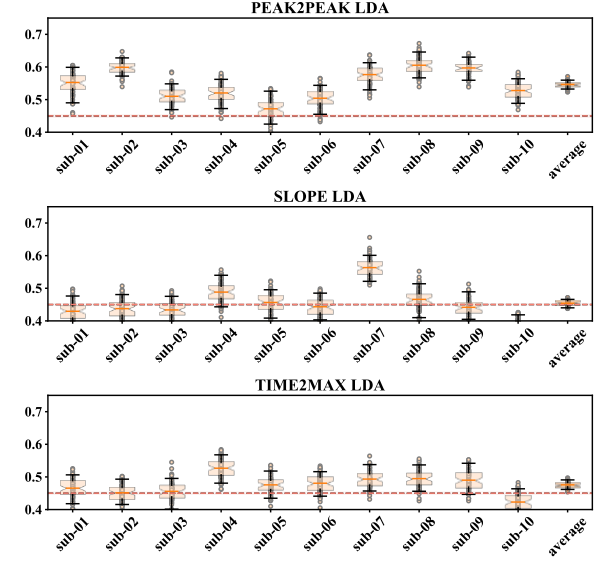
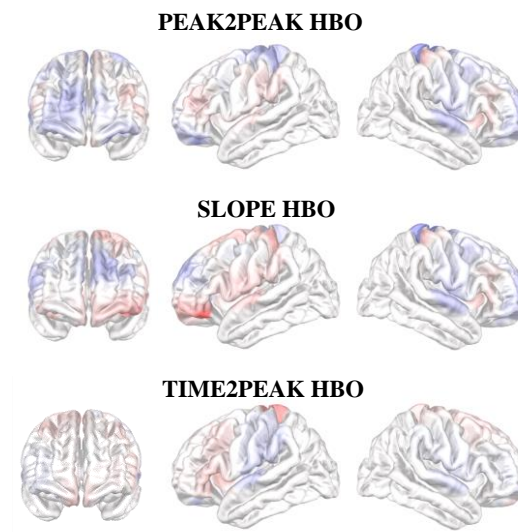
LDA Coefficients



Model Performance per Subject [AUC ROC]

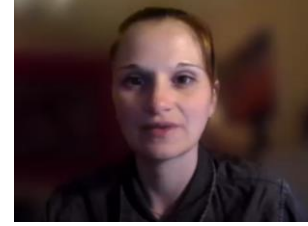


Model Performance per Subject [AUC ROC]

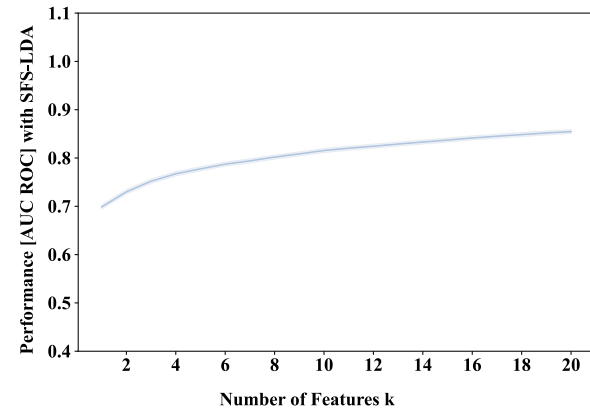


Performance of Working Memory Load Decoding

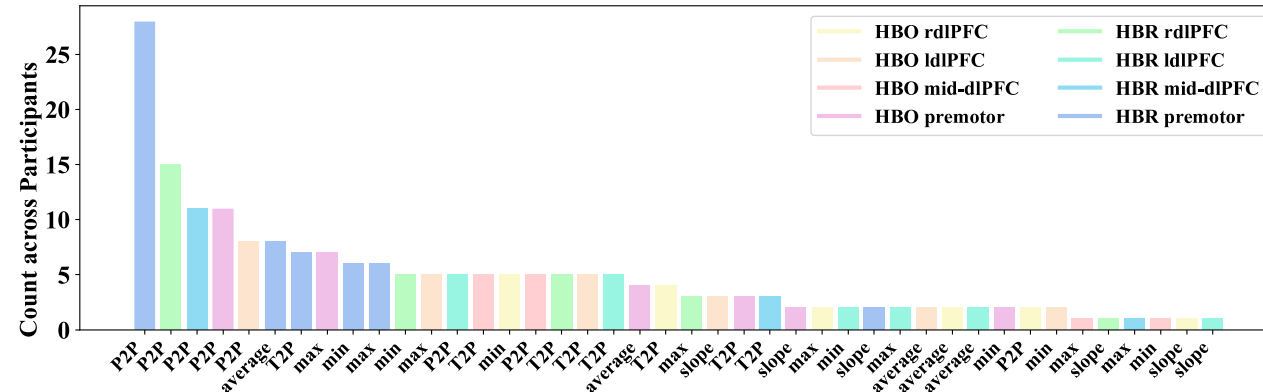
HBO and HBR Statistical Features



Average Decoding Performance as a Function of Feature Set Size

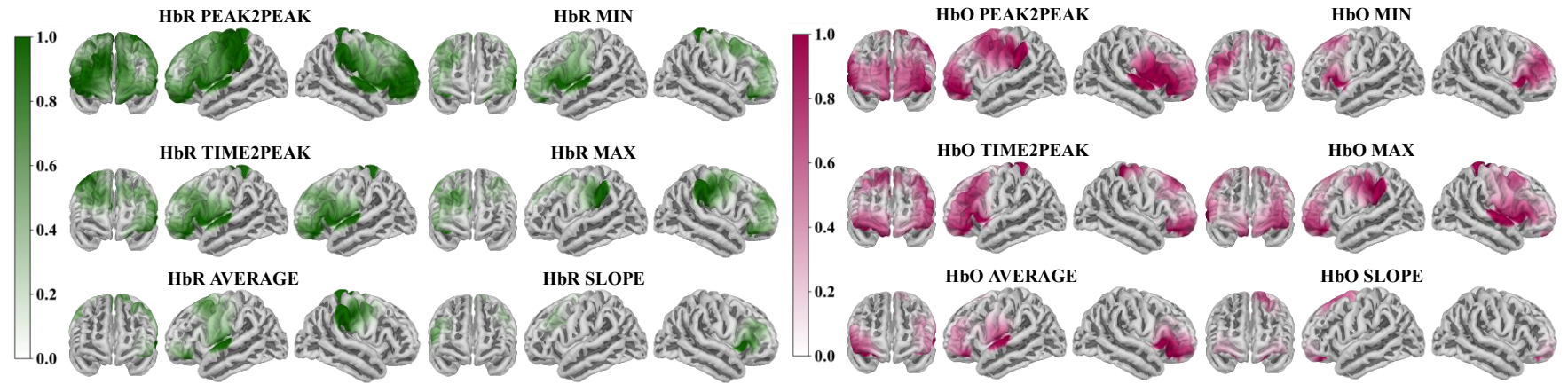
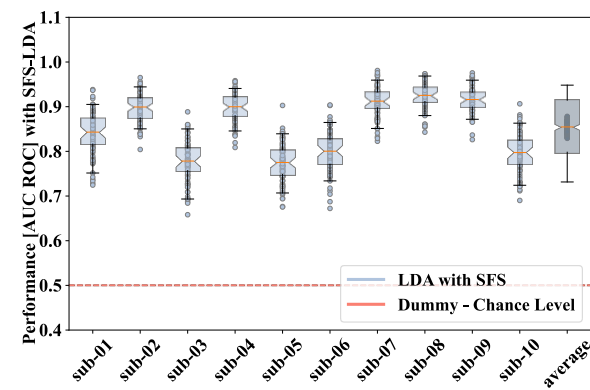


Feature Analysis of the LDA with SFS (k=20)



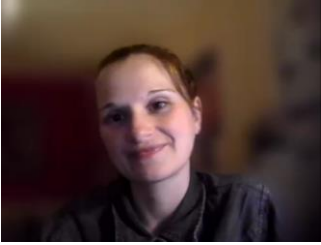
Features per Channels clustered in Regions of Interest

Decoding with optimized HbO and HbR Features (k=20)



Summary

NIRCademy – Mental State Decoding in a Industrial VR Learning Scenario



Feature Sets

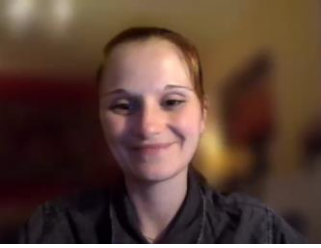
- Highest average decoding performance for a **combined HbO and HbR and optimized feature set**
- **Single statistical feature sets** yielded in rather **low** and below-chance level **decoding**
- **HbR-related features** contributed the most to our SFS-based decoding

Spatial Distribution

- **Informative channels** were rather **spatially distributed** throughout the PFC

Outlook

- **Future everyday world BCI applications** require the decoding of **more than two WM load levels**
- **Decisions** regarding **machine learning pipelines** and **feature sets** are vital and require further research



Thanks to the Team ;-)



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