Towards User-Aware VR Learning Environments

Mental State Decoding with Brain-Computer Interfaces and Virtual Reality

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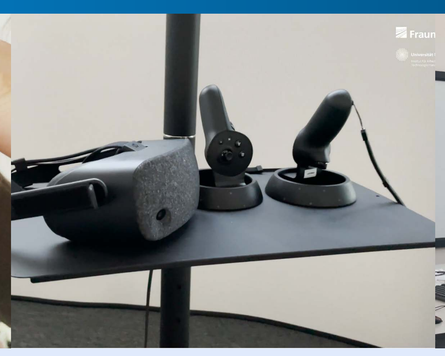
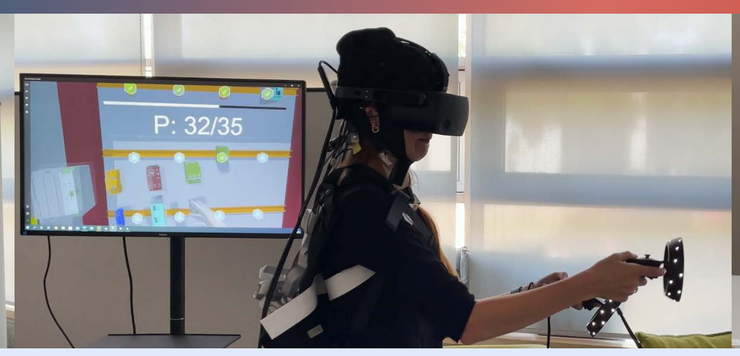
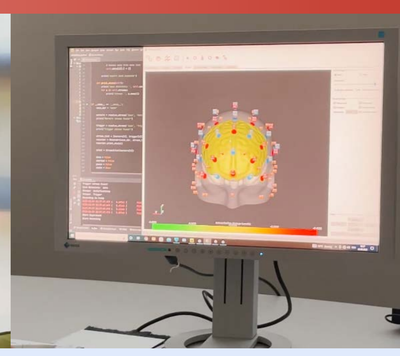




1 BACKGROUND

Brain-Computer Interfaces (BCIs) allow monitoring of users' mental states.
They can be combined with Virtual Reality (VR) in a learning environment to tailor the system to individual skills and needs.
Functional near-infrared spectroscopy (fNIRS) measures brain activity and is a suitable tool for real-world BCI applications.

Our aim is to a) investigate underlying brain patterns for mental state decoding and b) identify the learning progress of individuals in applied VR learning environments.

2 METHODS

9 participants performed a working memory task in a VR industrial learning scenario.
They had to install electrical components in a switch cabinet with a low (LW) and high working memory (HW) condition.

We measured the brain activity of the prefrontal cortex via fNIRS, behavioural responses, and subjective evaluations (NASA TLX).
Two approaches are suitable to investigate underlying brain patterns in mental state decoding:
Linear mixed-effects and Machine Learning Models.

Group-Level Statistic of Working Memory Load Levels

Linear Mixed-Effects (LMM) Model

LMM Coefficients

High - Low Working Memory Load

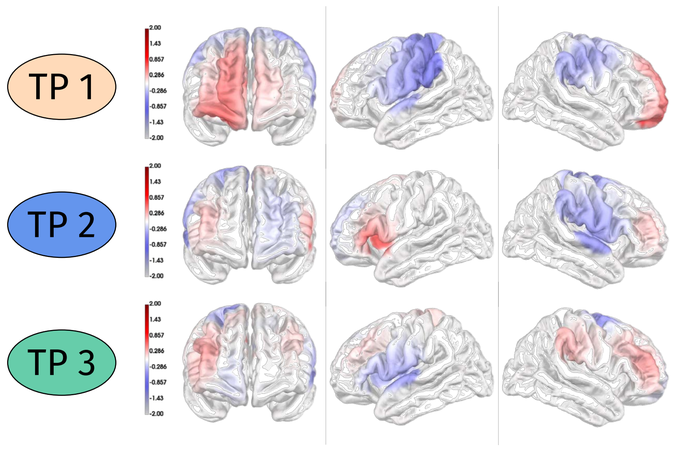
NIRcademy: fNIRS-based BCI + VR

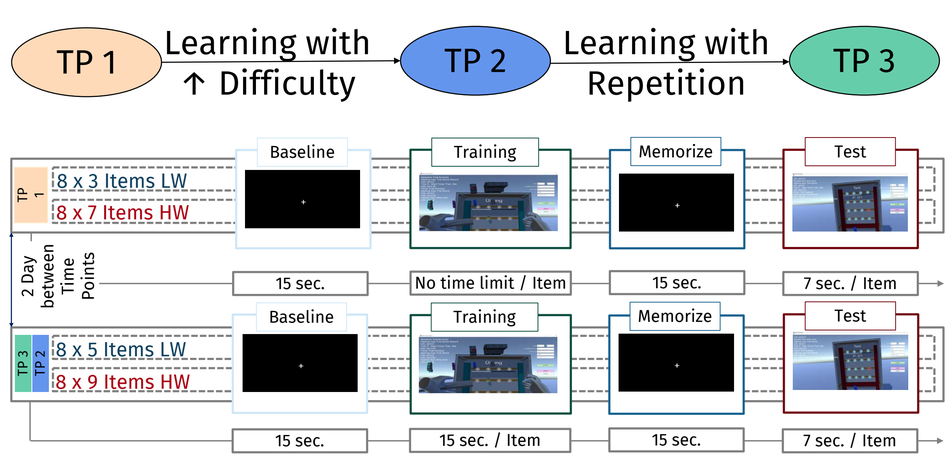
Group-level Decoding from Machine Learning Models

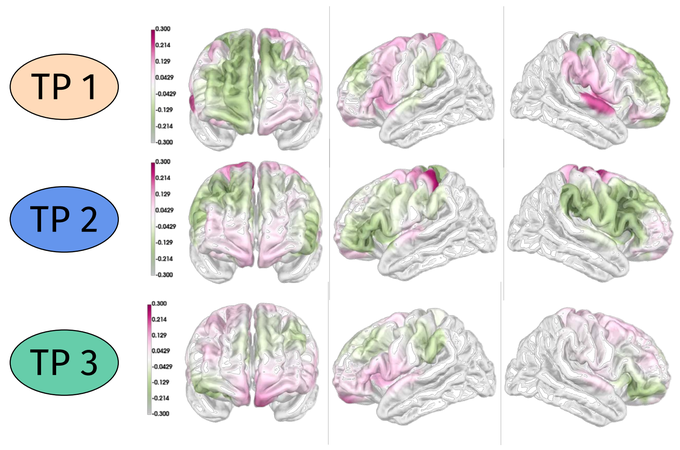
Machine Learning (ML) Models

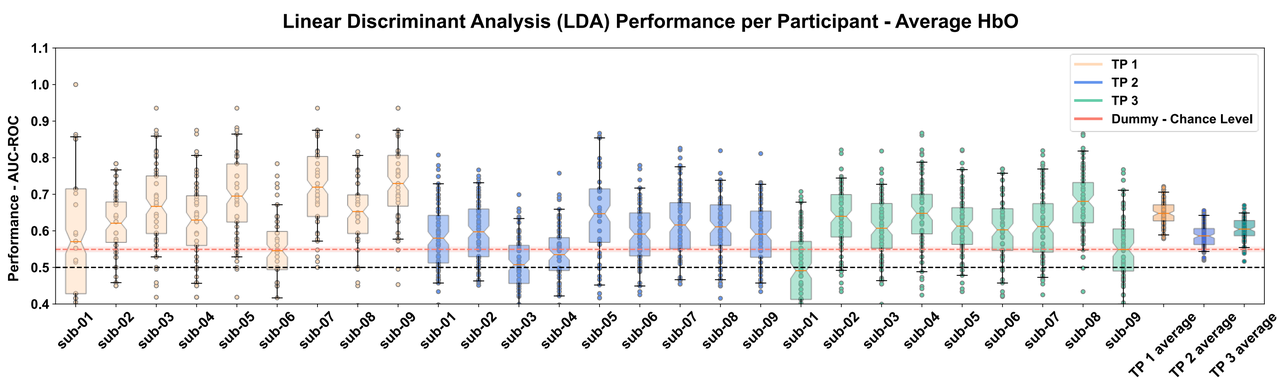
ML Coefficients

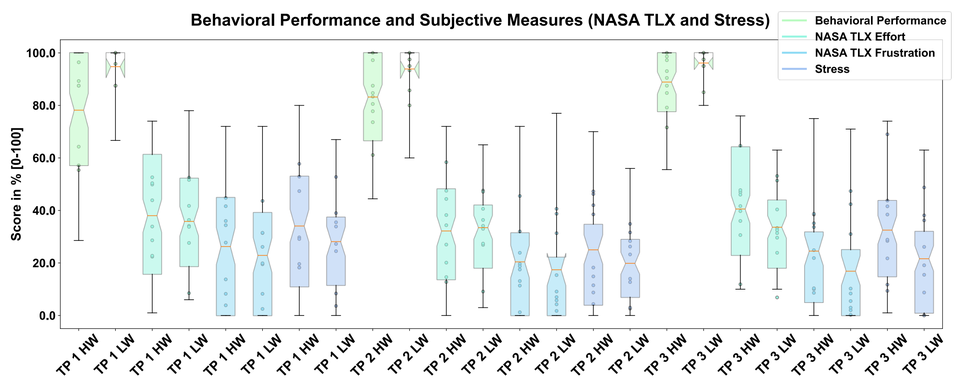
High (1) - Low (0) Working Memory Load











3 RESULTS & DISCUSSION

The feasibility study revealed a complex non-linear relationship between task difficulty level and prefrontal cortex activity.

Learning effects are visible in this relationship and in the classification performance.

Subjective measures could not differentiate the two difficulty levels.
This highlights the benefit of BCI-based mental state decoding.

4 APPLICATION

Mental state decoding using BCI in VR learning scenarios can be applied to several use case scenarios:

- safety training in critical infrastructures,
- robot-assisted language learning,
- human-robot collaborations
- robot-assisted medical interventions.

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