An Offline, Passive Brain-Computer Interface Classification Model Relevant to the NASA Artemis Mission

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Introduction

- Passive brain-computer interfaces (pBCI) have the potential to improve cognitive-motor performance in future Artemis missions
- However, pBCI must accurately classify mental workload using a small segment of brain activity (see Fig. 1)
- In this work we use an enhanced version of our computational model [1, 2] to predict mental workload with an HRI task

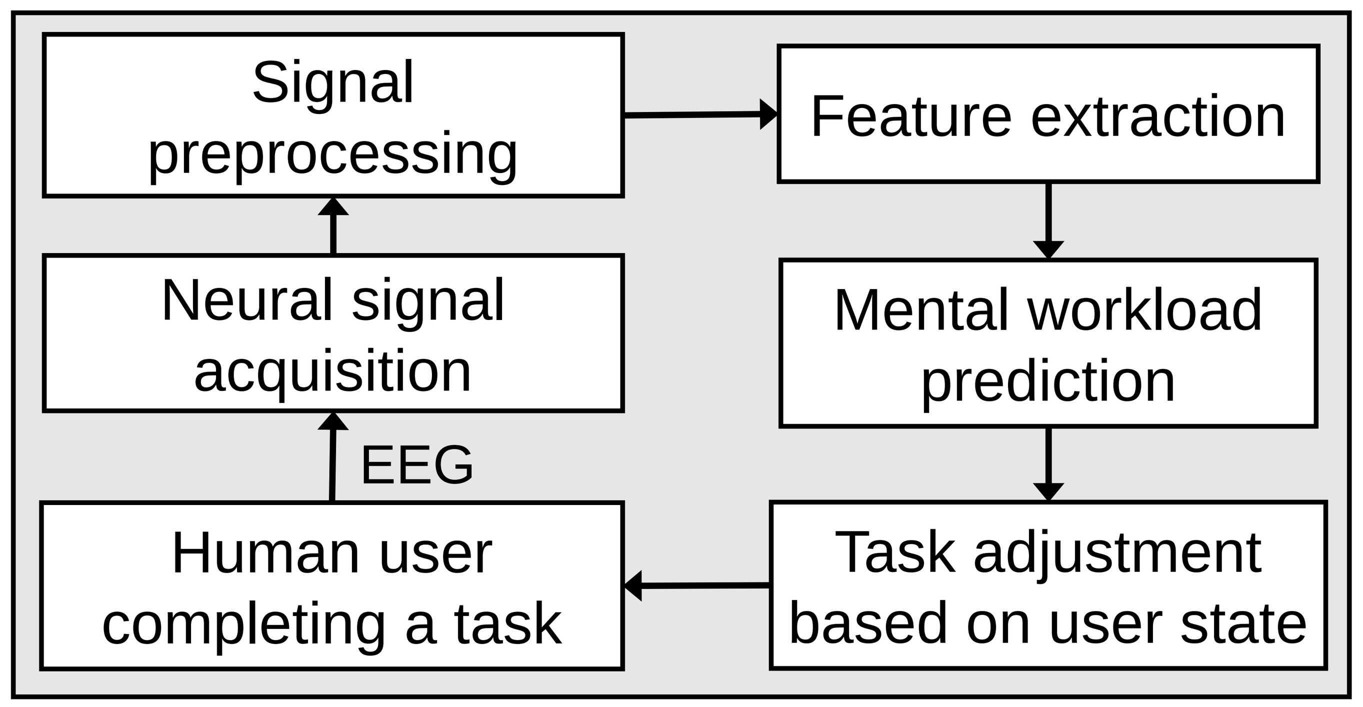

Fig. 1. Overview of a general pBCI system.

Methods

- Six participants completed the Rush Hour puzzle (two difficulty levels) with an engaged (RE) or disengaged (DE) robot
- EEG was collected, preprocessed, and segmented into 5-second windows
- Five frequency ranges were considered
- EEGs of ten channels were mapped into visibility graphs (VGs) and assembled as layers of a multiplex VG (MVG) [3]
- The edge overlap, or entanglement, of MVGs was computed [4]
- A support vector machine (SVM) classifier was trained with the computed measures to classify two levels of mental workload

Results

Classification Performance

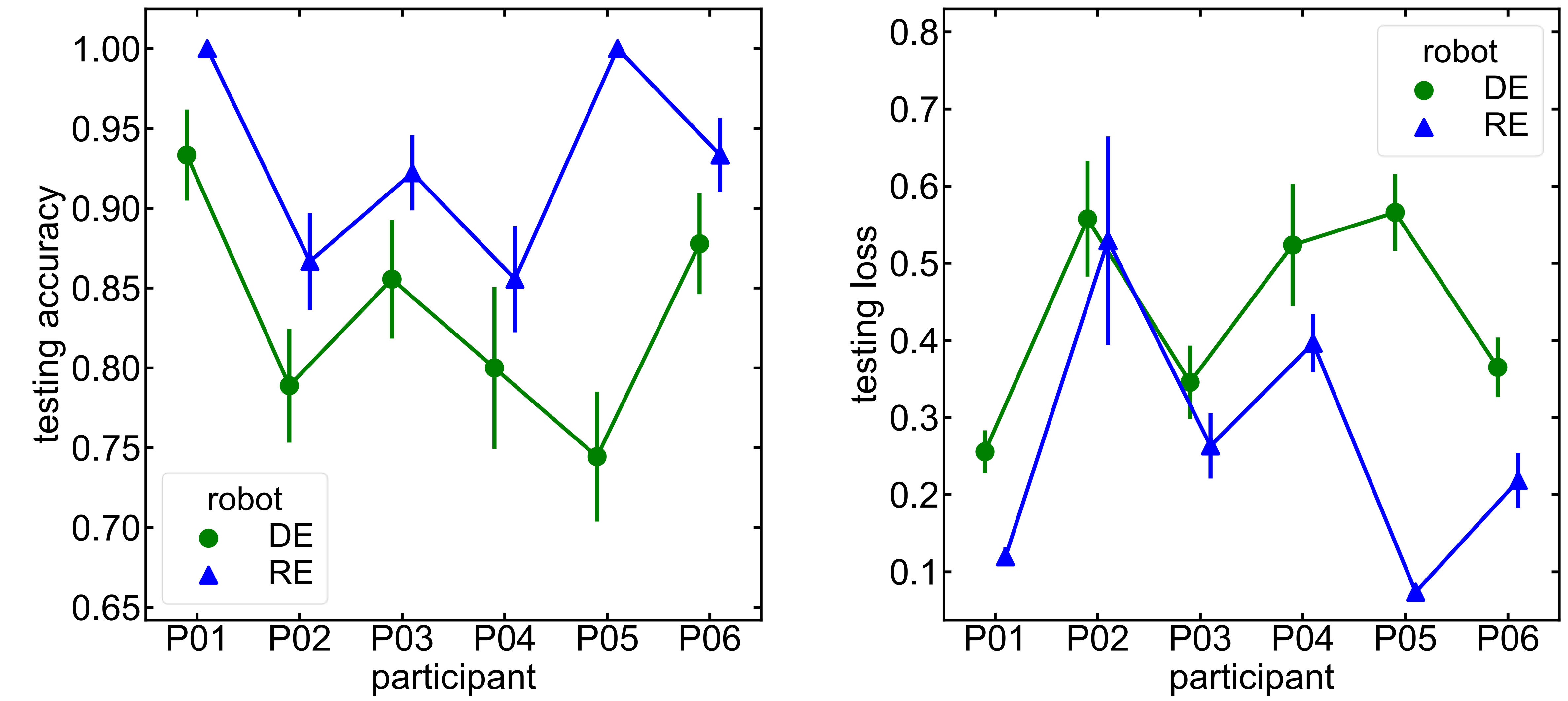

Fig. 2. Left panel: Testing accuracy scores for an SVM classifier tasked with prediction of two states of mental workload associated with two levels of task demand. Right panel: associated testing loss scores. Legend denotes level of robot involvement.

Statistical Network Analysis

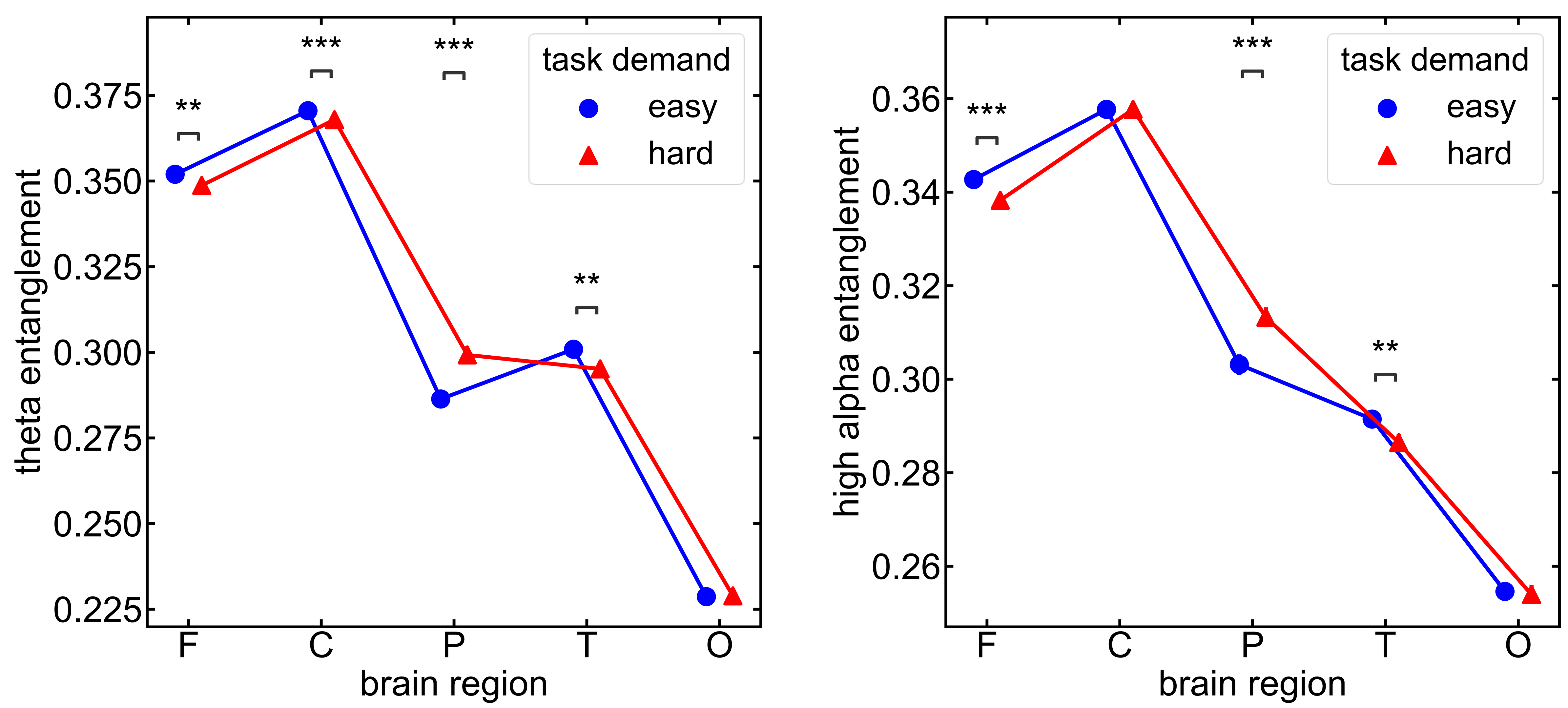

Fig. 3. Left panel: average layer entanglement of MVGs generated from EEGs filtered into the theta band (4-8 Hz) under two states of task demand. Right panel: associated measurement for the high-alpha band (11-13 Hz). $^{**}p<0.01$, $^{***}p<0.001$.

Discussion

- Average testing accuracy was 93% when robot was engaged, 83% when disengaged
- Average testing loss was 0.27 when robot was engaged, 0.44 when disengaged
- Significant decrease in network connectivity observed in frontal, central, and temporal brain regions when task demand increased
  - Opposite trend observed for parietal region
  - Observations consistent in both theta and high-alpha bands
- Future work:
  - Assess model feasibility in a real-time (online) pBCI scenario
  - Use MVGs to investigate dynamics of functional brain networks

References

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Acknowledgments

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