Predicting Rapid Shifts in Cognitive Resource Allocation

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Dr. Brooks received his M.D. and Ph.D. (neuroscience) from Washington University in St. Louis in 2012. Since that time, he has worked for the Army Research Laboratory, Vanda Pharmaceuticals, and most recently started a R & D company, D-Prime LLC.

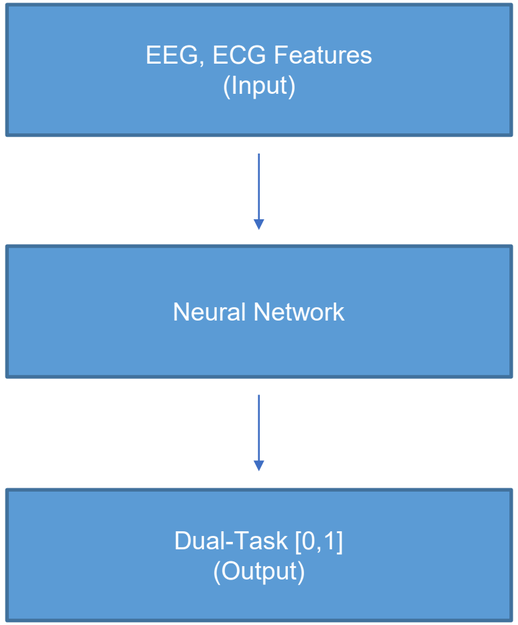
D-Prime's research interest include computational psychophysiology, algorithm development, and human-system interaction.

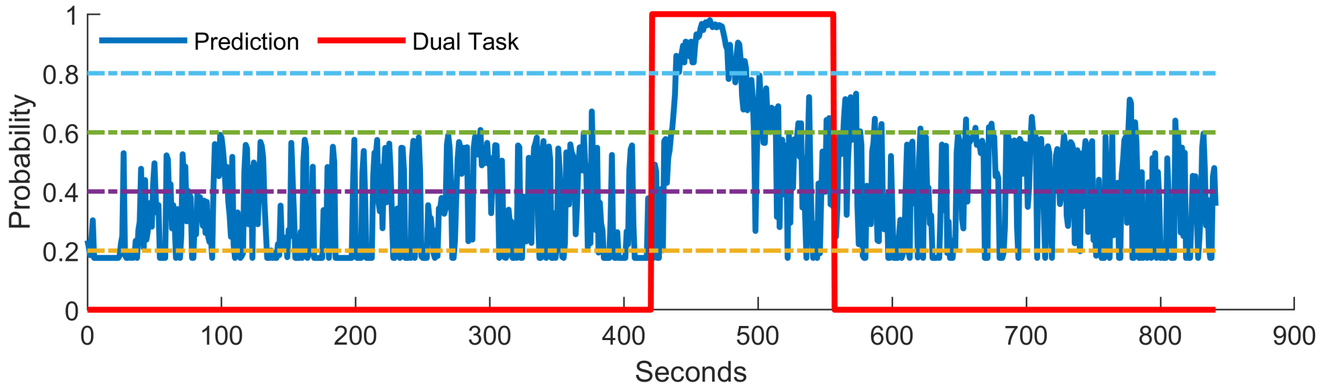
Overview – Cognitive Resources

- Cognitive resources (e.g. attention, working memory) are inherently limited
- Fluctuations in the availability of these resources can impact performance of ongoing tasks
- Detecting fluctuations in cognitive resources unobtrusively (without interrupting ongoing behavior, e.g. using a survey) is a challenging problem and typically involves psychophysiology (using various sensors to infer human state)
- Several models can detect cognitive resource allocation within a specific task, however very few are able to generalize across tasks
- In this work, we developed such a generalizable model that can operate in real-time to support human-system interaction

Psychophysiology Model

- Cognitive resources have been related to specific, functional networks in the electroencephalogram (EEG) and time-domain features derived from the electrocardiogram (ECG)
- We developed 250 features from these signals and used them as input to a neural network
- To train the model, we used a dataset in which participants switched between performing a single and dual task
- The target of the model was the binary classification of whether the participant was in the dual task
- The output of the model was [0,1] (whether the participant was in the dual task and an associated probability

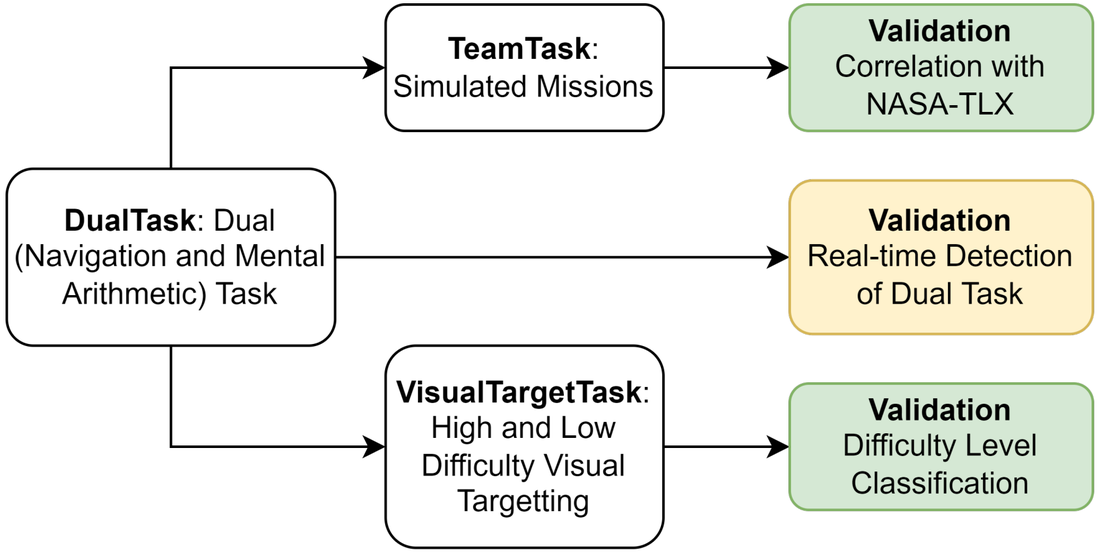




Validation Schema

- The first validation we performed was on an independent data set (TeamTask) in which ground truth allocation of cognitive resources were provided through the NASA-TLX
- The second validation was with a VisualTargetTask that examined visuospatial processing attentional resources

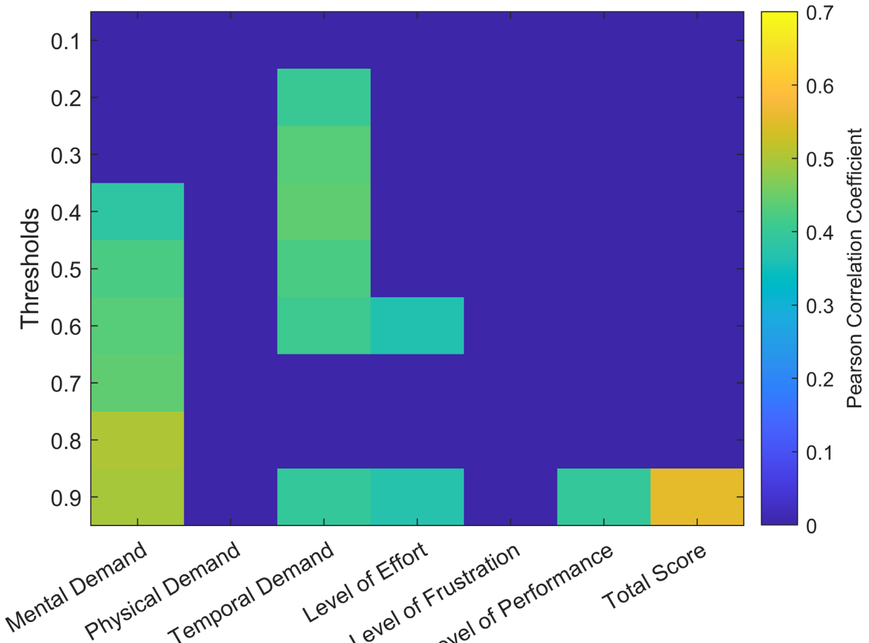
Cognitive Resource Depletion (CRD) Model Development and Validation Overview

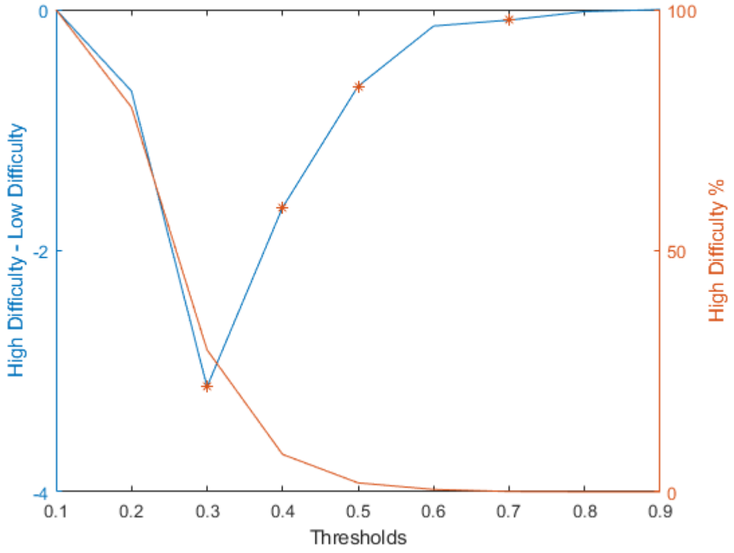


In all models, the 250 features used were derived from 10 channels of EEG and 1 channel of ECG

Results

- In order to test the robustness of our model we explored thresholds of classification in both external validation datasets. This enabled us to show the stability of predictions of the model
- In the TeamTask, the model showed consistent correlations with two specific subscores of the NASA-TLX: 1. Mental Demand, 2. Temporal Demand (top right)
- In the VisualTargetTask (bottom right) the model was able to discriminate high and low difficulty





Conclusions and Future Directions

- Our model of cognitive resource allocation is highly correlated with ground truth (NASA-TLX) measures of cognitive workload
- Furthermore, it is generalizable across independently collected datasets and heterogenous participants
- Our future work will embed this model into real-time systems that can modulate human-system interaction

- Future investigation will examine robust identification of appropriate thresholds, generalizability of the model to additional tasks, and incorporation in real-time systems