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DREXEL UNIVERSITY
CONQUER CollabOrative
Cognitive Neuroengineering & Quantitative Experimental Research

Wearable Brain and Body Sensing for Multimodal Assessment of Cognitive Workload and Training

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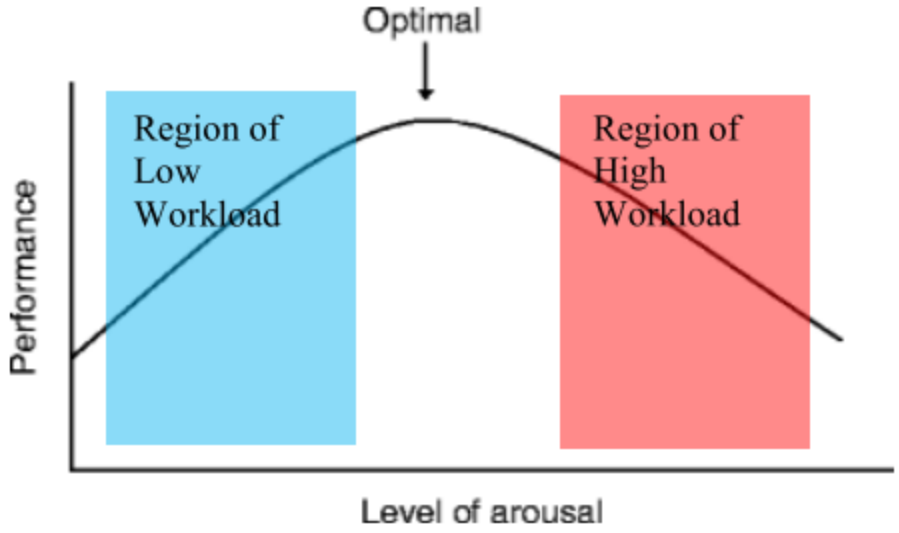
Introduction

- The efficiency and safety of mission operators is highly related to their ability to manage workload
  - Performance may appear equal for novice and skilled operators
- Therefore, we must be able to objectively and non-invasively measure it
  - Self-reported measures may be biased
  - Operators shouldn't be disturbed to measure workload
- Modern physio/neuroimaging gives complementary information

Cognitive Workload

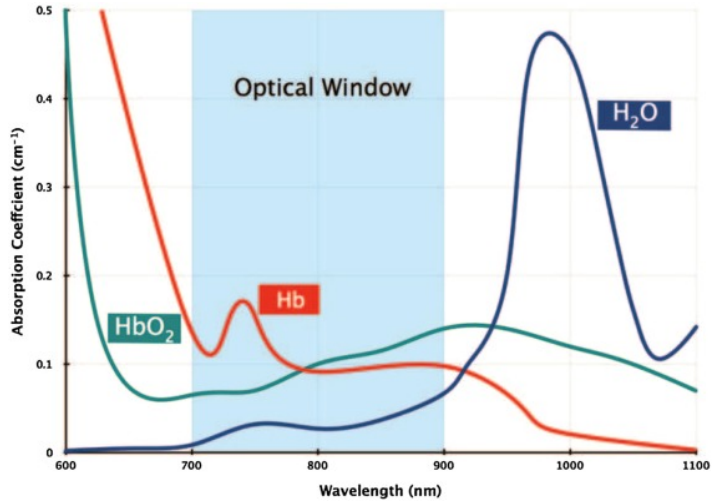
- The proportion of external demands to a performer's internal skill
- Related to working memory, which is limited
  - Cognitive Load Theory states three types:
  - Intrinsic, extraneous, and germane
- Performance is proportional to workload
  - Too low or high workload leads to lower performance
  - Highest learning at peak of curve



Sibi, S., et al. (2016). Monitoring driver cognitive load using functional near infrared spectroscopy in partially autonomous cars. 2016 IEEE Intelligent Vehicles Symposium (IV).

Functional Near-Infrared Spectroscopy

- Oxygenated blood flow correlates with workload
- Measures oxy- and deoxyhemoglobin concentrations in blood
  - Two wavelengths in optical window used (730/850 nm)
- Processed using modified Beer-Lambert Law
- fNIR Devices system used to record
  - 16 optodes over frontal cortex
  - 2 Hz recording rate

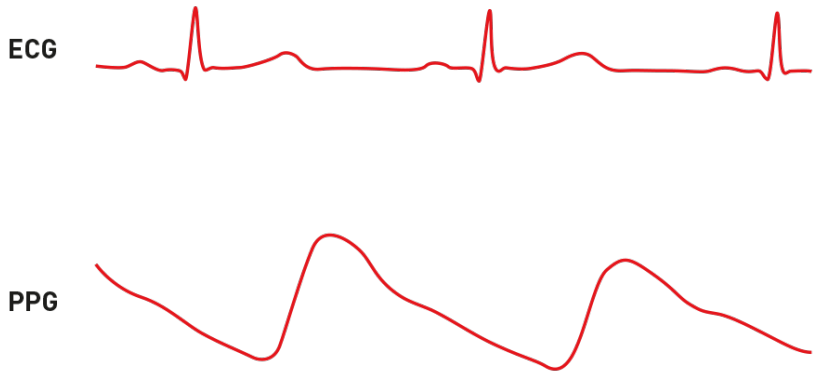


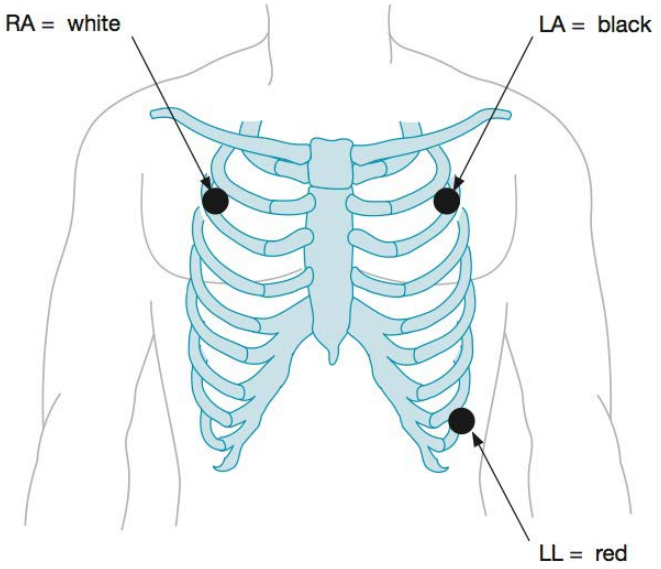
Electroencephalography

- Measures temporally localized neuron electrical activity
- Processed into power bands
  - Delta, theta, alpha, beta from low to high frequency
- Alpha power is correlated with workload
- Cognionics HD-72 dry electrode system used
  - 32 electrodes plus extensions
  - 500 Hz recording rate

Electrocardiogram and Plethysmography

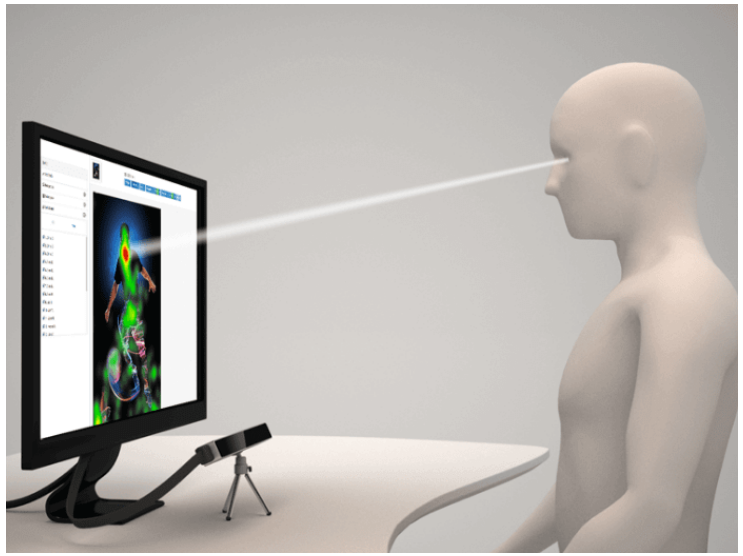
- Heart rate, heart rate variability (HRV), pulse shape affected by workload
- Cognionics HD-72 extensions used to record
  - ECG 3 electrodes placed on chest
  - PPG clip placed on earlobe
  - 500 Hz recording rate





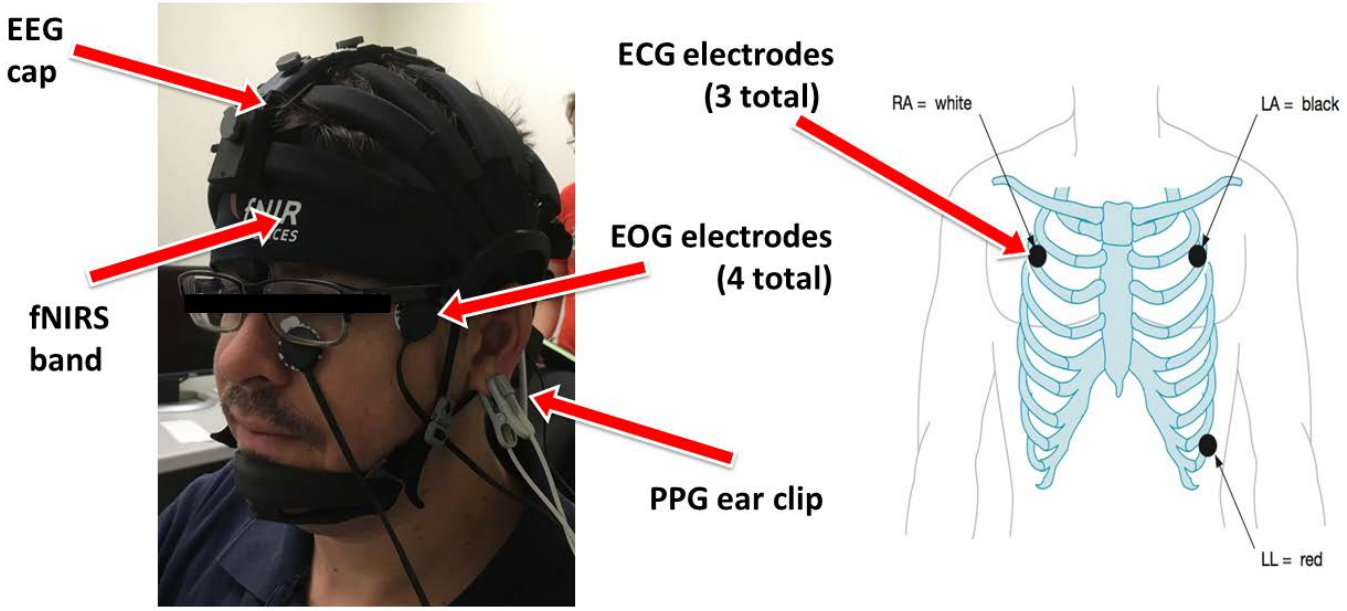
Eye Tracking and Electrooculogram

- Pupil diameter, blinks, saccades, and fixations correlated with workload
- Cognionics HD-72 used to record EOG
  - 2 electrodes above and below eye for up/down
  - 2 electrodes on outside of both eyes for left/right
  - 500 Hz recording rate
- Smart Eye Aurora recorded gaze and pupil information
  - Processed using OGAMA software
  - 60 Hz recording rate



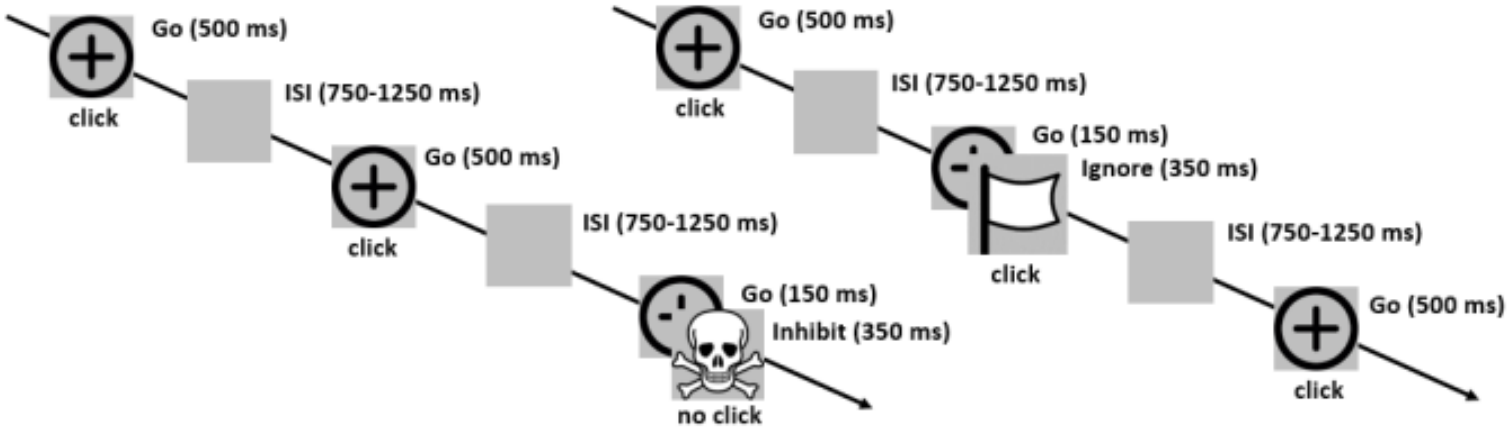
Study Design

- 23 participants (age 18-48, 7 males) recruited for study
- Experiment performed over four sessions, 60-90 minutes
- Six brain and body imaging modalities
- Six tasks targeting different domains of cognition presented to participants
- However, in this presentation:
  - Only inhibitory control
  - Only session 1



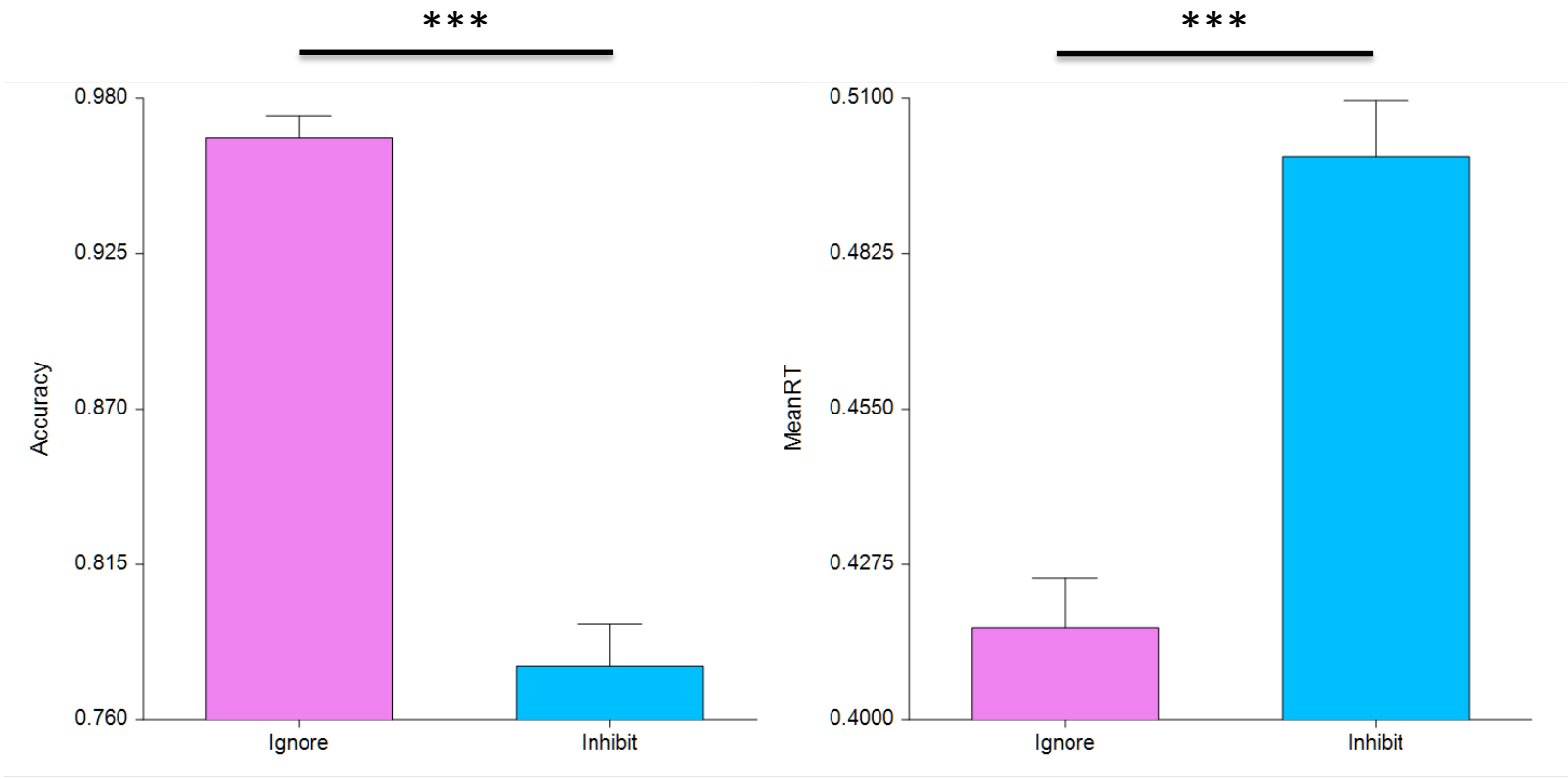
Inhibitory Control Task

- Modified go-stop task to represent reacting to friendly, neutral, and hostile targets
- Participants react to cross stimulus representing “go” (click button)
- One of three possible changes after 150 ms
  - Remains the same (click)
  - Changes to flag (ignore and click)
  - Changes to skull (inhibit and stop)



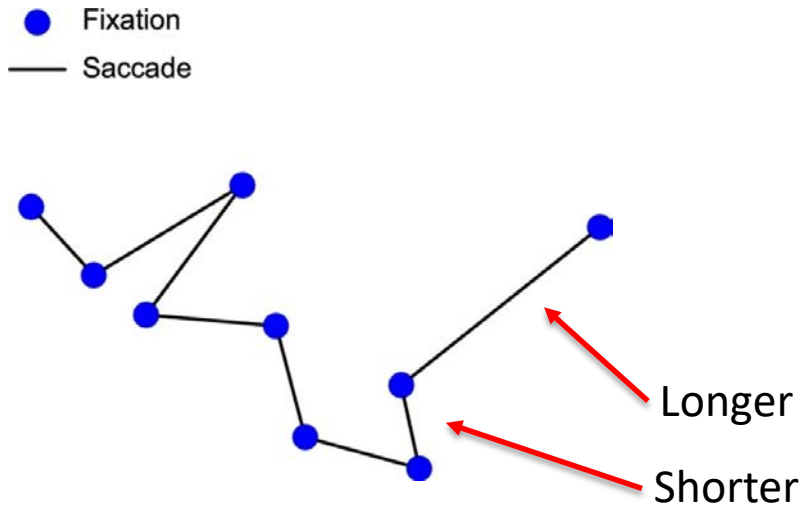
Behavioral Performance Measures

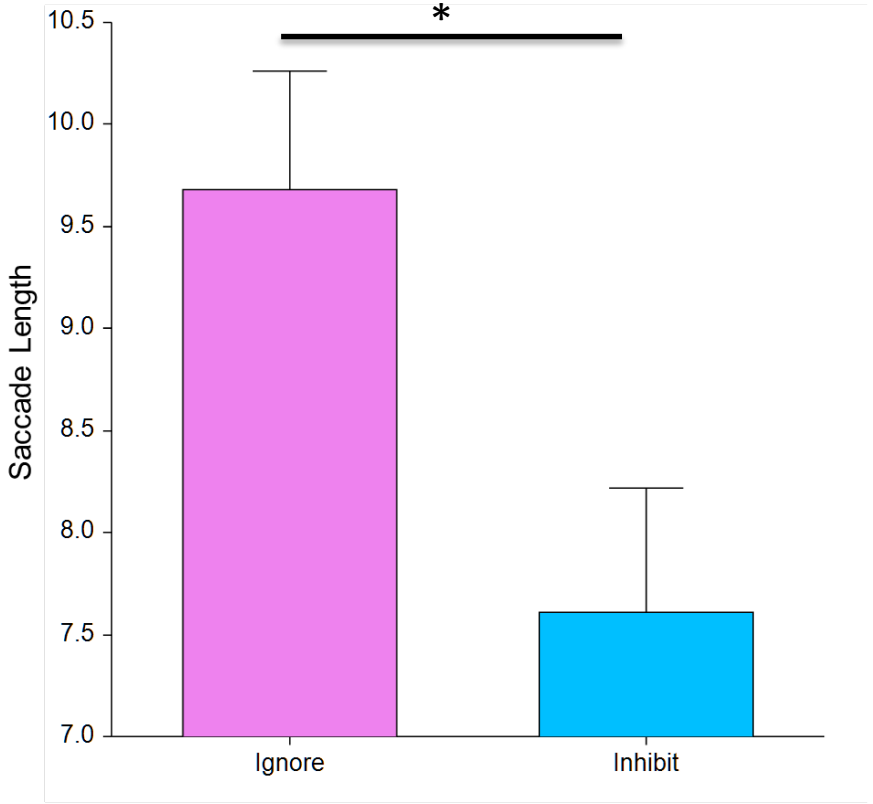
- Hard condition had significantly lower accuracy than easy ($p < 0.001$)
- Mean response time significantly higher for hard condition ($p < 0.001$)



Eye Tracking Measures

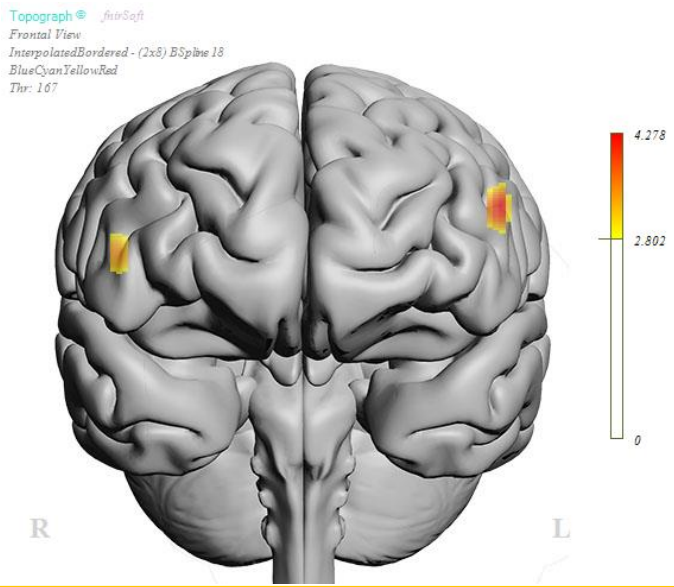
- Shorter saccade lengths are associated with increased workload
- Significantly shorter lengths were found in the hard condition

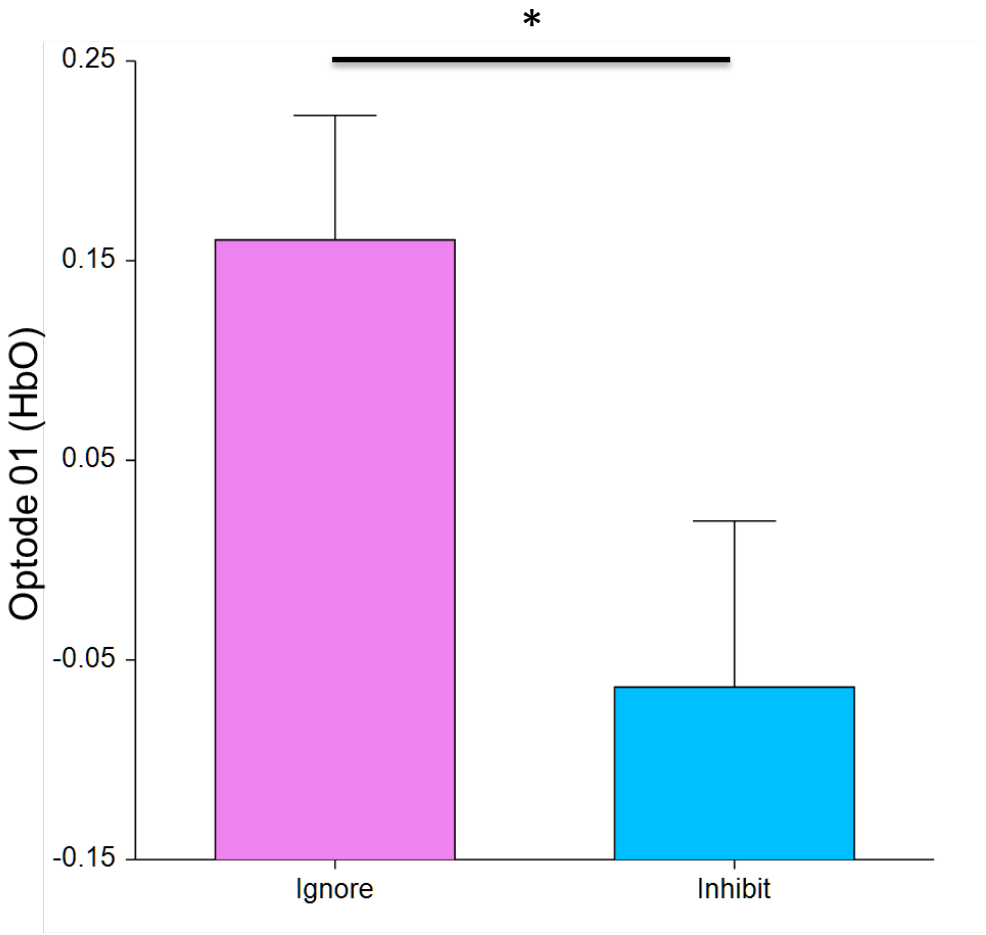




fNIRS Measures

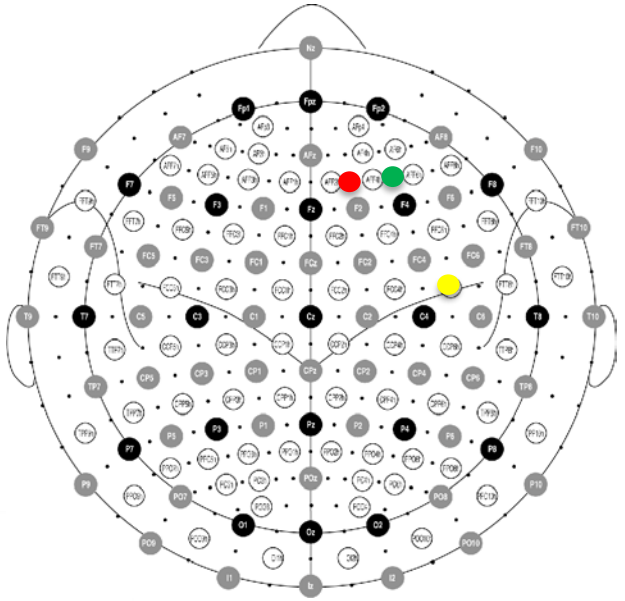
- In optode 1 in the left dorsolateral prefrontal cortex, a significant difference for HbO was found between hard and easy condition ($p < 0.05$)

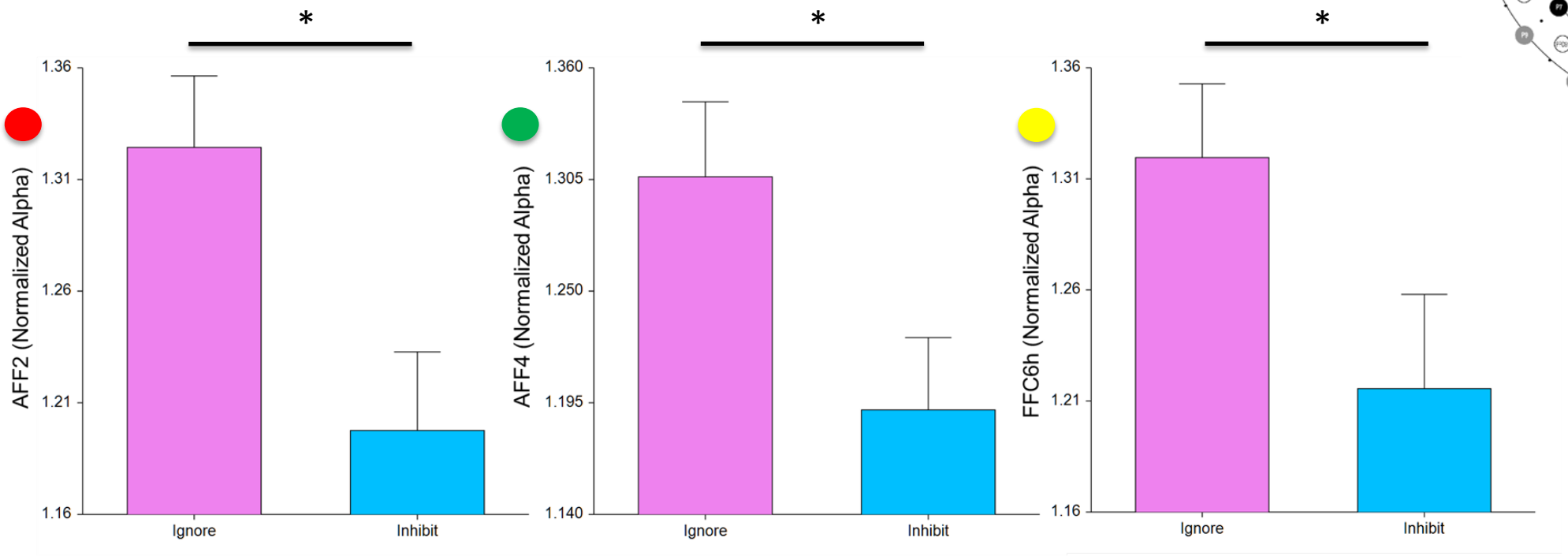




EEG Measures

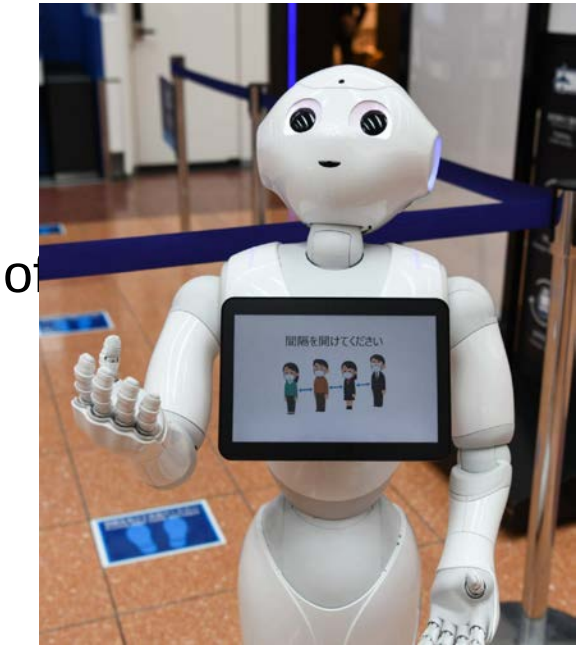
- Alpha power is correlated with mental workload
- Several frontal and right electrodes displayed significant differences at the $p < 0.05$ level





The Road Forward

- Multimodal physiological and neuroimaging provide sensitive measures of task workload, even with a single session
- Analysis of the remaining measures over all sessions will provide highly detailed database for six distinct cognitive domains
- Future applications will be used to dynamically allot tasks between operators to optimize teamwork
- Human-robot interaction as well as synthesis between people and AI will improve with cognitive workload monitoring



Thank you!

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