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Evaluation of Cognitive Function using Time-Domain Optical Neuroimaging

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Background

- Functional near-infrared spectroscopy (fNIRS) is a neuroimaging technique that uses near-infrared light to monitor changes in cortical blood oxygenation as a measure of brain activity [1].
- Recent advancements have enabled time-domain (TD)-fNIRS measurements from which absolute concentrations of oxy- (HbO) and deoxy-hemoglobin (HbR) can be derived.
- A new system with a high-density TD-sensor array in a compact, headset form factor is Kernel Flow (Kernel Inc., Los Angeles, CA) [2].
- We selected eight cognitive tasks with previously studied neural correlates for our experiment.
- **In this study, we utilized these tasks to investigate the neural correlates of cognitive function as measured with Kernel Flow.**

Methods - Experiment

Participants

- 15 healthy volunteers (11 males, mean age 23.33±3.09 years).

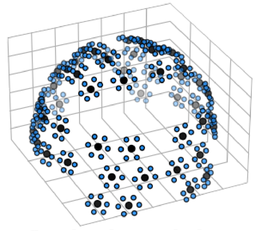
Experimental Protocol

- We conducted an optical brain imaging study to assess the cognitive, behavioral, and physiological responses of participants across eight computerized cognitive tasks.
- Each participant was seated in front of a stimuli presentation computer, fitted with the Kernel Flow headset, a smart watch, and completed the cognitive task blocks in sequence.
- Participant response time and response accuracy to presented stimuli were measured.

Cognitive Task	Domain of Cognition
Audio narrative	Recall, attention, audio processing
Go/no-go	Motor response inhibition
King Devick	Attention and language function
N-back	Working memory
Resting state	Default mode network and resting cortical relationships
Tower of London	Visual problem solving
Video narrative	Recall, attention, audio and video processing
vSAT	Visuospatial sustained attention

Kernel Flow

Experiment setup



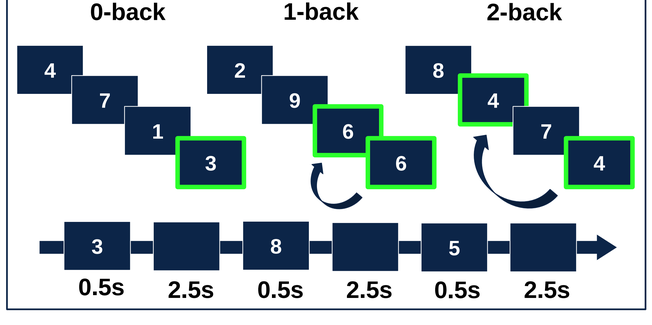
Optical modules

Example experiment

Block 1	Block 2	Block 3
1. Tower of London 2. N-back 3. Video narrative 1	4. vSAT 5. King Devick 6. Audio narrative	7. Resting state 8. Go/no-go 9. Video narrative 2

N-back task

3 trials per condition, 20 stimuli per trial



Methods - Analysis

Data Acquisition
312 TD-fNIRS optodes.
8 cognitive tasks.
Heart rate, temperature, and electrodermal activity.

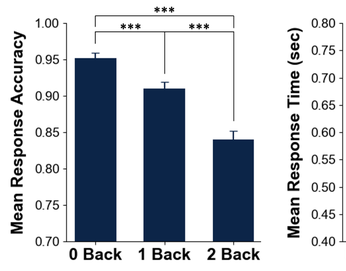
→ **Time-Synchronization**
Time-synchronize the recorded optical, behavioral, and physiological data.

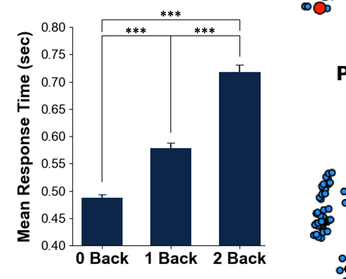
→ **Data Processing**
Compute the HbO changes relative to baseline for each task condition.

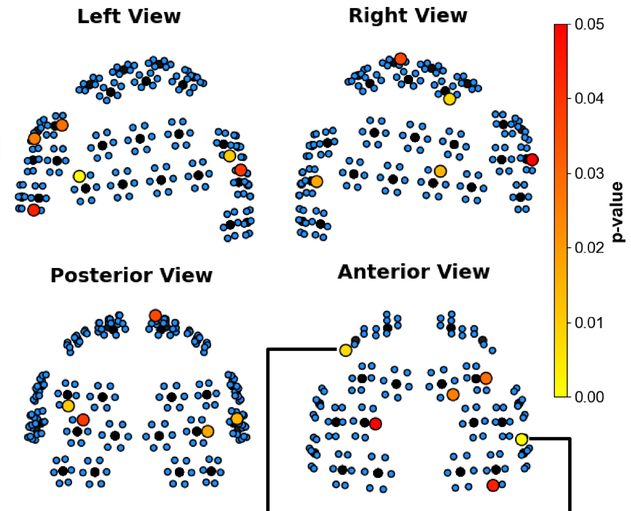
→ **Statistical Analysis**
Nonparametric Friedman test for each optode with task conditions.

Preliminary Results

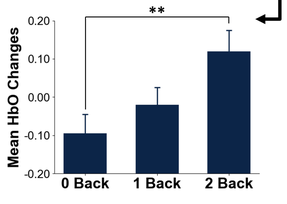
- There is a significant main effect of N-back task difficulty (0-, 1-, and 2-back conditions) for *response time* (F=159.19, p<<0.001) and *response accuracy* (F=33.62, p<<0.001).

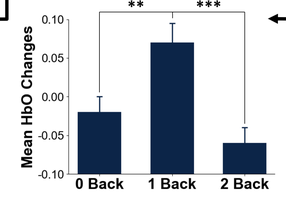






- There is a significant main effect of N-back task difficulty on fNIRS responses at multiple brain areas. Most significant channels (5.16<F<9.44, p<0.01).





** indicates p<0.01
*** indicates p<<0.001

Discussion

- As N-back task difficulty increased, there was an increase in response time and a decrease in response accuracy consistent with prior neuroimaging studies that used this task [3].
- Significant task load level-related differences were observed in dorsolateral prefrontal cortex (DLPFC) oxygenation changes from TD-fNIRS, as expected.
- These are the first results using Kernel Flow TD-fNIRS for a cognitive task experiment.

References

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