NEAR TO THE BRAIN

Functional Near-Infrared Spectroscopy as a Lightweight Brain Imaging Technique for Visualization

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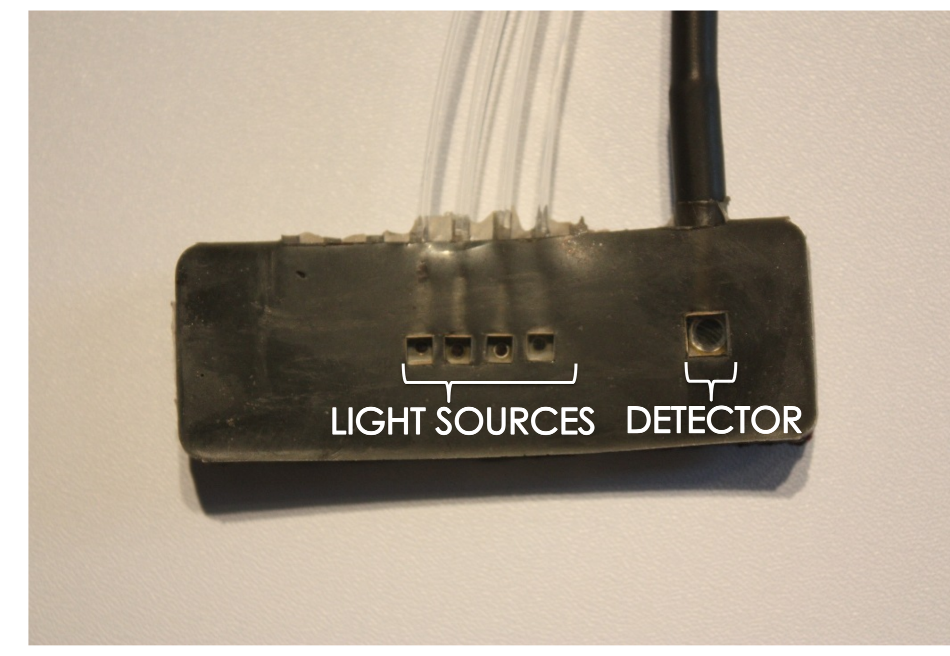
ABSTRACT

In order to better understand the user and visual interface, it is crucial to also understand human cognitive processes. Unfortunately, these processes are traditionally difficult to monitor without the use of cumbersome or expensive brain imaging equipment. In recent years, **functional near-infrared spectroscopy (fNIRS)** has emerged as a brain sensing technique that is both lightweight and easy to set up. We demonstrate the potential of fNIRS to examine current visualization techniques and influence the design of visual interfaces. We present two studies based on previous work in brightness contrast in visual search and angle vs. position comparisons in form. Our results indicate there are significant cognitive differences during visual search tasks of positive and negative contrast polarity. Furthermore, we are able to differentiate between angle and position comparisons under specific experimental conditions. We outline the potential of fNIRS to give objective, continuous, and near real-time feedback of brain activity in future visualization research.

FUNCTIONAL NEAR-INFRARED SPECTROSCOPY (fNIRS)

- *lightweight*
- *non-invasive*
- *easy to set up*
- *portable*
- *robust to movement artifacts*

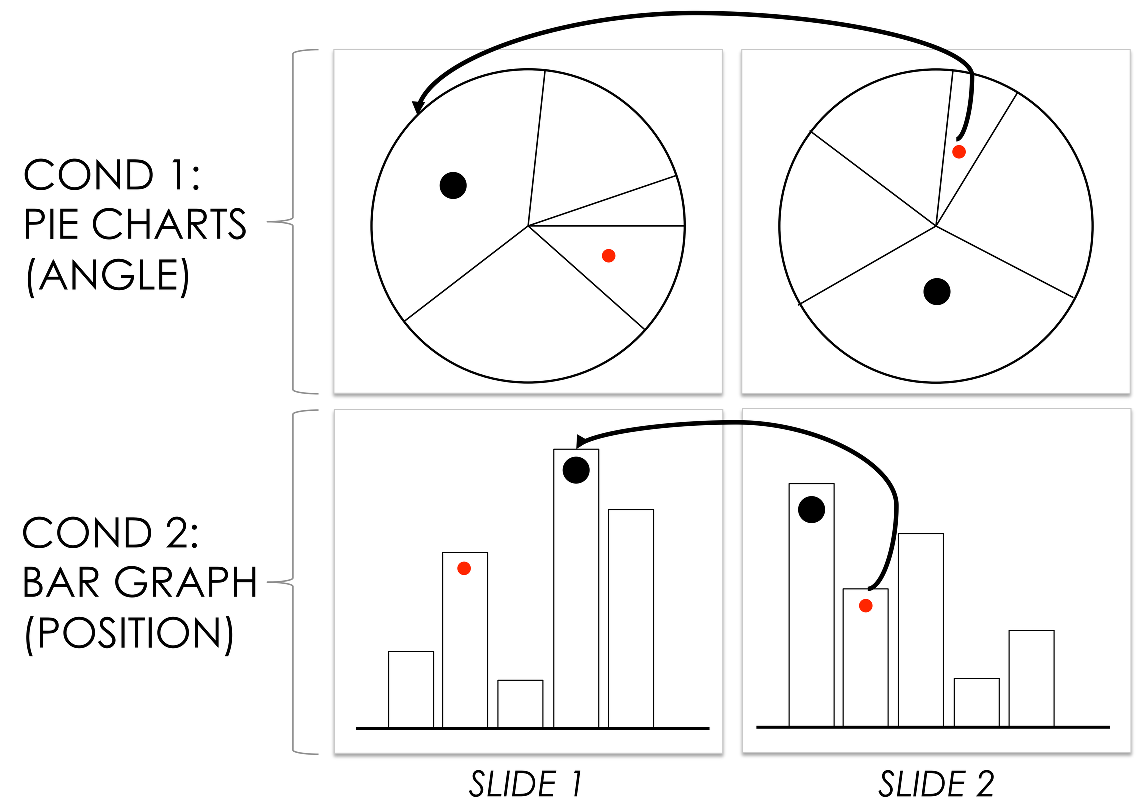


HOW DOES FNIRS WORK?

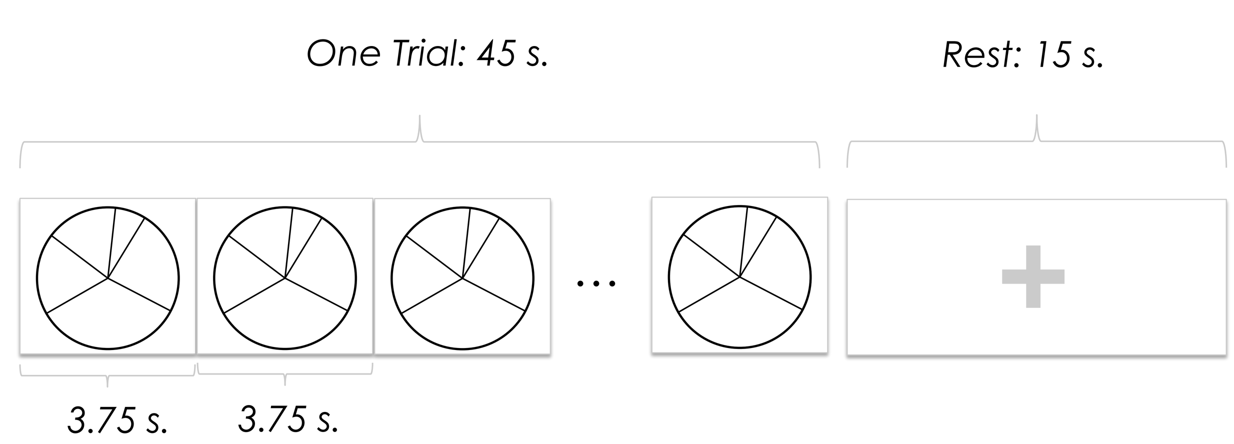
Functional near-infrared spectroscopy (fNIRS)uses light that is injected into the forehead in the near infrared range (650-900nm). At this wavelength, oxygenated and deoxygenated hemoglobin are the primary absorbers of light. By measuring the light returned to the detector, we can calculate the amount of oxygen in the blood (similar to fMRI), as well as the amount of blood in the tissue.

Can we use fNIRS to observe the brain while people interact with visualizations?

EXPERIMENT 1: ANGLE VS. POSITION (CLEVELAND & MCGILL)



EXPERIMENT PROTOCOL

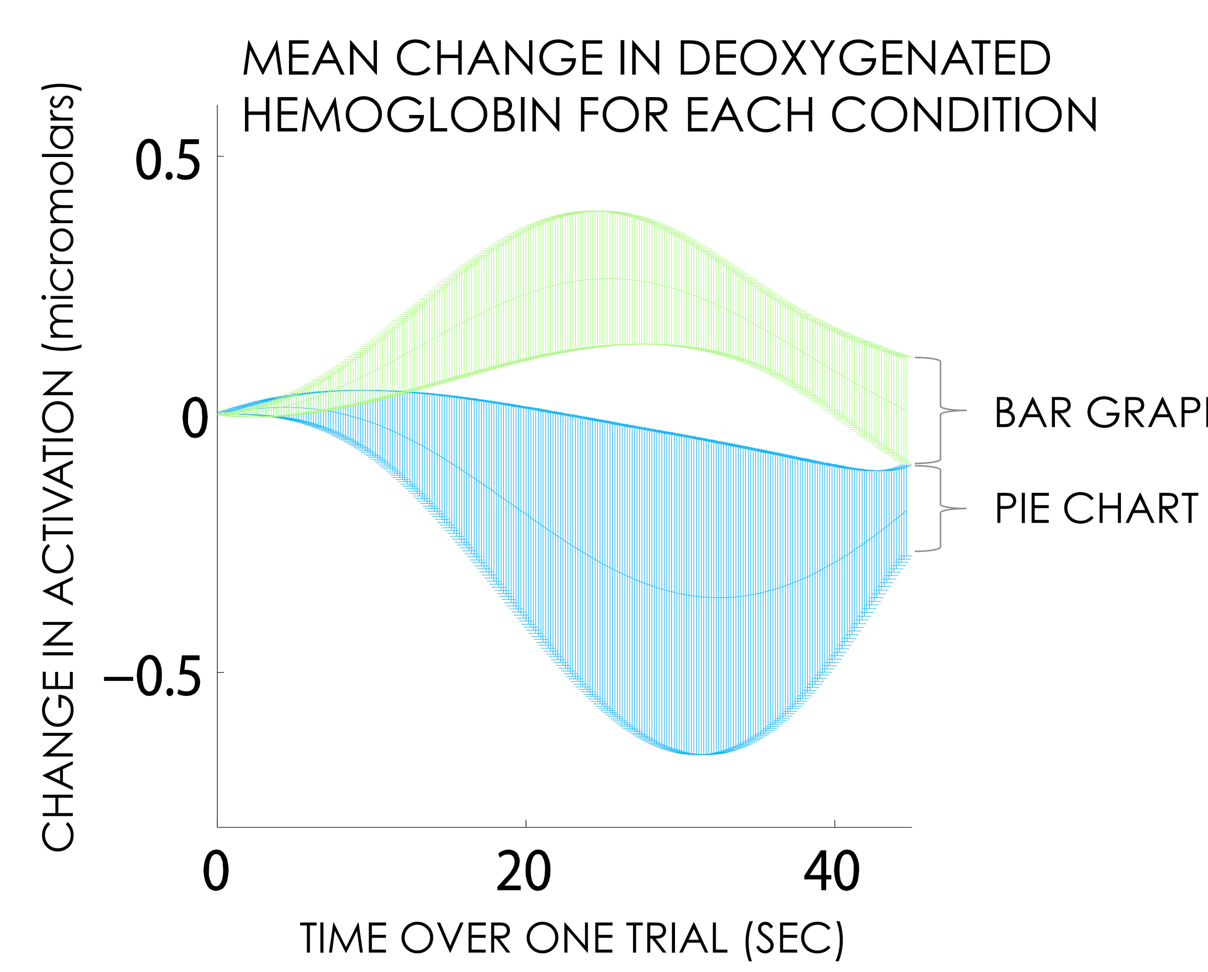


- 12 trials of each condition, displayed in random order
- 3 participants x 12 trials = 36 examples of each condition

HYPOTHESIS:

fNIRS can measure differences in spatial working memory between percentage judgments in bar graphs and in pie charts.

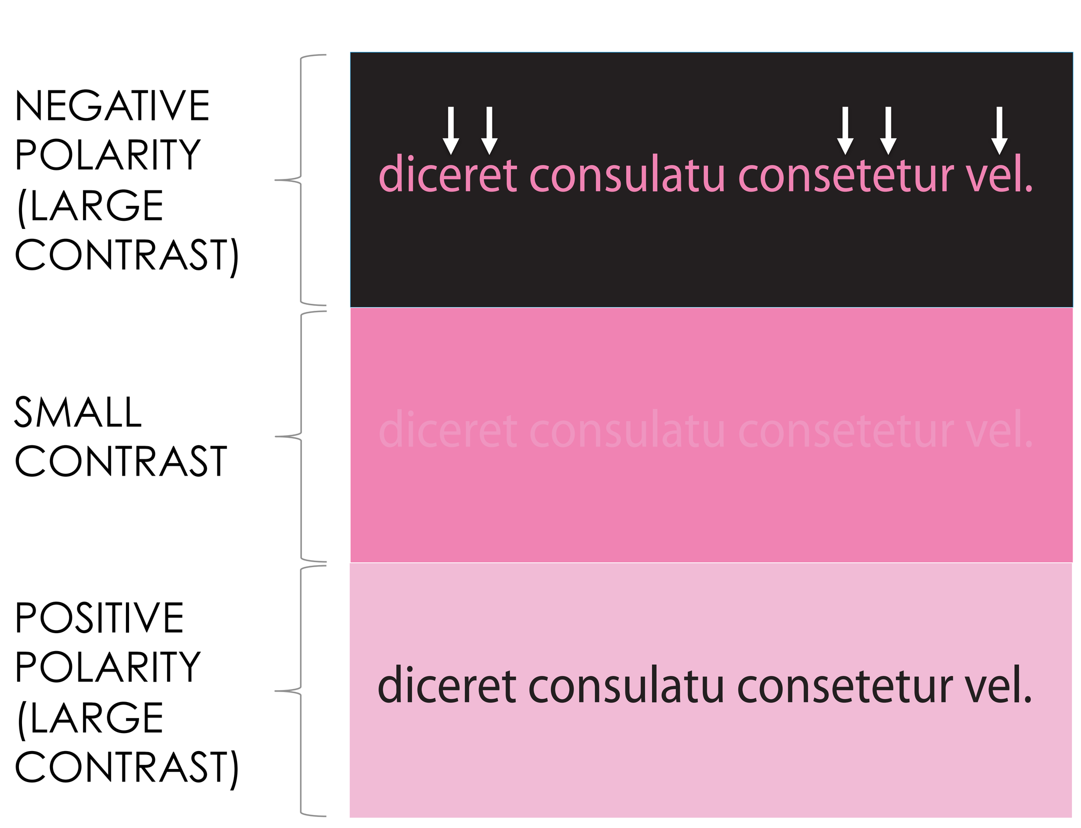
In Cleveland and McGill's classical experiment, participants made percentage judgments between two segments in the same bar graph or pie chart. Our modified version maps the n-back test, a task that induces short-term memory, to angle and position judgments. Instead of comparing segments in the same graph, participants compared a segment in the current graph with a segment in the *previous* graph.



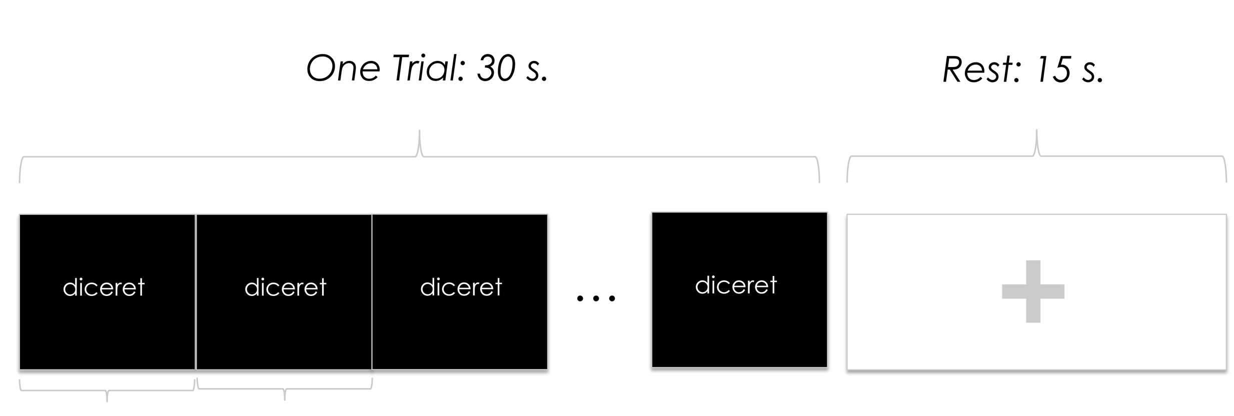
RESULTS:

There are measurable differences in the prefrontal cortex between the two conditions. We believe that similar setups may be used to examine interactions in more complex graphical layouts and forms where behavioral measures may be difficult to extract.

EXPERIMENT 2: VISUAL SEARCH AND BRIGHTNESS CONTRAST



EXPERIMENT PROTOCOL

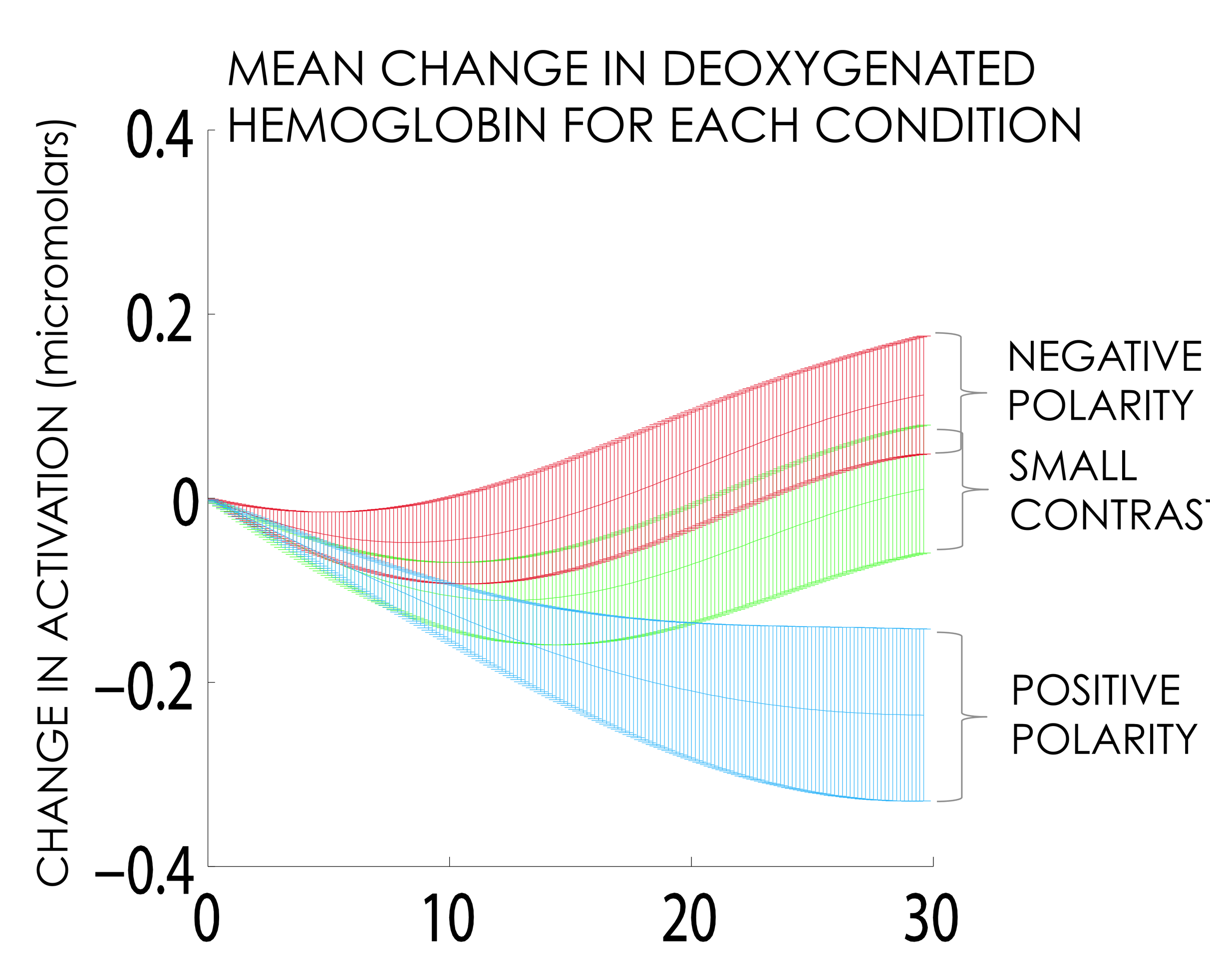


- 10 trials of each condition, displayed in random order
- 13 participants x 10 trials = 130 examples of each condition

HYPOTHESIS:

fNIRS can measure differences in visual search between small and large brightness contrast conditions, as well as positive and negative contrast polarity conditions.

We used a visual search task in which participants searched for occurrences of a character within a body of text. We showed phrases of fixed length on the screen for 3 second intervals, asking participants to press the space bar each time they saw the letter 'e'. By modifying the brightness contrast between the text and the background, we modified the difficulty of the visual search task.



RESULTS:

There are measurable differences in the prefrontal cortex between the three conditions. We believe that this study can be extended to investigate other visualization questions about optimal design for legibility, visual search, and reduction of visual clutter.