Detectable Changes in the Level of Cerebral Activation are Related to Auditory Working Memory Load of the Frontal Lobe: A Functional Near Infrared Spectroscopy Study.

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Introduction

- This study examined the concentration of oxygenated hemoglobin (oxyHb) during the N-Back task, a verbal working memory task, with a functional near infrared spectroscopy system (See Figure 1).
- The N-Back paradigm used here has 4 levels of working memory cognitive load ("0-back," "1-back," "2-back," and "3-back," see Figure 2).
- The relationship between the level of working memory load and hemodynamic response of oxyHb was explored.

Figure 1. Multi-channel Continuous Wave Near Infrared Imager and Helmet

Figure 2. N-Back Paradigm Conditions

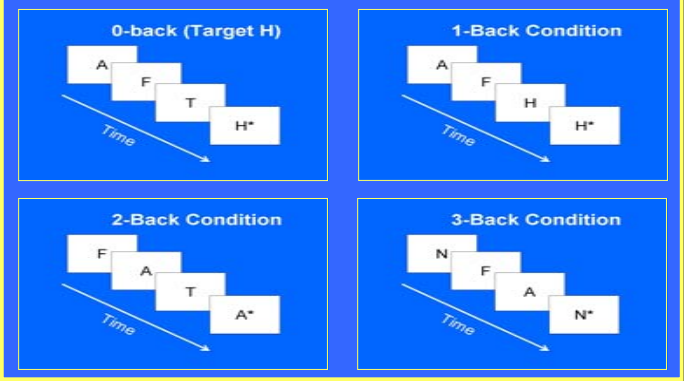
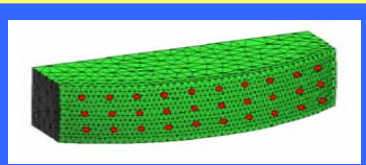


Figure 3. Three dimensional model of source-detector pairs of the frontal lobe.



Methods

Participants

- 9 Right-Handed Healthy Adults
- Age: 30.7 (11.3) years
- Education: 15.9 (2.7) years
- Free of substance abuse and major psychiatric disorders
- No history of neurological disease or trauma

Behavioral Task

N-Back Task

- Consonant letters were presented every three seconds auditorily in 24 second epochs.
- Four Conditions (0-back, 1-back, 2-back, 3-back)
- Each condition randomly presented 3 times

Procedures

Apparatus

- Multi-channel continuous wave near infrared imager (NIRx Medical Technologies; see Figure 2)
- 30 source and 30 detector optodes (900 channels)
- Duel wavelength of near infrared light (760nm and 830nm)
- Optodes placed on forehead 10% above nasion in a 10 cm by 3 cm rectangle configuration, Figure 3.

Data Preprocessing and Analysis

Preprocessing

- Near Infrared Analysis, Visualization and Imaging (NAVI) software (NIRx Medical Technologies, LLC)
  - Low-band pass filter (.15 Hz)
  - 15% mean Coefficients of Variation threshold
  - Oxy-Hb concentration was modeled with a modified Lambert-Beer analysis for each time point in each voxel of modeled space (Figure 3).
  - Data converted to Analyze format

Data Analysis

- AFNI image analysis software
  - Time-series deconvolved for each N-back Condition
  - N-Back conditions compared across participants with t-tests (random effects analysis).
  - Results corrected for multiple comparisons
    - $\alpha = 0.05$, cluster size = 31 contiguous voxels.
- Plots of oxyHb
  - Data baseline corrected over first 7 sec
  - Then averaged across subjects
  - Plots shown at locations of reliable difference

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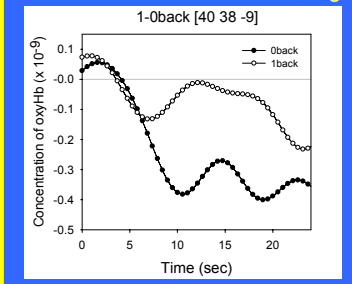
Results

Figure 4. 1-Back Minus 0-Back Tasks

Area of activation: BA 47, Right Middle Frontal Gyrus



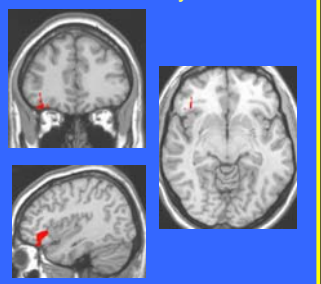
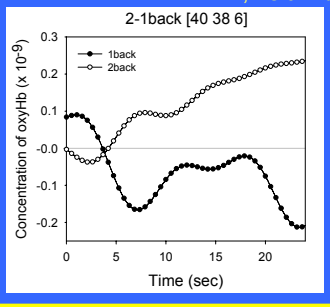


Figure 5. 2-Back Minus 1-Back Conditions

Area of activation: BA 10/46, Right Middle Frontal Gyrus
BA 47, Left Middle Frontal Gyrus.



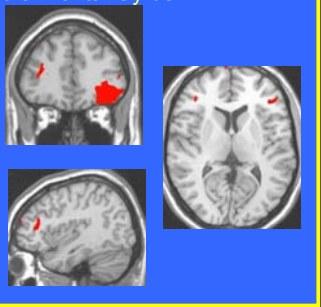
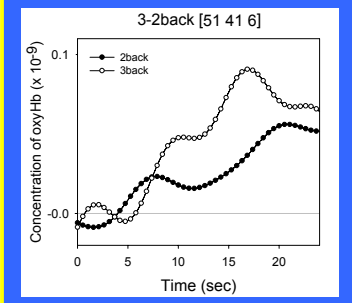
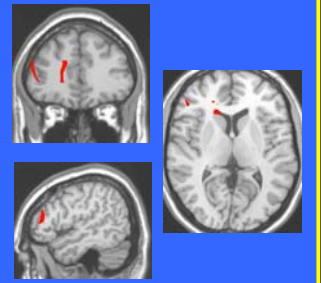


Figure 6. 3-Back Minus 2-Back Conditions

Area of Activation: BA 46, Right Inferior Frontal Gyrus





Conclusions

- Increased oxy-Hb is associated with greater verbal working memory cognitive demand primarily in right ventro-lateral prefrontal cortex (middle/inferior frontal gyrus).