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.

G.T. Voelbel[1,2], J. Lengenfelder[1,2], G. Wylie[1,2], R. L. Barbour[3,4], Y. Pei[3], A. Smith[1], & J. DeLuca[1,2]

[1]Kessler Medical Rehabilitation Research & Education Center, West Orange, NJ [2]University of Medicine and Dentistry of New Jersey
[3]NIRx Medical Technologies [4]SUNY Downstate Medical Center

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.
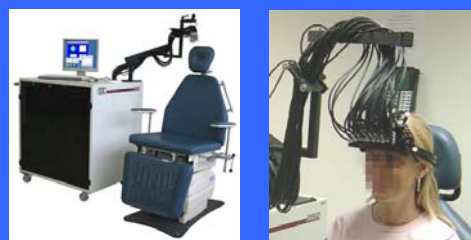Multi-channel
Continuous
Wave Near
Infrared Imager
and Helmet

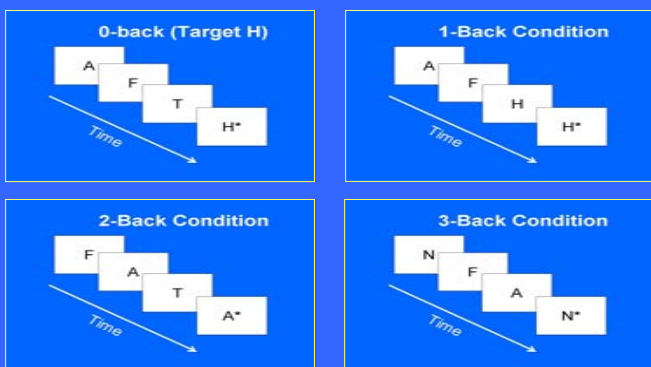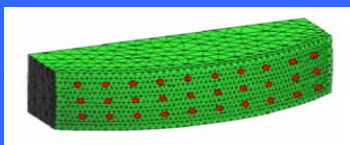Figure 2. N-Back Paradigm Conditions

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

Results

Figure 4. 1-Back Minus 0-Back Tasks
Area of activation: BA 47, Right Middle Frontal Gyrus
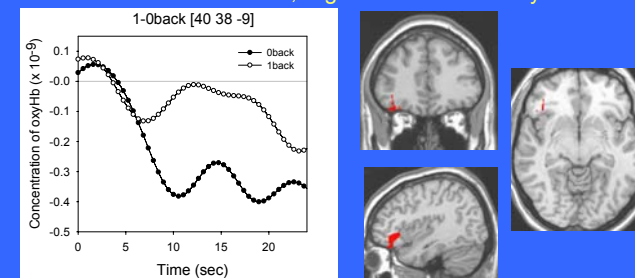

Figure 5. 2-Back Minus 1-Back Conditions
Area of activation: BA 10/46, Right Middle Frontal Gyrus
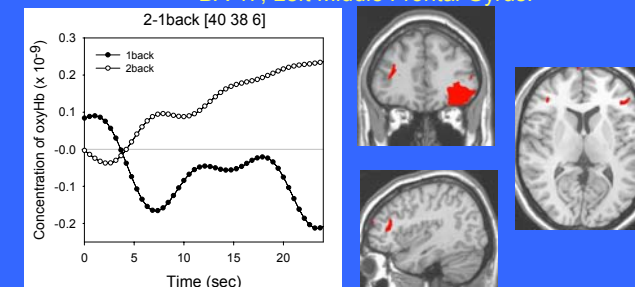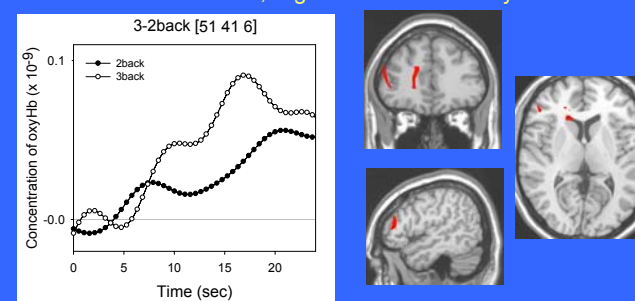BA 47, Left Middle Frontal Gyrus.

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).