

Study Goal:

The purpose of this study was a proof of concept evaluation of a multi-channel fNIRS system with TBI participants. The study investigated cerebral hemodynamics of frontal and temporal activity during a memory and verbal fluency task.

Understanding neuroimaging techniques has become an integral component of the medical speech/language pathologist's practice. Static and dynamic imaging techniques as computer tomography, magnetic resonance imaging, functional magnetic resonance imaging, positron emission tomography, magnetoencephalography have enhanced our knowledge base of brain-behavior relationships. However, these devices are expensive, non-portable, and require that patients endure confining test environments. In contrast, functional near-infrared spectroscopy (fNIRS) is relatively inexpensive, portable, and patients can be tested wearing onto a lightweight headset.

Cognitive-communicative disorders such as decreased short term memory and attention are a typical sequel of traumatic brain injury. fMRI has quantified prominent frontal hypometabolism in diffuse traumatic brain injury (TBI). Working memory, associated with the prefrontal cortex, is a frequent deficit with TBI. The traditional imaging modalities provide spatial resolution, while fNIRS has the potential to provide time-course data that may be useful in the rehabilitation of persons with TBI.

Functional Near-Infrared Spectroscopy (fNIRS)

fNIRS is an optical instrumentation that measures concentration changes of oxygenated and deoxygenated hemoglobin by means of characteristic absorption spectra of the hemoglobin. The Hitachi 4000 optical topography system, used in this study, employs a 16 channel continuous-wave (CW) laser system. Two infrared wavelengths are cycled through the light emitter during the measurement period. Since oxygenated blood absorbs light in different amounts than deoxygenated blood, this change is measured by the different wavelengths. Thus, it is a non-invasive, safe, portable device that allows on-line visualization of neuronal activity and has advantages over current neuroimaging techniques.

Subjects and Methodology:

Eight participants volunteered for this IRB approved study. Four participants had a diagnosis of traumatic brain injury, and four subjects had no history of neurologic damage. The TBI participants were matched to the control participants by age and sex. The four traumatic brain injury participants suffered diffuse injury and had been receiving cognitive-communicative therapy in an out-patient setting.

Two tasks were selected for all participants to perform. The first task was the N-back, a commonly used task to assess working memory. Participants viewed a sequence of single random digits (1-4) on a computer display. Prior to a digit series, participants were instructed to remember the digit that was just seen (0-back) or to remember the digit that was 1-back. Both tasks were repeated. The complexity of the task was limited to 0-1 back due to the cognitive level of the participants.

The second task was a verbal fluency task. The participants were asked to say words that began with the letter “f” for 60s. Subsequently, the participants visually saw words on the computer screen that began with “f” for 60s followed by a second trial of stating words that began with “f”.

The participants were familiarized with the tasks prior to the placement of the headband. During measurement, the headband, consisting of 16 illuminating and detecting light guides arranged at 3 cm. separation, was placed on the scalp to cover the frontal and temporal areas of the brain bilaterally. The detectors evaluated the change in the oxygen level and displayed these to a computer screen. The investigators monitored various graphic representations to observe neuronal changes and to record behavioral responses.

A baseline measurement was taken for two minutes followed by the presentation of the tasks. All tasks were separated by a two minute rest period totaling fNIRS measurement time to 25 minutes. After the experiment, the participants were offered the opportunity to watch the graphic display on the computer screen of the varying levels of oxygenated and deoxygenated blood flow during the experimental tasks and rest periods.

Data Analysis and Results:

The integral data was exported as txt-files and processed by a custom-designed MatLab application. Quantitative analyses were conducted to compare group means of age and sex-matched control participants with those in the TBI group. Group analyses were performed averaging the 0-Back and 1-Back task, aggregate average of N-Back tasks, and the word fluency tasks.

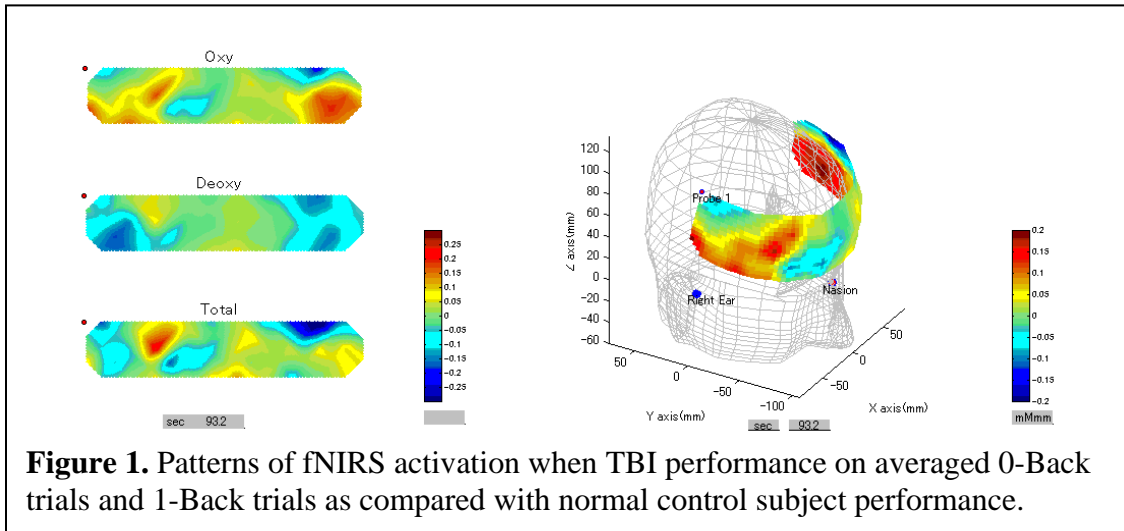
There was a distinctive pattern change when comparing the TBI and normal participants for the 0-Back tasks. The TBI group showed a distinct increase in deoxy-Hb with a simultaneous decrease in oxy-Hb. The control group, however, showed a weak but noticeable activation in the frontal lobe bilaterally. Regarding the 1-Back tasks, there was a similar pattern with an increase deoxy-Hb bilaterally for the TBI group with a contrasting increase in oxy-Hb for the controls in the same area. When subtracting the averaged TBI data from the averaged control data, activation in the temporal areas in both hemispheres was strong.

When comparing group data for the Word Fluency task, there was no significant difference. Both groups showed strong activation in temporal areas bilaterally. However, when TBI data was subtracted from control data, there was a third distinct activation area in the right frontal area.

The technology used in this study was noninvasive and tolerated well by the participants in the study. All participants appeared to tolerate the headband and the tasks well. There were no reported or observed adverse affects.

Discussion:

fNIRS appeared to be a suitable tool for measuring blood oxygenation changes bilaterally in the frontal and temporal areas (Figure 1). General patterns showed greater activation with controls than with impaired populations. The TBI group showed an increase in the deoxy-Hb levels during the N-Back tasks. A similar increase in the deoxy-Hb levels was also noted with some aphasics in a naming task (as reported by Sakatani et al., 1998). This trend needs further investigation.



Conclusion:

Although there are still questions as to transfer function between neural activity and vascular response, this technology was useful in exploring language and memory activated responses of the cerebral blood system and hemodynamics. Plausible explanations for the differing response patterns between the control and impaired groups will be discussed. Future studies intend to compare fNIRS results among other impaired populations such as those with Alzheimer's disease, and to explore the possibility of utilizing this device to monitor treatment effects.