

# Assessments of posttraumatic stress disorder by functional near infrared spectroscopy: A preliminary report

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**Abstract:** Post-traumatic stress disorders (PTSD) affect up to 20% of service members in the global war on terror. We use a portable multi-channel fNIRS device to assess student veterans with PTSD; preliminary results are reported.

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**OCIS codes:** (170.1610) Clinical applications; (170.2655) Functional monitoring and imaging; (170.4580) Optical diagnostics for medicine;

## 1. Introduction

Post-traumatic stress disorder (PTSD) is a common neuropsychiatric disorder that can develop after exposure to any traumatic event, resulting in psychological trauma. The estimated lifetime prevalence of PTSD is 7.8% among adult Americans [1], and it is elevated in vulnerable populations. The traumas most commonly associated with PTSD are combat exposure and witnessing among men, as well as rape and sexual molestation among women. Numerous studies have reported the presence of cognitive dysfunction associated with PTSD, including memory impairments, attention deficits and dysexecutive syndromes. While various rehabilitation interventions are utilized to treat patients with PTSD, there is a lack of portable and reliable neuroimaging technique to assess the effectiveness of interventions and to monitor long-term recovery, with particular attention to restoration of highly cognitive functions. The use of functional MRI (fMRI) is often limited by the medical cost, body confinement and availability of the facility.

Combat-related PTSD affects up to 20 percent of service members in the global war on terror and is often persistent in their return to civilian life. Veterans' educational benefits are the largest federal program for student financial aid in America, and are important incentives to join the U.S. military service under the All Voluntary Force (AVF). As of 2009, more than 270,000 veterans who served in Iraq and Afghanistan wars had enrolled in colleges. At UT Arlington, veteran enrollment reached 1,128 in spring 2011, more than double the number two years ago. For the veterans with neuropsychiatric symptoms or disorders, however, this compensatory mechanism may be difficult or impossible to utilize fully in the absence of special support and protective mechanisms [2]. Thus, supported education interventions are provided by School of Social Work at UT Arlington to address the needs of these student veterans who are mainly from North Texas community.

Functional near infrared spectroscopy (fNIRS) has gone through several stages of hardware and software developments in the past decade and now is ready for its possible and optimal usage in the clinical environment. It becomes well accepted that fNIRS can reliably detect a variety of cortical activities with good sensitivity. Compared with other neuroimaging modalities, such as fMRI, fNIRS has advantages of being compact, low-cost, and easy to implement. In an exploratory study, we have used a portable, multi-channel fNIRS system to assess a group of student veterans with PTSD and co-morbidities who are involved in the supported education interventions. Their frontal cortex activations in response to three neuropsychological tests are measured and compared with those in healthy controls. While the short-term goal of this study is to evaluate the potential neurocognitive improvements in these student veterans along with supported education interventions, we also aim to prove the feasibility of fNIRS as a tool for therapeutic evaluation and guidance in a generalized population with PTSD.

## 2. Methods

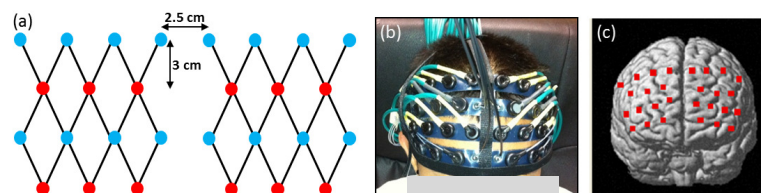


Fig. 1. The optical probe array and placement: (a) Geometry of the array in which red filled circles represent sources and blue filled circles represent detectors, (b) probe array placement on a subject's head, and (c) co-registered optodes' positions on an anatomical MRI of the brain.

## 2.1 Instrument

A high-density fNIRS system (Cephalogics LLC.) was used to scan the frontal cortex of the human subjects. The probe consisted of 12 source fibers and 16 detector fibers (TechEn Inc.), which mainly covered the dorsolateral (BA9) and anterior (BA10) regions.

## 2.2 Protocols

Three neuropsychological tests were developed to assess the cognitive functions in student veterans with PTSD. All of these tests were identified to elicit distinct activations in the frontal cortex. Also, these protocols have been approved by IRB of the University of Texas at Arlington.

**Digit forward and backward:** The digit forward and backward trials assess working memory, which is composed of component processes involved in encoding, maintaining, and recall memories [3]. Both trials started from a series of 6 digits that were presented sequentially on a LCD monitor (one digit per second). Then a blank screen was displayed for 10 seconds, at which time the subjects were required to look at the screen and covertly rehearse the digits continuously. After this retention interval, a key pad was displayed and the subjects were instructed to recall the digits either in a forward or a backward order by clicking the key pad, followed by a 10-second rest. Same type of task was repeated 8 times (i.e., 8 blocks) in each trial to attain an averaged hemodynamic response.

**Pro- and anti- saccades:** The saccadic tasks assess functions related to quick eye movements and inhibition process. Both trials started from a dark-green cross displayed at the center of a LCD monitor, which the subjects were instructed to stare at. Then a red spot (target) was presented on one horizontal side of the monitor for half second and then vanished. In pro-saccade, the subjects were instructed to stare at or follow the target quickly till it vanished. In anti-saccade, the subjects were instructed to voluntarily move eyes to the opposite direction. The target appeared 8 times per block, followed by a 25-second rest. Each trial consisted of 8 blocks. The pro-saccade is a relatively reflexive saccade, whereas in anti-saccade the reflexive process is inhibited. Activation attributed to inhibition was attained by subtracting the hemodynamic response in pro-saccade from that in anti-saccade.

**Stroop test:** A classical Stroop test includes three trials, and we employed trials 1 and 2 only. Trial 1 is a congruent task in which names of colors were presented in black color on top of a LCD monitor. The subjects were instructed to press one of two buttons given to make a name-to-name match. Trial 2 is an incongruent task that comprises a conflict between a color word name and its color, thus creating interference between word reading and color naming. The subjects were instructed to press one of the two buttons to match the word color on top of the screen to the color name on bottom of the screen. Each trial consisted of 8 blocks, 5 tasks per block. Activation attributed to the interference was attained by subtracting the hemodynamic response in trial 1 from that in trial 2.

## 3. Results

We have measured 8 student veterans with PTSD (8 males) prior to the supported education interventions and 12 healthy controls (11 males and 1 female). One Vietnam combat veteran (55 years) had severe memory impairments and failed to complete the digit forward and backward test. Therefore, we excluded his data from group analysis. Other veterans with PTSD had very close behavioral scores (in terms of accuracy and reaction time) to the controls.

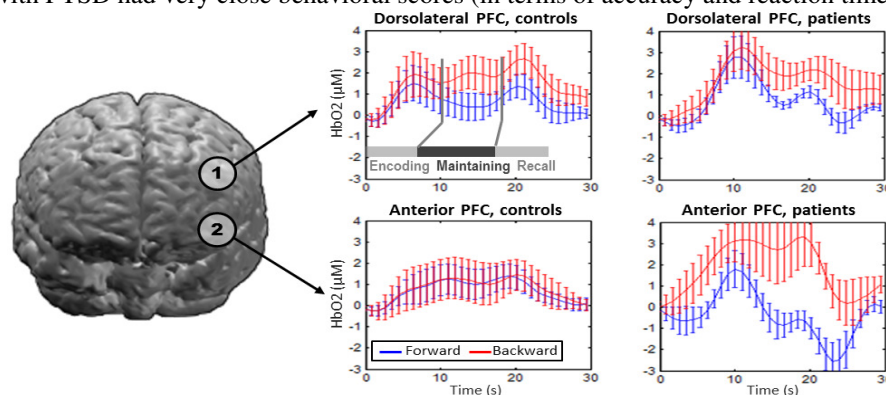


Fig. 2. Group-averaged [HbO<sub>2</sub>] changes (N=12 for controls and N=7 for veteran patients) in response to digit forward and backward tasks that are measured at left dorsolateral and left anterior frontal regions. Two groups show distinct response patterns at the left anterior frontal cortex.

**Digit forward and backward:** As shown in Fig. 2, we have observed clear 3-phasic patterns at the dorsolateral frontal cortex (BA 9) modulated by the encoding, maintaining and recall stages, for which the difference between control group and veteran group is insignificant. The 3-phasic pattern agrees well with the previous literatures [3]. However, the two groups show distinct response patterns at the anterior frontal cortex (BA 10). In this region, the

control group has slight and consistent activations in both the forward and backward trials. In the veteran group, the anterior response seems to be modulated by the level of difficulty: the forward trial shows little activation or even temporary deactivations whereas the backward trial shows great activation. The difference between the two groups in the anterior frontal region can be seen more clearly in an image-wise comparison, as shown in Fig. 3.

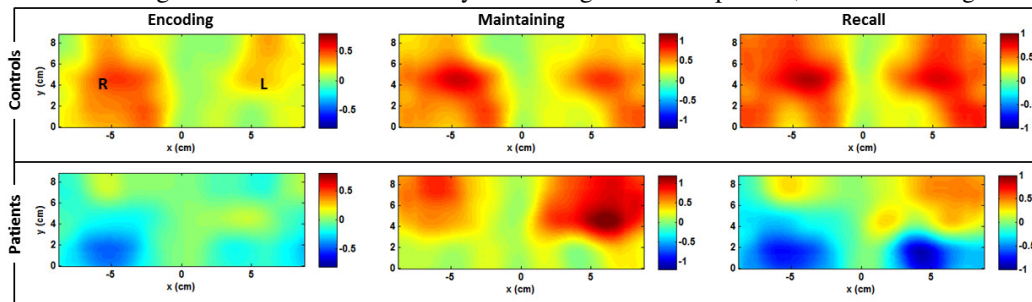


Fig. 3. Distinct activation patterns ( $\Delta[\text{HbO}_2]$ , in  $\mu\text{M}$ ) between healthy controls (top,  $N=12$ ) and veterans with PTSD (bottom,  $N=7$ ) during digit forward task. Images are averaged within each group. During the encoding and recall stages, veteran patients show deactivations in the anterior frontal cortex (BA10), which is significantly different to the healthy controls ( $p < 0.05$  during encoding stage and  $p < 0.02$  during recall stage).

**Pro- and anti- saccades:** In the control group, the anti-saccade leads to higher activation than the pro-saccade as a result of inhibition process. The difference is mainly at the right dorsolateral and right anterior cortices, as demonstrated in left panel of Fig. 4. In sharp contrast, the veteran group shows even less activation in the anti-saccade than the pro-saccade, which may indicate a failure of inhibition in this population. This conjecture needs to be further confirmed because we have observed significant individual variations.

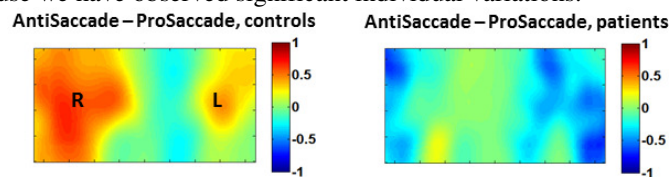


Fig. 4. Distinct activation patterns ( $\Delta[\text{HbO}_2]$ , in  $\mu\text{M}$ ) between healthy controls (left,  $N=12$ ) and veterans with PTSD (right,  $N=7$ ) during saccade tests. The control group shows activation in the right dorsolateral area (BA9) as an effect of inhibition process (Saccade2 – Saccade1), whereas the patient group shows slight deactivations in both left and right dorsolateral areas (BA9).

**Stroop test:** In the control group, the difference between congruent and incongruent trials demonstrated clear activation at the left dorsolateral region, very close to the inferior frontal gyrus, due to the interference. The image is shown in the left panel of Fig. 5. In the veteran group, the difference between congruent and incongruent trials is much less, which is shown in the right panel of Fig. 5.

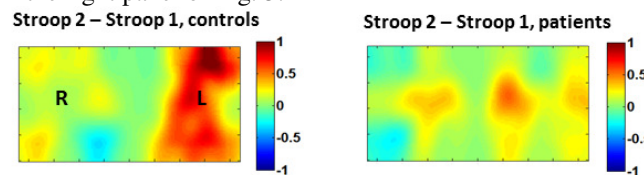


Fig. 5. Distinct activation patterns ( $\Delta[\text{HbO}_2]$ , in  $\mu\text{M}$ ) between healthy controls (left,  $N=12$ ) and veterans with PTSD (right,  $N=7$ ) during Stroop tests. The control group shows clear activation in the left dorsolateral area (BA9) as an effect of interference (Stroop2 – Stroop1), whereas the patient group shows little changes.

### 3. Discussions

The preliminary results have demonstrated quite different functionalities of veterans with PTSD at the frontal cortex, prior to the interventions, as compared with healthy controls. These results provide a strong support to the overall goal of this study, which is to evaluate the potential neurocognitive improvements in student veterans with PTSD along supported education interventions. We have also identified several factors for improved protocols that may have significant impacts on the results, such as the level of difficulty in digit tasks. To minimize the potential bias in the results, an expanded data collection from healthy student veterans is also planned.

### 4. References

- [1] R.C. Kessler, A. Sonnega, E. Bromet, M. Hughes, C.B. Nelson, "Posttraumatic stress disorder in the national comorbidity survey," *Arch Gen Psychiatry* **52**, 1048-1060 (1995)
- [2] A. Smith-Osborne, "Mental health risk factors and protective mechanisms for post-secondary educational attainment among young adult veterans," *Dissertation Abstracts International* **67(09)**, 3594A (2006).
- [3] X. Sun, X. Zhang, X. Chen, P. Zhang, M. Bao, D. Zhang, J. Chen, S. He, X. Hu, "Age-dependent brain activation during forward and backward digit recall revealed by fMRI," *Neuroimage* **26(1)**, 36-47 (2005).