Is Functional Near Infrared Spectroscopy (fNIRS) Appropriate for your Research?

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Functional near infrared spectroscopy (fNIRS) is an emerging neuroimaging technique that has found home in various human factors and ergonomics applications. Why fNIRS? Is it better than EEG or fMRI? Is it an appropriate neuroimaging technique for my research/application? What are the methodological considerations for fNIRS analyses? This panel discussion is aimed at answering these questions, among others, when panelists from varied human factors and ergonomics applications discuss how they employ fNIRS in their investigations.

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INTRODUCTION

Functional near infrared spectroscopy (fNIRS) fNIRS measures is an emerging non-invasive optical technique for measuring cerebral hemodynamic changes similar to Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI) but with lower spatial resolution. By utilizing the neurovascular coupling between neuronal activity and regional cerebral blood flow, fNIRS measures regional cerebral hemodynamic changes (i.e., changes in oxy- and deoxy-hemoglobin levels). fNIRS is portable, inexpensive, and has shown to be an effective tool in quantifying cognitive workload (Ayaz et al., 2012) and cortical activation during static and dynamic motor movements, without causing substantial movement artifact issues. This panel will discuss the methodological considerations for fNIRS research in aviation, physical ergonomics, and mobile applications.

Introduction and Methodological Considerations with fNIRS

(Presenter: Hasan Ayaz, Drexel University, Philadelphia, PA; University of Pennsylvania, Philadelphia, PA)

Functional near infrared spectroscopy (fNIRS) is a noninvasive, safe and portable optical neuroimaging method that can be used to assess brain dynamics during skill acquisition and performance of complex work and everyday tasks. Originally developed for clinical monitoring of tissue oxygenation, fNIRS evolved into a useful research tool for neuroimaging starting as early as 1980s. The technology since then has advanced significantly including improvements made in sensor hardware, signal processing algorithms and software for data acquisition and analyses. This has enabled localized brain activation measurements with wearable mobile capabilities at relatively low cost systems. This talk will discuss current capabilities, limitations and opportunities with fNIRS neuroimaging in neuroergonomics applications.

fNIRS Applications in Physical Ergonomics

(Presenter: Ranjana K Mehta, Texas A&M University, College Station, TX)

Ergonomics has long since moved from being a science of improving work efficiency to now being focused on enhancing well-being while improving systems performance. The primary goal of ergonomics is to ensure that work demands are always lower than operator capacity, and the conventional assessment of physical work demands include measuring biomechanical and physiological outcomes, such as joint torque, muscle activity, and heart rate, in laboratory and field settings (Mehta and Agnew, 2012). To effectively understand how humans interact with work systems, it is not only important to ask how well they perform, but also *why* they perform a certain way. Neuroergonomics, the study of brain and behavior at work, can fill in the gaps on the neural bases of both physical and cognitive performance that were left unanswered with traditional ergonomic assessments. While neuroergonomic approaches in understanding cognitive functioning during work is gaining wide popularity (Ayaz et al., 2012; Mehta, Shortz, and Benden, 2015), assessing neural correlates of physical work capacity has received little attention (Mehta and Parasuraman, 2014). Like any new field, physical neuroergonomics research first needs to understand the capabilities, limitations, and considerations of existing neuroimaging techniques on simulated work environments that can help build the knowledge base necessary to perform research in naturalistic work environments (Mehta and Parasuraman, 2013). fNIRS techniques for neuroergonomics research that has expanded our understanding of the neural correlates of operators' physical capabilities and limitations when they interact with work systems will be discussed (Mehta, 2016). Specifically, application of functional near infrared spectroscopy (fNIRS) to measure cortical activity associated with neuromuscular function will be covered (Mehta and Shortz, 2014).

Use of Functional Near Infrared Spectroscopy in Aviation - Training and Workload Assessment for Safe Piloting
(Presenter: Kurtulus Izzetoglu, Drexel University, Philadelphia, PA)

A wearable optical brain imaging device can provide airman's cognitive state and relative level of expertise for a given level of performance. Drexel University's Optical Brain Imaging team has developed a functional near-infrared spectroscopy (fNIRS) technology applicable to assessing human performance in military and civilian aviation operations. The fNIRS is a field deployable monitoring system that quantifies cortical activation-related hemodynamic changes under various naturalistic conditions. fNIRS has been already deployed for objective measure of cognitive state and level of expertise, which allows for dynamic interventions in the training process, and helps to assure robust performance under adverse circumstances. The audience will be introduced to the use of fNIRS in aviation, including manned and unmanned pilot training, and air traffic controller workload assessment.

Modernization of the National Airspace System: fNIRS to assess changes in workload with the introduction of the Next Generation Air Transportation System
(Presenter: Ben Willems, Atlantic City International Airport, Federal Aviation Administration William J. Hughes Technical Center, NJ, USA)

The National Airspace System (NAS) of the United States is undergoing an extensive modernization under the Next Generation Air Transportation System (NextGen). For several decades, the human computer interface (HCI) formats, automated functions, and procedures in the NAS remained unchanged. Because of that consistency, operators in the NAS were able to overlearn their job-related tasks to the extent that a high level of automaticity set in. This has allowed United States air traffic controllers and pilots to create and maintain the safest aviation system in the world. The introduction of radically new HCI formats, automated functions, and procedures will affect controller and pilot workload, situation awareness (SA), and efficiency. Our task as researchers is to ensure that these changes the impact on the operators in the NAS will limit the levels of workload, SA, and efficiency to ensure a continued safe and efficient operation of the NAS.
Aviation researchers often rely on feedback from subject matter experts (SMEs) to convey the impact of a change in HCI formats, automated functions, and procedures on their perceived workload. Some research techniques will use post-scenario evaluation of the workload while others focus on collecting real-time workload assessment during activities within a scenario. The NASA Task Load Index (TLX) is one example of the former approach. The NASA TLX asks participants to rate a scenario of six different aspects of workload after the fact. Techniques such as the Air Traffic Workload Input Technique (ATWIT) and the Instantaneous Subjective Assessment (ISA) are examples of the latter. ATWIT and ISA query participants during the scenario about their overall workload at the time of the query.
The disadvantage of any of these subjective workload assessment techniques is that they all have the inherent assumption that participants will be able to compare their workload experienced under the new conditions with that experienced in the past. Some of the change in HCI formats, automated functions, and procedures that NextGen will make it difficult for SMEs to provide subjective feedback, because they have not experienced working with these new capabilities in the past. To address this issue, we continue to search for objective measures of workload such as physiological measures. We have been able to successfully use one physiological measure, the functional Infra-Red Spectography (fNIRS) measure of oxygenation, that is easily applicable in the aviation domain. During one of our experiments we found that real-time subjective workload ratings did not coincide with the objective fNIRS measure of oxygenation. We will discuss the reasons for this discrepancy as well as the challenges of interpreting fNIRS results under high task load conditions.

Wireless Mobile Functional Near Infrared Spectroscopy
(Presenter: Ryan McKendrick, M.A., George Mason University, Fairfax, VA)

Mobile and wearable computing devices will change the nature of work and how we study it. Wireless mobile functional near infrared spectroscopy (mfNIRS) is a powerful tool for answering the new research questions that will arise from increased mobility during work. mfNIRS is currently being used to examine the effects of environment, physical workload and the interactions between environment, physical workload and cognitive workload. It is also being used to assess product usability via comparing measures of mental workload, situation awareness and usage strategies between mobile devices such as smart phones and smart glasses. As the robustness of mfNIRS improves it could be used in future military, sport and work research that is intractable with other tools of neurophysiological assessment.

Bringing Neuroscience out of the Lab and into Complex Realistic Environments
(Presenter: Matthias Ziegler, Advanced Technologies Laboratories, Lockheed Martin, USA)

Neuroscience research has provided us with detailed knowledge of how the brain works and task specific workload levels, however much of this work has been done in controlled laboratory environments using specially developed tasks designed to elicit a response in the brain region being measured. Research into complex tasks and realistic environments creates many challenges. The ease of use and signal durability of Functional Near Infrared Spectroscopy (fNIRS) make it a useful tool in this transition into complex realistic environments. Using fNIRS we have been able to obtain changing workload measurements during flight simulator experiments by implementing multiple cognitive tasks with varied complexity: from simple tasks adapted for flight domain (n-back, situational awareness, etc.) to complicated flight related tasks that simultaneously test multiple cognitive functions (flight maneuvers and landing tasks). fNIRS may allow the next step moving from the complex task environment to realistic noisy settings, such as a cockpit.

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