Brain Sensing with fNIRS in the Car

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ABSTRACT

We propose using functional near-infrared spectroscopy (fNIRS) to measure brain activity during driving tasks. Functional NIRS is a relatively new brain sensing technology that is portable and non-invasive, making it possible to sense brain activity in environments that would not be possible using most traditional imaging techniques. This provides us with the opportunity to better understand changes in cognitive state during mobile tasks, such as driving. Our research aims to integrate fNIRS into an existing driving test bed and explore signal processing and classification algorithms to study the sensitivity of fNIRS brain sensing to changes in the driver's workload level in real-time.

Categories and Subject Descriptors

H.1.2 [**User/Machine Systems**]: Human factors

General Terms

Human Factors.

Keywords

Brain sensing; Driving; fNIRS; Physiological computing.

1. INTRODUCTION

Drivers have numerous demands and distractions while navigating the vehicle, both on the road as well as from people and technology within the vehicle. As new interfaces and technologies are introduced into vehicles, it is critical to assess the cognitive workload that the driver is experiencing to ensure safe operation of the vehicle. An understanding of the changing cognitive state of a driver in real-time can inform the design of in-vehicle interfaces.

Recent work has looked at measuring physiological signals such as heart rate, respiration and skin conductance [5]. Functional near-infrared spectroscopy (Figure 1) [1,11] recently has been used in human-computer interaction research to assess cognitive states in real-time during tasks on a computer [2,7,8,9]. Because fNIRS is portable and non-invasive, it has potential for use in a car, and a few studies have taken steps in this direction [3,6,10]. In addition, it may offer complementary information to other sensors.

In our work, we are integrating fNIRS sensing with other physiological and environmental sensors. With this, we can study whether fNIRS has promise as an assessment method for in-vehicle tasks. Specifically, we are investigating the sensitivity of fNIRS to working memory demands, using an established task called the n-back task.

2. FNIRS BACKGROUND

Functional near-infrared spectroscopy provides a measure of oxygenated and deoxygenated blood in the cortex. Light of near-

infrared wavelengths is sent into the brain cortex where it scatters and some is absorbed by the oxygenated and deoxygenated hemoglobin in that area of the brain. A sensitive light detector can determine the intensity of the light that returns back to the surface of the head. This raw light intensity value can be used to calculate the oxygenation in the blood, which also indicates brain activity in that area.

3. EXPERIMENTS

We plan to study working memory demands that come from secondary tasks while driving. While there is a wide range of secondary tasks that a driver may perform, we will use the n-back task, which has established capacity for eliciting scaled levels of working memory demand [4,5]. This serves as a proxy for various secondary tasks that a driver may perform. Our experiments will be conducted using a driving simulation environment equipped with fNIRS. The fNIRS data will be analyzed to determine whether there are patterns in the data that correlate with varying levels of working memory demands. We have the simulation and fNIRS system in place, and we are making the final preparations for running the studies.

3.1 Simulation Environment

The driving simulator consists of a fixed-base, full-cab Volkswagen New Beetle situated in front of an 8×8ft projection screen (Figure 2). Participants have an approximately 40-degree view of a virtual environment at a resolution of 1024×768 pixels. Graphical updates to the virtual world are computed by using Systems Technology Inc. STISIM Drive and STISIM Open Module based upon a driver's interaction with the wheel, brake, and accelerator. Additional feedback to the driver is provided through the wheel's force feedback system and auditory cues. Custom data acquisition software supports time-based triggering of visual and auditory stimuli and is used to present prerecorded instructions and items for the cognitive task while subjects are in the simulator.

3.2 fNIRS Setup

The fNIRS device in the vehicle is a multichannel frequency domain OxiplexTS from ISS Inc. (Champaign, IL). Two probes will be placed on the forehead to measure the two hemispheres of the anterior prefrontal cortex (Figure 1). The source-detector distanc-

Figure 1. Two fNIRS sensors (right) are attached under a headband (left). There are four near-infrared light sources and a light detector on each sensor.
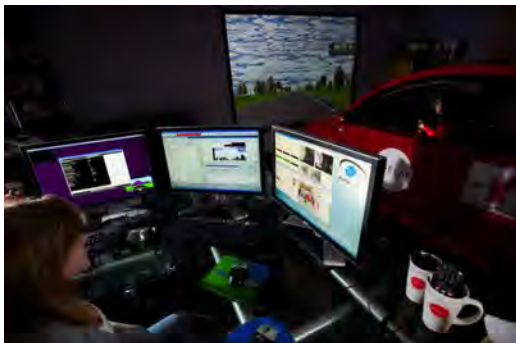
Figure 2. Driving simulation environment. The participants sit in the red car (shown in the back, right) and are instrumented with fNIRS and other physiological sensors (EKG, skin conductance). The screen in the front presents the simulated driving environment.

es are 1.5, 2, 2.5, and 3cm. Each distance measures a different depth in the cortex. Each source emits two near-infrared wavelengths (690 nm and 830 nm) to detect and differentiate between oxygenated and deoxygenated hemoglobin. The sampling rate is 6.25 Hz.

3.3 Driving Task and Secondary Task

The initial feasibility experiments will follow a protocol similar to that described in [4]. Participants will sit in the car and drive in the simulated environment. While driving, they will receive auditory prompts to perform "n-back" tasks of varying difficulty levels. In each task, a series of single-digit numbers (0-9) are presented aurally in random order. The participant must respond to each new number presentation by saying out loud the number n-positions back in the sequence. For a 0-back, the participant simply responds with the current number. At the 1-back difficulty level, they respond with the number one position back in the sequence. The more difficult 2-back requires recalling and responding with the number 2 positions back in the sequence.

4. DISCUSSION

This initial study will determine the feasibility of measuring fNIRS signals during driving tasks. Our goal in analyzing the fNIRS data will be to determine whether there are features in the signal that help to accurately classify the driver's working memory demand. We will develop analysis methods and techniques suitable for such tasks, as well as techniques for combining fNIRS with other sensors to get a more reliable classification of working memory demand. Future studies will expand this work to more realistic tasks, and to real-time assessment, if the feasibility study shows promise.

This research will allow us to examine the working memory demands of new interfaces being introduced to vehicles and could be used during design stages of such interfaces. In addition, as vehicles become more functional and autonomous, it will be increasingly important to understand the real-time cognitive state of the driver so that the vehicle can adapt to the user's state in real time.

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