The Dashboard: Building an Interface for Analyzing and Visualizing Brain Signals

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ABSTRACT
Human-computer interaction research has steadily been incorporating brain signals to supplement physiological signals during data collection. In order to interpret the brain signals, researchers must be able to analyze and visualize the raw data. However, the currently available tools to analyze raw brain sensor data are limited, hindering research that requires brain signals. The intention of the Dashboard Project is to provide a tool that automatically processes and analyzes brain data for the researcher, speeding up and simplifying the process of interpreting results. The Dashboard was created with a focus on functional near-infrared spectroscopy (fNIRS) data, but will eventually be applied to other sensors in addition to fNIRS, making brain signal input more accessible during research regardless what type of brain sensor is used.

Author Keywords
Brain-computer interface; brain signals; brain sensors; functional near-infrared spectroscopy; fNIRS.

ACM Classification Keywords
General Terms: Human Factors, Measurement, Performance.

INTRODUCTION
During human-computer interaction research, physiological measurements, (e.g. measurements of time, heart rate, skin conductance, etc.) can be enhanced using supplemental brain data. Neuroimaging techniques such as functional near-infrared spectroscopy (fNIRS) have increasingly been used to provide insight on the operation of participants' brains. We focus on fNIRS for this study, as it is portable, noninvasive, low-cost, and has relatively little background noise disturbing the data readings. This makes it an optimal tool for studies that require somewhat mobile participants.

In order to interpret any brain sensor output, the researcher must be able to analyze and interpret the raw data. The few tools that have previously been developed for this purpose fail to provide an easy-to-use interface that automatically analyzes and intuitively displays raw brain data. The development of The Dashboard introduces a tool that automatically processes, analyzes, and visualizes raw brain sensor data. The Dashboard interface is built using correct software development principles, so that the program is intuitive and easy for the user to operate. While initially created with a focus on fNIRS, the tool will be extended to include data from other sensors, increasing the accessibility of brain signals as supplemental data in HCI research.

Background on fNIRS
The Dashboard development focused on data collected from functional near-infrared spectroscopy (fNIRS). A type of neuroimaging technology, fNIRS is portable, noninvasive, and provides relatively little background noise in its readings. Each piece of machinery is equipped with fiber-optic probes that send infrared light into the brain, at wavelengths of 690 and 830 nanometers. The light scatters in the targeted area of the brain, exits, and is measured by detectors on the fNIRS tool. However, some of the infrared light is absorbed by the oxygen in the blood in that area of the brain before it exits. From this, we can figure out the amount of oxygenated and deoxygenated blood in that part of the brain, which can be used to estimate brain activity.

Current Applications
Drexel's Advanced Interactions Research (AIR) Lab has two currently ongoing studies that exemplify the importance of brain signal use and an interface to analyze the data. Both use the fNIRS brain sensor. The first deals with changes in cognitive state while driving. Because fNIRS is portable, maintaining relatively little background noise, the subject wearing it can perform tasks without compromising the brain data. Therefore, fNIRS is a convenient tool for measuring the cognitive state of participants driving or simulating driving. In this study, participants are presented with tasks to perform while driving, and changes in their brain activity are recorded. The results of this study are critical, as they provide insight on the cognitive workload of drivers to ensure that the vehicle is driven safely.

The second study is looking into intelligent tutoring systems, particularly to improve STEM education. Through the use of fNIRS technology, the lab can better grasp whether a student is actually learning the material. Currently, the only measurements that are used to determine this are number of questions gotten correct, time it takes to answer a question, whether the participant asked for a hint and how long they waited before asking for one, etc. By including brain data, the lab can gain a clearer image of how deeply the participant is learning, and whether or not they are attempting to "cheat" the system (ex. by immediately asking for a hint without attempting the project).

The research process can be simplified and move much more quickly if the analysis of the necessary brain data is mechanized. The Dashboard will provide that service for the researcher, allowing efficient interpretation of brain sensor results.

RELATED WORK

Working with brain sensors is becoming more common, but is still a relatively new advancement in the field of HCI. Regardless, prior studies exist, both in using fNIRS in the field, as well as regarding potential interfaces for the brain data collected from such sensors.

fNIRS Research

As the use of fNIRS, as well as other neuroimaging devices, becomes increasingly common, techniques for their use must be developed. Erin Solovey presents such guidelines in the paper "Designing Implicit Interfaces for Physiological Computing: Guidelines and Lessons Learned Using fNIRS." Through case studies, she was able to determine the conditions suitable for fNIRS results. Motion can disrupt brain sensor data, but the fNIRS device has comparatively little background noise, and it was found that typing and mouse-clicking provide very little interference with readings (5). In another of her studies, "Using fNIRS Brain Sensing in Realistic HCI Settings: Experiments and Guidelines," the usability of fNIRS during research was investigated further. It was found that eye movement and blinking additionally did not create too much interference in the fNIRS readings, and that minor head movements, respiration and heartbeat, ambient light, and ambient noise could be corrected for in order prevent data corruption (9). This opens up fNIRS sensors to studies where the participant must manipulate a computer to complete a task.

Solovey reaffirmed that incorporating passive fNIRS data is invaluable, as it allows for a second view of the user's cognitive state, particularly when the user is unable to accurately identify it explicitly ("Designing Implicit Interfaces", 22). Furthermore, the use of real-time analysis allows the data to be in tune with the user, and for the machinery to react to user behavior more appropriately ("Designing Implicit Interfaces", 23). Such findings have directed our work with the Dashboard project.

Brain-Computer Interfaces

Technology that acts as an interface between the brain and computer is scarce; the Dashboard is a needed tool. There do exist other such projects, with similar goals. FlyLoop emerged very recently to address the increased use of wearable brain sensors. FlyLoop aims to be accessible to researchers so that they can minimize the amount of engineering the have to do themselves in order to interpret brain sensor data (Peck, 5). The development of FlyLoop includes easily understandable language for its operation, improving its usability (Peck, 6). These features of this particular technology are valuable assets that have been taken into consideration during the creation of the Dashboard. Peck also described long-term goals of the FlyLoop tool in his study, which have helped forge the direction of the Dashboard's development. Once such goal to broaden the use of wearable brain sensors in the HCI field by creating a tool that makes their use practical and efficient (6). We have built the Dashboard with the same vision in mind concerning the role of brain data in HCI research.

SYSTEM DESCRIPTION

The raw data from brain sensors is channeled directly to a text file as it is being collected during research. At the end of data collection, the researcher has an assortment of files containing all of the raw data that needs to be analyzed.

The Dashboard operates by first launching an application allowing the user to create a project. The user must specify the location of the directory containing the raw brain sensor data, as well as the location of the stimulus file, which contains information about when each participant was exposed to a particular stimulus. This file is important, as it allows the Dashboard user to see how each participant responded to a given stimulus once the data is analyzed. The user must also give the specifications and credentials to an appropriate database where the data can be stored.

Creating a new project first runs a file that parses the raw data text files and the stimulus file, reading, organizing, and entering the data into the given database. This is the current development stage of the Dashboard.

The information in the database will be accessed by scripts that analyze the raw data, and connect it to the Dashboard interface, creating visual representations of the analyzed information. The point at which a new stimulus was administered is labeled.

The user has the ability to select which subject's data to view. The user will also be able to view physiological data, such as skin conductance and heart rate. These additional components will be addressed in future stages of development.

DISCUSSION

Focusing on physiological signals when conducting HCI research fails to depict a full picture of how a participant is responding to a stimulus. The use of brain sensors to provide the additional brain signal data offers invaluable new insight on participants' cognitive processes. A tool that computerizes the process of interpreting brain signals makes the use of this supplemental data accessible and practical, improving results without slowing down the process.

Brain Sensors in HCI Research

Neuroimaging technology has steadily been changing HCI research with the development of portable, affordable brain sensor tools such as fNIRS. Prior to incorporating brain signals in studies, researchers had only physiological signals as indicators of how the brain responded to stimuli. These are easily measurable, and can provide explicit data regarding the user's cognitive state. However, they do not provide a complete picture. Participants can monitor their own cognitive states and record them to a researcher in many situations, but that data is not always reliable. Often, users cannot accurately determine their own state, or are unable to communicate it appropriately or at all. In these instances, brain sensors are necessary, supplemental means of collecting passive, implicit data.

The Dashboard as a Brain-Computer Interface

While brain signals provide valuable insight, the process of incorporating the data is currently a tedious one. There are very few tools that can be used to analyze brain sensor data, particularly tools that can be applied to a variety of sensors. Without an efficient brain-computer interface, the process of analyzing the brain data becomes what should be an unnecessary step in the research process. The creation of the Dashboard will eliminate this step, allowing for the use of brain data in HCI research without significantly slowing down the research.

CONCLUSIONS

The inclusion of brain signals in data collection is the current direction of HCI research, but requires proper support if it is going to become practical for widespread, general use. One of the primary obstacles to using brain sensor data in research is the inefficient process of transforming the raw data into interpretable results. The lack of existing tools that perform this task forces researchers to accept a lengthier research process if they want to include brain data in their conclusions. The Dashboard is a necessary tool for the advancement of the field, as it prevents researchers from having to make the tradeoff of time for the use of brain data.

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When the Dashboard is finished, it will provide researchers with the ability to efficiently integrate brain signals into their studies, better allowing for advancements in HCI research.

FUTURE WORK

Many additional developments still need to be made to the Dashboard tool. Once an interface that appropriately displays fNIRS data is completed, there are two major features that can be developed to further HCI research.

Real-Time Analysis

The current Dashboard requires that the researcher perform analysis after the completion of data collection. Only once all the raw data has been saved in an assortment of text files can the user analyze the fNIRS output with the Dashboard. Future work on the Dashboard could focus on real-time analysis, where the Dashboard is able to analyze and graphically display the sensor's output while the data is being collected. Including this feature would speed up the process of brain data analysis even further than the Dashboard already does.

Extension Beyond fNIRS

The Dashboard, as it is now built, acts on the assumption that the researcher is using fNIRS to collect brain data. It is currently being used solely for fNIRS data analysis, but should eventually support a variety of brain sensors that may be used to conduct HCI research. The code used to parse the raw data text files are specific to fNIRS output. A Dashboard that supports a host of brain sensors would include an option to let the user specify the brain sensor type, indicating which parsing algorithm should be used. Research governing other types of brain sensors should be the future direction of the Dashboard project once it has been completed as an interface for fNIRS data.