Using Brain-Computer Interfaces to Analyze EEG Data for Safety Improvement

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Abstract | Brain-computer interfaces (BCIs) deliver commands using electroencephalographic (EEG) activity or other electro-physiological measures of brain function. In this paper, we use EEG signals to collect important information about the states of a subject. Vigilance states are particularly important in this project. Drowsiness is a well-known safety issue for operators who must stay alert consistently for long periods of time. The objective of the present work was to record EEG data of individuals using a single-channel active dry electrode system. The hardware used in this work are the NeuroSky Mindwave, Mindset and Myndplay, three commercially available noninvasive BCI headsets. Raw data are presented and compared among the devices.

Keywords | Safety; Brain-computer interface (BCI); Fatigue; single-channel EEG; Dry sensors

1 Introduction

Society relies upon 24-hour operations or shiftwork in industries such as transportation, health care, manufacturing industries, aviation and many other public services.
As a consequence of long shifts, sleep deprivation has become the focus of health and safety concerns. Increasing safety in critical operations is a major challenge for the government, employers, and the public. People exposed to shift-work can have major disruptions in sleep and circadian rhythms [8, 3]. The disruption of the circadian rhythm may reduce waking alertness, impair performance, and increase fatigue [4]. Drowsiness, in particular, is the transition state between awakening and sleep during which a decrease in vigilance occurs. This state is a contributing factor in thousands of crashes, injuries and fatalities annually [2]. Any of the aforementioned activities, if pursued long enough, will render a person unable to maintain focused performance; this is as true for driving as well as any other skill and is a precursor for accidents [5].

Electroencephalography (EEG) provides a noninvasive means of reliably monitoring brain activity spatially and temporally. The EEG signal may be one of the most predictable and reliable physiological indicators to measure the level of alertness [4]. Use of EEG technology until now, however, has been limited to hospitals and laboratories due to its complexity both in signal collection as well as in data interpretation. Extensive wiring and hardware render EEG cumbersome for individual use, and wet electrodes are not appropriate for quotidian use. Dry and non-contact electrodes offer a more comfortable, easy-to-use alternative to the traditional gel electrode, but they currently provide limited signal strength. The presence of hair, which hinders access to a large portion of the scalp, poses an additional challenge to EEG measurement.

Other factors, such as muscle movement, negatively affect the quality of EEG measurements as well; this makes it harder to apply their use to real-world situations. With the advance of technology, we hope rectifications of these problems are made to increase the accuracy of these devices for use in everyday situations. In the meantime, this research will give more insight into the operation of commercial EEG devices and the best ways to manipulate them to identify different vigilance states. The following section will describe previous related work in the field. Section 3 will provide the research methodology, including important background information and the materials used for this project. In section 4, we will present the results of our research followed by our discussion and conclusions.

2 Related Work

Various studies have been conducted to best analyze the correlation between EEG data and vigilance states of drowsiness and non-drowsiness in connection to safety implementations. However, very few studies have approached the problem using dry EEG devices. In one such approach, a unique EEG device was created using a single-channel dry electrode. The electrode was designed to measure a unit gain analog signal. Data was collected near the occipital lobe, and signals were processed using power spectral analysis.

Our analysis uses commercially available dry EEG devices. The Neurosky Company offers reliable low level EEG headsets and stable software tools for researchers and developers. Many researchers have succeeded in testing these single-channel devices in recent projects.

Our project seeks to test the viability of these products in real-world safety applications.

3 Methodology

3.1 Background Information

Background research shows that alpha waves (frequency 8-13 Hz), theta waves (frequency 4-7 Hz), and beta waves (frequency 14-30 Hz) [1] are most important when predicting drowsiness. Alpha waves are associated with meditation and relaxation. They can also be attributed to attention or concentration at slower frequencies [7].Theta waves are directly associated with drowsiness and are prevalent during stage 1 of the sleep cycle. The presence of beta waves is related to concentration. Experts determine the first signs of drowsiness to be a diminishing of alpha waves and slow rolling eye movements, referred to as SREMs [6]. During drowsiness, alpha waves should become more broken and inconsistent, theta waves should become more prevalent, and the amount of beta waves should diminish.

Experimental pre-testing was performed by obtaining EEG data and analyzing it using BCI2000. Data was obtained from healthy subjects in 5 minute segments, classifying the subject's condition as either drowsy or alert.

3.2 Hardware and Software

Neurosky's hardware, the think-gear module, uses a dry active sensor technology to read brain signals. Traditionally, standard medical electroencephalography devices use a conductive gel to facilitate the reading of the signals. Dry active sensor technology does not need such a gel. For this reason, headsets based on Neurosky technology are very low cost, and easy to handle. Three Neurosky devices were tested and compared: Mindset, Mindwave, and the MyndPlay Brain Band. Table 1 shows the comparison of consumer brain computer interface devices used. Among them, we discarded the Mindset as a viable BCI device because of its bulky design and noisy signal. The software used for data acquisition and storage was BCI2000.The BCI2000 platform is a general-purpose system for brain-computer interface (BCI) research and have been extendedly used in academic research.

A Matlab toolkit was used for manipulation of the raw EEG data. Matlab was chosen for its simplicity and its ability to integrate seamlessly with the BCI2000 software. The experimental framework used is shown if Figure 1.

Table 1 Comparison of BCI systems

	MindWave	MindSet	MyndPlay Band
EEG Channels	1	1	1
Connectivity	Wireless RF Adapter	Bluetooth	Bluetooth
Wireless Output	RF	Bluetooth (audio and voice)	Bluetooth
Receiver	USB RF Receiver	Bluetooth	Bluetooth
Reference (ground) type	Ear clip	Earphone pad	Ear Hook
Appearance	Headset	Headset with headphones	Velcro headband
Cost	$99	$199	$150

3.3 Data Collection and Manipulation

Five subjects were used for performing the second iteration of testing. Before EEG data was collected, the alertness state of each individual was classified and recorded as either drowsy or alert. Three individuals were recorded as being alert, and two individuals were recorded as experiencing fatigue. EEG data collection was performed for a total of five minutes for each individual. Upon collection of the raw EEG measures, the Matlab Signal Processing toolkit was used to perform power spectral density and graph the results for each subject. Graphs were then overlaid for analysis as to their correlation and validity. Such analysis was conducted on drowsy versus drowsy, alert versus alert, and drowsy versus alert data.

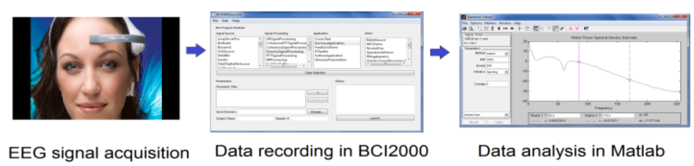

Figure 1 Experimental framework

4 Results

Raw plots of the collected data are shown in Figure 2.Power spectral density was computed, plotted, and compared for each of the subjects (figure 3). Significant differences were observed between the two states. Drowsy states produced lower levels of alpha and beta waves within the power spectral analysis. Very similar levels of theta waves were observed for drowsy and alert states within the power spectral analysis.

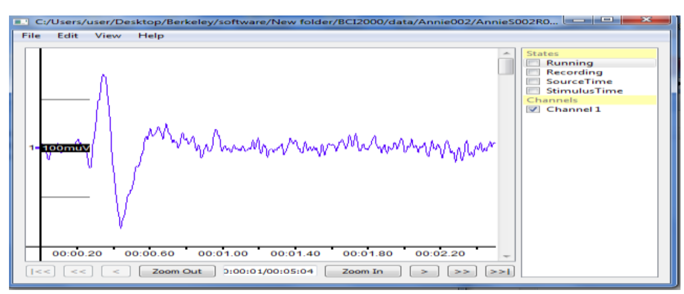

Figure 2 Sample raw signal, visualized in real time in BCI200

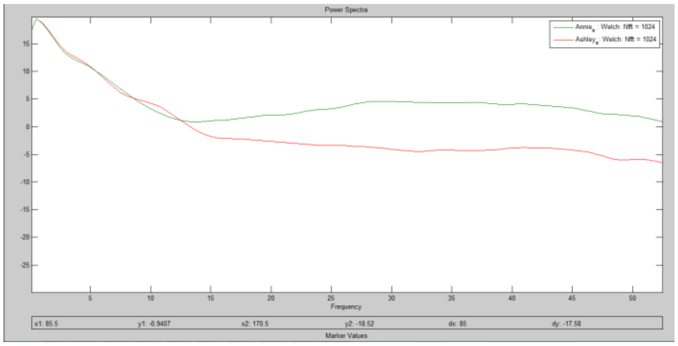

Figure 3 Sample spectral analysis, comparing subjects in a fatigued (red) and alert (green) state

5 Discussion and Conclusions

Comparisons of our data to previous works have produced favorable results. Our results closely replicate analyses of single channel EEG research projects. This shows that the commercially available dry EEG devices produced by NeuroSky are a viable solution for use in real-world applications. These devices' ability to integrate with open source software, such as BCI2000, and flexible script languages, such as Matlab, make them suitable candidates for further research in the detection of vigilance states. Of the three devices tested, the MindWave produced the most accurate data due to its physical and technical properties.

In the future, we hope to develop a program with a self-learning algorithm using the BCI2000 software to accurately sense drowsiness. The program will use a sample of the individuals normal EEG to detect fluctuations in brain wave frequencies and will issue an alert from the device when drowsiness has been detected. Further research will also be done on the behavior of brain waves during other vigilance states, such as inebriation versus sobriety.

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