The Ability of Low-Cost, Wearable Devices to Recognize Enhanced Functional States

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Abstract - **This study will assess the ability of the InteraXon Muse 2, a low-cost, EEG system and the Tobii Pro Nano eye tracker to detect changes in cognitive state such as stress and workload. There were 10 total participants in this study, and all were Virginia Tech Students. Participants completed a Stroop Test, Psychomotor Vigilance Test, and a Multiple object tracking task under four conditions including 1) a control with no countermeasure 2) one minute meditation before each task 3) the introduction of blue ambient lighting during the task 4) and both a minute meditation and blue ambient lighting. An ANOVA test will be used to assess if there is a significant difference between each state and then a post-hoc test will be used to compare each condition. This will contribute to the research that will allow for enhanced biofeedback technologies that optimize cognitive state in high-risk professions like pilots and surgeons.**

INTRODUCTION

The advancement of low-cost, wearable technology provides objective measurements that can be utilized to both classify and improve the functional state of aircraft pilots. To interpret the biosignals from these devices, features such as bandpowers and heart rate variability (HRV) are extracted from electroencephalography (EEG) and photoplethysmography (PPG) signals, respectively [3]. Trends from these features can correlate to aspects of a user's function state. Among other qualities, EEG signal bandpowers can detect levels of engagement and workload [4]. HRV has been found to directly correlate with positive and negative emotions [5]. When used simultaneously, bandpowers and HRV create an optimal system to quantify stress levels [6]. Past work from NASA Langley's Research Center has verified the ability of a low-cost EEG system to classify crewmembers' awareness and overall cognitive state. These findings are aimed to build a foundation towards the utilization of a real-time monitoring system to classify crewmembers' states [7,8]. Additional work at NASA has found this low-cost system to measure attention with similar accuracy as more advanced systems during benchmark tasks and flight simulations [9]. With the enhanced understanding and accuracy of these psychophysiological measures, the effectiveness of countermeasures to improve functional state can be evaluated. Using EEG and HRV, ambient lighting has been discovered to increase focus and performance in automotive tasks and is now utilized in some cars [10, 11]. Additionally, a single mindfulness session is capable of both reducing stress and increasing focus in a task [12]. These countermeasures can be applied to pilots to ensure safe operations of aircrafts. However, the ability of low-cost, wearable devices to identify the effects of these countermeasures has yet to be extensively researched. The verification of a low-cost, wearable device's ability to successfully identify when countermeasures are effective would be a transformative advancement in crew state monitoring and aircraft controls safety.

METHODS

Devices

The low-cost (less than $300), Muse 2 will be evaluated in this study as it is used to collect data [13]. This wireless headset, shown in Figure 1, includes four dry EEG electrodes and a PPG sensor with locations along the forehead and behind the ears. Through past research, I have worked to create a preprocessing pipeline for the Muse headset to extract signals for comparison during different tasks including a high and low workload flight simulator [1]. I have additionally worked with the Muse to assess signal quality during a simulated extravehicular activity [2]. These preprocessing methods and signal quality metrics will be utilized in this experiment to identify and eliminate signal noise.

Figure 1. Muse 2 Headset

The Tobii Pro Nano, seen in Figure 2, is an eye tracking bar put at the base of a computer screen that tracks the movement of subjects' pupils using an infrared camera. It connects to the Tobii Eye Tracking Software and the data collected from this device can be recorded using MATLAB. Eye tracking metrics including saccade and fixation duration and rate will be used to assess the cognitive load of study participants.

Figure 2. Tobii Pro Nano

Tasks

The computer-based tasks, the Stroop Test, PVT, and MOT, are commonly used in psychology research. During the Stroop Test, participants verbally list the colors of words during congruent and incongruent conditions, and their accuracy and time measurements are recorded each time. Congruent conditions include when the word and the color of the word agree while incongruent conditions are when the word represented disagrees with the color of the word. During the PVT, participants click the mouse each time a number shows up on the screen and begins counting the time until the mouse is clicked. Their average reaction time is recorded at the end of each session. During the MOT, eight dots appear, four of which are highlighted using a different color. All the dots return to the same color and then move around an enclosed rectangle for a short period of time. Once they stop, the participant is asked if one of the dots is one of the original four highlighted dots.

Experimental Method

10 subjects were recruited for this study using email announcements and recruitment flyers for Virginia Tech students. Based on a recruitment flyer or email, participants followed a link to fill out an interest form to participate in the study. Then, an email was sent with detailed information about the study, a consent form for review, and a survey to choose a time slot for the study. I then sent a second email to those who have completed these steps with the meeting room information. Upon arrival, participants signed the consent document and filled out a brief demographics survey that will ask about their age, gender, and race. Following this, the procedure to complete the tasks lasted approximately an hour for each participant. To start each sensor was calibrated and the Muse headset was placed on the participant. The signal quality was checked using a visual assessment of the raw EEG signal at each electrode. The participant then completed each task, described above, in a training session before officially starting data recording. Once training was completed, a randomized order was decided by an algorithm in MATLAB and the stream was started for the data recording from each device. The Muse was worn on the participants forehead and wrap behind the ears. The eye tracker at the base of the computer screen began using a camera to track the participants eye movements. Each task was be completed in MATLAB. For the control task, the participant completed the tests on the computer without changes in behavior or environment. During the ambient lighting condition, the light color changed to a blue ambient light using Arduino controlled Neopixel light strips. During the meditation condition, the participant completed a one-minute guided meditation using the Muse App, installed on the computer, before completing the set of tasks. The gift card was then be given to the participant in person before leaving. I will also share my end of

the year poster with each participant to see the overall findings of the research.

RESULTS

The results of this study wil include performance results from the cognitive tasks completed as well as the analysis of psychophysiological data collected by the Muse and the eye tracker. The time difference, accuracy, and response time in the stroop test, MOT, and PVT, respectively, will be assessed. The bandpowers of the EEG signal will be analyzed for how they vary between conditions for each participant. Finally, the eye tracking data will help in the assessment of cognitive load by comparing saccade and fixation duration and rate between each condition.

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REFERENCES

[1] Laiti, J, & Wusk, G, & Gabler, H. “Comparing Signal Preprocessing Techniques for a Low-Cost EEG System,” presented at the Biomedical Engineering Society Annual Meeting, October 17, 2020.

[2] Laiti, J, & Wusk, G, & Gabler, H. “Using A Wearable, Low-Cost Brain Monitoring System During an Ambulatory Virtual Reality Extravehicular Activity (EVA) Simulation,” presented at the Human Research Program Investigators' Workshop, February 1, 2021.

[3] Kinnunen1, Hannu, et al. “IOPscience.” Physiological Measurement, IOP Publishing, 1 May 2020, iopscience.iop.org/article/10.1088/1361-6579/ab840a/meta.

[4] Stikic, Maja, et al. “Modeling Temporal Sequences of Cognitive State Changes Based on a Combination of EEG-Engagement, EEG-Workload, and Heart Rate Metrics.” Frontiers, Frontiers, 8 Oct. 2014.

[5] Longis, Evelina De, et al. “Inertia of Emotions and Inertia of the Heart: Physiological Processes Underlying Inertia of Negative Emotions at Work.” International Journal of Psychophysiology, Elsevier, 26 June 2020.

[6] J. W. Ahn, Y. Ku, and H. C. Kim, “A Novel Wearable EEG and ECG Recording System for Stress Assessment,” Sensors, vol. 19, no. 9, p. 1991, Apr. 2019.

[7] A. Harrivel, “Comparative EEG Sensor Analysis for Attentional State Prediction,” presented at the AsMA 89th Annual Scientific Meeting, May 7, 2018.

[8] Angela R., Harrivel. et al.,“NASA Technical Reports Server (NTRS).” NASA, NASA, January 4, 2016.

[9] Angela R., Harrivel. et al, “Prediction of Cognitive States during Flight Simulation using Multimodal Psychophysiological Sensing,” NASA, January 5, 2017, doi: 10.2514/6.2017-1135.