Fabric Electrodes for Physiological Sensing in a VR HMD

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ABSTRACT

This paper explores the development and testing of fabric electrodes to collect a range of physiological measures. The aim is to integrate these sensors into a Virtual Reality (VR) headset to collect physiological and muscular motion data that will help detect emotion, cognitive load and facial expressions. As part of an on-going project, we have already developed prototypes of the EMG and GSR sensors. A head phantom has been developed for the purpose of testing and validating electrode performance.

KEYWORDS

Physiological Sensors, Virtual Reality, Empathic Computing

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1 INTRODUCTION

In this paper, we report on the development and testing of sensors using fabric electrodes for use within a VR headset. We also show a head phantom that will be used for validation of sensors. Many studies using physiological sensors in VR have been conducted [3, 5, 7] using Galvanic Skin Response (GSR), Electromyography (EMG), Electrooculography (EOG) and Electroencephalography (EEG). These sensors have, to varying degrees of success, demonstrated the ability to detect emotion, cognitive load and other bodily effects that manifest themselves as physiological changes. However, these sensors are often uncomfortable to use over extended periods of time, resulting in pain and/or discomfort owing to the materials they are made of i.e. metal, hard plastic etc.

We present ongoing efforts to develop and integrate fabric electrodes into a VR HMD. Similar research has been done in integrating sensors into an HMD [2]. However, the novelty of our work is in the use of fabric electrodes for the sensors. The goal of this research project is to ensure user comfort and thereby allow for extended use of a VR HMD; and to reliably collect data using multiple physiological sensor types to enable the detection of emotion, cognitive load and inter-brain synchrony, among other parameters[4, 6].

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2 METHODOLOGY

The development of a physiological sensor array that is fully integrated with a VR HMD will incorporate the following steps:



Figure 1: Image of the Different Electrodes Tested, From left to right: Silver Fabric, Copper Fabric, Copper Tape, 3D Printed

Sensor Development: The development was based on the materials and methods described by [1]. Various shapes, sizes and materials (Figure 1) were tested before we settled on the leftmost electrode shown in Figure 1. This electrode is constructed from silver cloth, is soft to touch and comfortable when worn on the forehead using a sweatband. Silver was chosen since the copper-based fabric electrode that exhibited the best signal-to-noise-ration (SNR) is also prone to corrosion, especially when placed in sweaty and/or oily environments such as the head and face.

Head Phantom Development: Figure 2 shows the head phantom that was developed for initially testing of the electrodes. This was a scaled model (1:8) and was made to test the electrical properties of the materials. Initial tests have demonstrated that the gel recipe used to make the head phantom is capable of mimicking the electrical properties of the human head.

Sensor Validation: To validate the working of the fabric electrode, we first constructed a GSR sensor. This sensor utilises a simple circuit that applies a voltage across two electrodes. The change in ionic activity due to sweat results in a change in skin conductance.

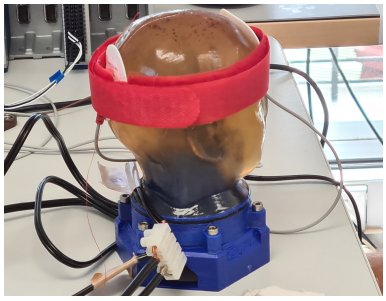


Figure 2: Image of the Head Phantom with Function Generator and 2 Electrodes Connected

This is read by a change in the voltage read across the electrodes. A physical low pass filter with a cutoff frequency of 2Hz was added. The results from our preliminary sensor validation test can be found in the Results section.

Integration: While we are yet to begin the integration of the sensors into a VR HMD, we do have a layout that we have created (Figure 3).



Figure 3: Image of Face-pad of HMD with Red Points Indicating Electrode positions

3 RESULTS

To validate data collected by the GSR sensor, we recorded information simultaneously with our sensor and a gold standard - Shimmer GSR sensor. We used the Stroop test [8] to determine the effectiveness, and validate the functioning of the GSR sensor. A baseline measure was first acquired. During this measurement, the participant was required to sit still and not engage in any activity. Following this, a Stroop test was administered to induce stress in the participant. Feature extraction and analysis of the data was then used to compare the two data sets. Data was normalised and interpolated, then plotted next to each other to visualise (Figure 4).

Figure 4 shows that the performance of our sensor closely matched that of the Shimmer.

4 DISCUSSION

The work detailed in this paper has demonstrated that the fabric electrodes we have developed can be reliably used to acquire physiological signals. Their performance compares well with the established gold standard for physiological signal acquisition i.e. Shimmer GSR sensor. They have also shown to be comfortable to wear. Based on these preliminary results, it appears that these electrodes are well suited to integration into a VR HMD. However, the



Figure 4: Normalised Plot of Shimmer and Prototype Circuit GSR Data

challenge with this will be to be seen how good the electrodes are at acquiring other signal types. Particularly, the acquisition of EEG can be challenging given the amplitude of signals, and the noise a typical ambulatory VR environment can generate in the acquired data.

5 CONCLUSIONS

We have demonstrated prototype physiological sensors that can be integrated into a VR HMD. Additionally, we have also developed a head phantom that can be used to validate these sensors. We are in the process of extending sensor development to cover other physiological signals such as EEG and heart rate. This will be followed up with a full user study to confirm the effectiveness of signal acquisition and the comfort afforded by the sensors.

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