Using Smart Eyewear to Sense Electrodermal Activity While Reading

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ABSTRACT

In this paper, we present the use of smart eyewear as reading glasses and as non-intrusive sensing devices that can measure the electrodermal activity (EDA) of readers of fiction in real-time using electrodes on the forehead. EDA has seen extensive use in the past decade in accessing emotional arousal, with research linking human skin sweating to the emotional state of a subject. Traditional ways of measuring EDA involve using the fingers, which has the highest concentration of eccrine sweat glands, but this method proves to be intrusive in non-laboratory environments as most daily activities require the use of one's hands. In this paper, we discuss the viability of using smart eyewear to measure and visualize a reader's physiological signals as well as provide some background in EDA research.

KEYWORDS

Skin Conductance; Electrodermal Activity; Smart Eyewear; Wearable Devices; Emotion Detection

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1 INTRODUCTION

The major impact of reading works of fiction lies in the emotions it induces and often times is the dividing factor on its reception by the public. Stories have been around for as long as civilization has, and with it, literature as well. Be it prose, poetry, or fables, the act of reading has always entertained and educated people across multiple cultures and age groups. Consequently, any discussion of literature cannot be made without taking into consideration that it is a medium that induces emotions or feelings. As put by Johansen, literature is 'designed to arouse and form the feelings of the listeners and readers.' [11] This is also addressed in a philosophical dilemma known as the paradox of fiction, a term first coined by Colin Radford and Michael Weston in 1970, questioning why humans are emotionally moved by events that they know are not real. [18] To this end, Johansen argues literature possesses the ability to create worlds that are, although fictional, very similar in multiple aspects to the real world in which we live. [11] As empathetic creatures, we humans tend to imagine about others and self-insert ourselves in the events that unfold in the lives of the said others, regardless of whether they are real or fictional.

Through literature, we can 'learn about emotions and understand our own feelings.' [4] It has been suggested that consuming fictional narratives play an important role in helping people learn about their own selves and internalize their emotions. [16] One study suggests that people who consume more fiction tend to be more empathetic, as consuming fiction is a simulation of social experiences that can help them practice interpersonal skills. [17] Hilgard likened this experience to something akin to hypnosis, that the reader is 'transformed or transported by what he reads and is swept emotionally into the experience described by the author.' [9] Nell uses a similar metaphor, calling it the experience a 'reading trance'. [15] Therefore, exploring different ways to clearly identify and measure emotional reactions that are induced by reading works of fiction can also help us move closer to understanding our own emotions.

According to the first-quarter 2021 executive summary provided by NPD BookScan, the publishing industry has seen a 29 percent growth across the adult fiction and young adult fiction genres over the past year, which is a surprising development as book sales have been on a steady decline for the past decade. Kristen McLean of NPD Books describes this as "the highest volume of Q1 print sales since NPD BookScan began tracking sales in 2004." The growth in young adult fiction is the most notable in the fact that one of the biggest factors credited for the growth is the social media platform TikTok, where the BookTok hashtag has gained popularity amidst the pandemic. As such, the experience of reading itself is transforming from something that used to be private and passive to an experience that can connect people in times of isolation. It is

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for this reason that we propose the application of smart eyewear as reading glasses, utilizing electrodermal activity (EDA) sensors on the forehead. As a smart device capable of unobtrusive emotion sensing, it can serve as an example of how physiological signals and emotional changes can be tracked through a reading session without significantly altering the experience in a non-laboratory setting. This also opens up possibilities for the user to be able to have visual records or their reading sessions in the form of visualizations, just as one would do with fitness apps.

2 RELATED WORKS

2.1 Physiological Signals and Reading

Existing research on eliciting emotions in the form of physiological signals have done so using other mediums such as pictures, which makes use of the widely known International Affective Picture System (IAPS), movie clips [12], music [14], and others. In contrast, using text to perform a similar task, especially long texts like short stories or even novels haven't been explored to a great degree. Studies that examine the physiological effects of short emotional words [13] and short fragments of text [10] have been conducted.

While there are definite advantages to using short materials to quickly provide different stimuli repeatedly to the subject, measuring the physiological signals in response to longer texts also has its advantages. As noted by Golland et. al [8], short fragments of text can not be expected to engage readers in a way that full length stories would. Wise et. al compared the emotional responses of subjects who came across unpleasant fictional news stories by specifically searching for them or just surfing the web. [24] Subjects who were actively searching for the news story with background information experienced stronger physiological reactions than those who were just surfing, suggesting that prior knowledge of the context and the level of engagement is important in the emotional experience.

2.2 Skin Conductance and Emotional Arousal

Traditionally in sweat gland biology, there are two major types of sweat glands called eccrine and apocrine. [23] A third type of sweat gland, tentatively called the apoeccrine sweat gland, was introduced in 1987 by Sato et. al. [20] Among these, eccrine sweat glands are most often associated with having more involvement in emotional responses compared to the other two types of sweat glands. This can be accredited to eccrine sweat glands being innervated with the sympathetic nervous system that accompany various psychological processes, including emotional arousal. [5]

Skin conductance and electrodermal activity (EDA) has had widespread use in psychological research. [21] Skin conductance refers to a changes in electrical conductance in the skin from changes in the rate of sweat secretion by the sweat glands. [2] Measurements of EDA mostly focus on two parameters known as Skin Conductance Response (SCR) and Skin Conductance Level (SCL). SCR refers to quick changes, usually within the range of seconds, in response to emotional stimuli, while the SCL refers to slower changes, within the range of minutes or hours, and is commonly associated with the general condition of the subject. These parameters have been used extensively in the past decade to access emotional arousal, as many studies suggest that SCL increases as emotional arousal increases. [1, 3]

2.3 Smart Eyewear and Sensing

EDA is traditionally measured using the subject's finger, as the highest density of eccrine sweat glands are found on the palms and soles (about 600 to 700 glands/square cm), followed by the forehead (181 glands/square cm), forearm (108 glands/square centimeter), and the back (64 glands/square centimeter). [7, 19] However, measuring EDA using the fingers prove to be intrusive in non-laboratory environments since most daily activities require the use of hands [6], and reading is no exception. For our purposes, as the smart eyewear can serve a purpose other than sensing (such as having prescription lenses or blue light filters for those who read on tablets), it can be used to sense EDA with relatively less effect on the experience of reading itself. SC measurements on body parts other than the hand has been explored by van Dooren et. al, where they measured SCL and SCR on 16 different parts of the body. It was found that apart from the fingers, the forehead, foot, and shoulders were the most promising for EDA measurements [22], which reinforces the viability of using smart eyewear to measure EDA. Additionally, other sensing modalities related to emotions such as heartbeat sensors using the temples and cognitive load [25] can be used together with the EDA sensors, opening up the possibilities of more data-rich visualizations to the user and other very interesting applications.

Figure 1: Testing setup with Jins MEME outfitted with electrodes and PCB with analog circuitry.

Figure 2: Wristband to measure EDA using the fingers.

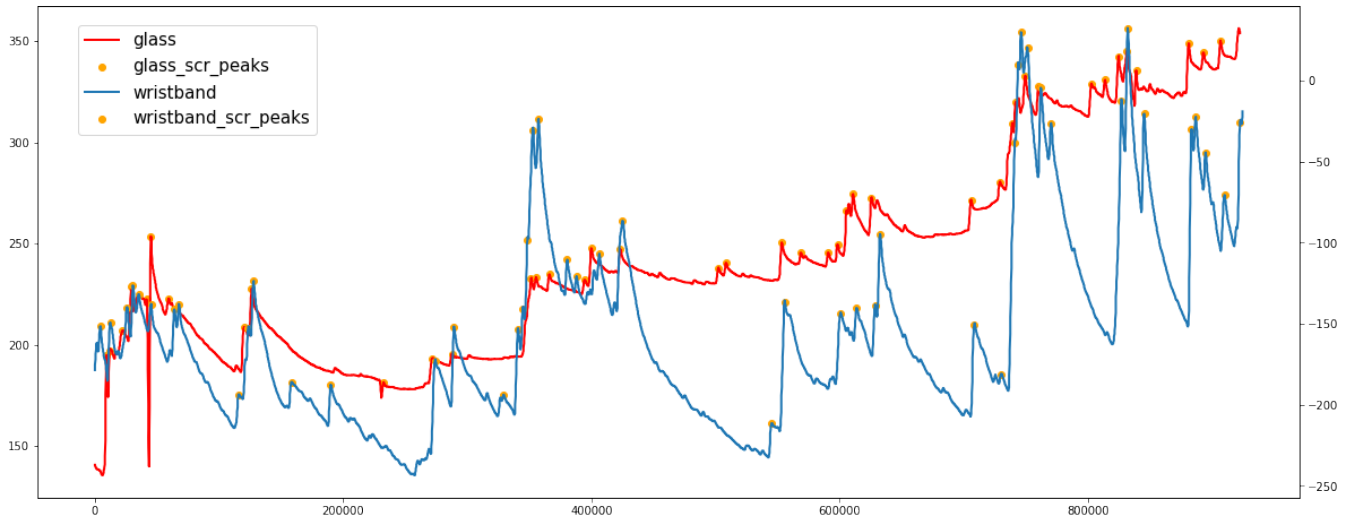

Figure 3: Comparison of the SCR readings taken with the electrodes on the forehead (red) and the fingers (blue). The SCR peaks of each are highlighted in yellow.

3 APPROACH

For the prototype, we used a Jins MEME, an off-the-shelf smart eyewear as our base, based on ready availability. Two electrodes were attached facing upwards to both sides of the bridge so that they would be touching the forehead of the wearer (See Figure 1). For the initial experiment, we also measured EDA with the fingers, the more conventional method of measuring EDA, using a wristband (See Figure 2). Both the MEME and the wristband used the same analog front-end PCB circuitry, with a wheatstone bridge connected to a differential ADC that communicates to an ESP32 chip over I2C. The goal of this was to verify the viability of using smart eyewear as a device that could reliably measure EDA even compared to the conventional way of measuring using the fingers. The subject was made to read "Snow, Glass, Apples", a horror-themed short story by English author Neil Gaiman while wearing both devices. The recording session took 20 minutes in total in a quiet environment in order to eliminate any other external factors that could affect the recording.

As can be seen on the graph in Figure 3, the SCR taken by the MEME show a steady increase in intensity as the reader reads through the rising action and climax of the story, which is located at the end of the story, showing a similar trend to the SCR taken using the wristbands. The data taken on the glasses do show a much smaller fluctuation during the peaks than that of the wristband, which is to be expected due to the difference in concentration of sweat glands present on the forehead as opposed to the palm. [7, 19] Another point worth noting is how the SCR peaks (highlighted in yellow) of the data taken with the MEME matches that of the wristband. These readings demonstrates how smart glasses can be used as reading glasses that could also serve as a non-intrusive sensing device. In addition, the small size of the components mean that there is no need to alter the size or weight of the device significantly. As the data taken from the forehead using these devices also were shown to be viable, it may allow readers to use the device to measure their reading sessions and share and compare their experience with others.

4 FUTURE WORK

More extensive and rigorous testing on many more subjects is needed to better establish that the readings taken on the forehead using smart eyewear are as consistent as the ones taken using the fingers. There also exists the problem of other variables such as movement and excessive sebum (oily skin) that could interfere with the readings using the forehead.

Once this can be sufficiently established, the next step of the project would be to add other sensing modalities related to emotion sensing, such as heartrate sensors on the temples or cognitive load using face temperatures. Another angle would be to find a way to visualize the data taken in a form that can make sense to the average user.

Smart eyewear being used as sensing devices, especially in the act of reading, has its strengths in the fact that it is much less intrusive than measuring with the fingers and that glasses already hold a place in the reading experience as prescription glasses or blue light filters. Being able to measure one's experience while reading a work of fiction and visualize it can help open new dimensions and transform the act of reading from an isolated solitary experience to one that can help people connect to others.

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