Differences in Psychophysiological Reactions to Anxiety in Individuals with Varying Trait Anxiety Scores

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ABSTRACT

This study investigated the differences in the psychophysiological reaction to anxious situations in individuals with higher (greater than or equal to 40) trait anxiety scores in comparison to those with lower (less than 40) trait anxiety scores. This information may be useful for convenient anxiety treatment options and health trackers toward effectively recording and interpreting physiological data from individuals who are generally more anxious. Ten adults completed an IRB (Institutional Review Board) approved study in which all participants completed the Trait Anxiety Scale (Form Y-2) of the State Trait Anxiety Inventory, and subsequently underwent four phases of baseline, introduction, virtual reality simulation, and recovery during which EEG (electroencephalogram), heart rate, and skin conductance data was collected. Participants also recorded their self-interpreted anxiety on a scale of 1-10 after each phase of the experiment. The brief introduction phase and virtual reality simulation were designed to elicit mild anxiety. Results show no statistically significance difference in average percent difference in skin conductance or heart rate changes between baseline to introduction, baseline to virtual reality or baseline to recovery between individuals with high (greater than or equal to 40) trait anxiety scores and average or low (less than 40) scores. These findings imply important information that trait anxiety does not necessarily correlate to more severe physiological reactions to anxious situations and confirms that manifestations of anxiety may vary greatly between individuals. Most importantly, evaluative measures for the effectiveness of potential health tracking applications or anxiety treatments would be most effective if perceived anxiety intensities were given more value than solely physiological data.

CCS CONCEPTS

• **Human-centered computing → Accessibility technologies**;

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KEYWORDS

Anxiety; Psychophysiology; Virtual Reality; Electroencephalography; Assistive Technology

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1 INTRODUCTION

It is perfectly normal for a person to experience occasional anxiety throughout their lifetime. The feeling can manifest itself before a job interview, an exam, a date, or many other common life or social situations. However, in many cases, the feeling begins to interfere or impair daily life. Anxiety disorders are the most common mental illness in the United States and affect 40 million adults in the U.S. age 18 and older every year. Those 40 million adults comprise roughly 18.1% of the population [2]. Anxiety manifests within individuals in different ways but common symptoms include increased perspiration and heart rate. An individual may be experiencing an anxiety disorder when symptoms persist and interfere with daily life.

Current treatments for anxiety disorders resort to either pharmacological or psychotherapy methods. While both of these methods have been found effective, it is estimated that 36.9% of individuals who experience anxiety disorders actually receive treatment for their anxiety [2, 12]. Pharmacological treatment can take years of sorting through âĂIJblack boxâĂİ warning antidepressants that may potentially cause suicidal thoughts, and alternatively, benzodiazepines can put their users at high risk of addiction.

The apparent need for new, convenient and effective methods of anxiety treatment is coupled with the necessity of a better understanding of the inner psychophysiological workings of anxiety within an individual. While other studies have been conducted on EEG activity patterns as an assessment method of behavioral therapy treatments [11], none use additional sensors to verify and validate specific moments of anxiety in a virtual reality simulation. It is important to explore the possible difference in physiological reactions to anxiety in individuals with higher general (trait) anxiety levels. This information is crucial in the design considerations

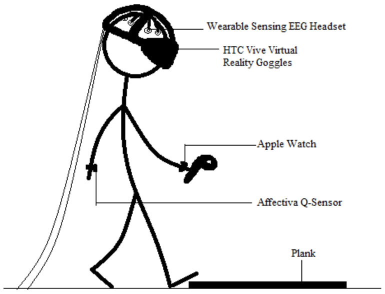

Figure 1: This image describes the setup of the equipment during the virtual reality phase of the study. The individual is wearing the Wearable Sensing EEG Headset underneath the HTC Vive Virtual Reality Goggles along with an Apple Watch on one wrist and the Affectiva Q-Sensor on the other. The physical plank on the ground is used to make the virtual reality experience as immersive as possible.

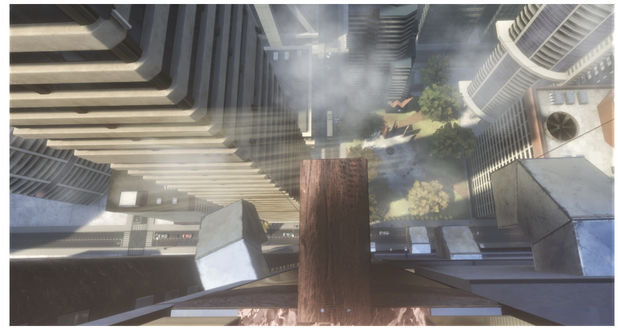

Figure 2: A screenshot from the RichieâĂŹs Plank Experiment gameplay which demonstrates the view of the participant during the virtual reality phase of the experiment. The challenge to complete is walking out to the edge of the plank and returning to the elevator.

of treatment options available to the general public. For example, personal health trackers may benefit from knowledge of a predisposed sensitivity to more severe physiological reactions in anxious situations. Current research on new intervention methods to treat anxiety include the use of electrical stimulation, mobile cognitive behavioral therapy, and mindfulness applications, as well as virtual reality simulations in the context of exposure therapies [6, 7, 10]. These methods require a reliable evaluation metric to assess the effectiveness at alleviating symptoms. Virtual Reality now offers a multi-sensory immersive experience that can be used to evaluate new intervention methods of treating anxiety.

In this study, a virtual reality simulation is used to induce anxiety in eighteen participants while EEG (electroencephalogram) activity, heart rate, and skin conductance are recorded. Heart rate and skin conductance were chosen to be recorded as reliable measures of common symptoms of an anxious state (e.g., elevated heart rate and perspiration). The EEG activity recorded gives information about the physical location of activity in the brain and the frequency at which it occurs. These measures of electrical activity are beneficial in the development of tools for personal health and may influence design of treatment or therapy options for an individual by considering their activity. In this study, all participants were asked to complete the Trait Anxiety Form (Y-2) of the State Trait Anxiety Inventory after having read and signed an IRB-approved consent form. The State Trait Anxiety Inventory includes two subscales of measurement. The first, the State Anxiety Scale (S - Anxiety) is used to evaluate an individualâĂŹs current state of anxiety. State Anxiety scoring reflects how the individual feels âĂIJright now,âĂİ in a 20 question subjective survey. The other subscale of measurement in the State Trait Anxiety Inventory is the Trait Anxiety Scale (T-Anxiety) which evaluates stable aspects of âĂIJanxiety pronenessâĂİ and the general states of calmness, confidence, and security that an individual exhibits [8]. Participants additionally intermittently reflected how intensely they felt anxiety on a self-reported Likert scale of one to ten after each phase of the experiment. Each participant underwent four recording intervals or phases (baseline, introduction, virtual reality, recovery) in which the individualâĂŹs baseline serves as his or her control metric to which all other phases are compared. This method takes into account that individuals have varying baseline physiological states as well as severity in reactions to anxious situations and provides an interpretation that can be analyzed across all individuals.

2 METHODS

Eighteen adults were recruited to participate in this study. These participants included nine males and nine females from ages nineteen to seventy. Thirteen participants had no clinical diagnosis of anxiety disorders and five had clinical diagnoses of anxiety disorders. All participants were rated with the state-trait anxiety inventory (STAI) form corresponding to trait anxiety (Y-2). All participants underwent five-phases of biometric recording that consisted of heart rate, skin conductance, and EEG activity. The phases of the experiment included a baseline recording, an introduction, a virtual reality simulation, and a rest recording.

2.1 Participants

Throughout the duration of the study, 18 different participants volunteered to contribute to this research study. This group consisted of 9 males and 9 females. Unfortunately, due to data loss caused by sensor malfunction, only 11 participants completed the experiment with all sensor data completely intact. Additionally, of the 11 participants who completed the experiment, one participant experienced an adverse reaction in skin conductance resulting in an outlier sample that was not included in data analysis. The resulting 10 participants include 5 males and 5 females. The ages of these participants range from 19 to 70 with an average of 36 and a standard deviation of 19.64. Exclusion criteria included individuals under the age of 18 or over the age of 60 or non-English-speaking individuals.

2.2 Equipment and Measures

The equipment used in this study included a desktop computer running a VR simulation through an HTC Vive, a Wearable Sensing EEG system, an Apple watch, and a Q-sensor.

2.2.1 HTC Vive. The HTC Vive was used to provide an immersive and realistic experience to the user during the virtual reality simulation. The system consists of a headset of large goggles with an internal digital display with a resolution of 1080 x 1200 pixels per eye. The headset is tightened onto the head of the user with Velcro straps. Additionally, the user was given one controller with vibro-tactile feedback to navigate the initial part of the simulation, as well as two earbuds that contributed to the immersive audio of the simulation and allowed a channel of communication to the user for instruction [4].

2.2.2 Apple Watch. The Apple watch continuously recorded and stored heart rate information through photoplethysmography (use of LED lights and photodiode sensors) on the back of the watch. The heart rate sensor supports a range of up to 30 to 210 beats per minute. This recording involved no active effort from the individual in the operation of this sensor [5].

2.2.3 Affectiva Q-Sensor. . The Q-sensor by Affectiva was used in this study to record electrodermal activity through a small sensor placed on the bottom of the participantâĂŹs wrist and tightened in place with a wristband. The device records skin conductance or electrodermal activity or galvanic skin response (GSR) fluctuations at a sample rate of 8 hertz using Q Live software. The Q-sensor uses small electrical signals (less than 5 microwatts of power) to measure the wearers GSR. The output recordings were exported to CSV files for further analysis in Microsoft Excel.

2.2.4 EEG System. The EEG system used was the Wearable Sensing DSI-7 Dry Electrode Headset. With a sampling frequency of 300Hz, the Wearable Sensing headset is a wireless, dry-electrode EEG system with seven sensors positioned at F3, F4, C3, C4, Pz, P3, and P4 locations of the 10-20 International Standard [1].

2.2.5 Anxiety Measures and Scoring. . Participants completed the Trait Anxiety form (Y-2) of the State - Trait Anxiety Inventory (STAI). The State - Trait Anxiety Inventory is a commonly used measure of trait anxiety and according to the American Psychological Association, state anxiety that can be used in clinical settings to diagnose anxiety or distinguish it from depressive symptoms [3]. The 20 item trait questionnaire is used to assess an individualâĂŹs general anxiety as opposed to the state assessment in which the questionnaire is used to quantify an individualâĂŹs current state of anxiety.

3 PROCEDURES

Data was collected on four major intervals for each participant with measures of heart rate, skin conductance, and EEG activity. These intervals included baseline, introduction, virtual reality, and rest recordings. The total length of time for the study for each individual varied approximately from fifteen to thirty-five minutes. Upon entrance, the participant was asked to read and complete an informed consent form, a trait anxiety questionnaire, and the first section of a subject information form, in that order. Afterwards, all sensors (GSR, HR, EEG) were attached to the participant to begin recordings.

3.1 Baseline

The participant is first asked to fill out the baseline portion of the second part of the participant information form with an honest approximation of their anxiety level on a Likert scale of one to ten. The baseline recording consisted of a one-minute period of time in which skin conductance, heart rate, and EEG activity were measured for each individual; this serves as the most important interval of data. To integrate a person-centered approach and take into account the variability of symptom progression between individuals during anxious states, all experimental data collected must be analyzed within the individual as a comparison to their baseline recording.

3.2 Introduction

During the introduction period of the study, a one-minute recording of all metrics began as the research conductor read aloud the following statement: âĂIJThe virtual reality you are about to experience might provoke some stress or anxietyâĂŤ just to remind you, you can remove the headset if you feel uncomfortable. If you begin to feel nauseous or sick, please let one of the operators know and we will escort you to a seat and make a receptacle available.âĂİ While the consent form clearly states minimal potential risks including a possible sense of heightened anxiety, the introduction serves to induce an objectless-fear in the participant - most closely resembling the ambiguity that anxiety represents. After this minute elapsed, the participant was prompted to again fill out the corresponding introduction section of the subject information form reflecting their current anxiety level (post-introduction) on a Likert scale of one to ten.

3.3 Virtual Reality

Once the user was prepared to begin the simulation, the HTC Vive goggles/headset is placed over the EEG system carefully and the user is given earbuds to place in either ear and one HTC Vive controller. The Vive was running the game âĂIJRichieâĂŹs Plank ExperimentâĂİ in which the user is placed in a simulated elevator. The participant is then instructed to select the option on the panel to their right labeled âĂIJPlankâĂİ by moving their controller onto the button in the simulation and to wait for further instruction. This action marks the beginning of the first virtual reality recording referred to as âĂIJVR 1âĂİ spanning thirty seconds. The participant then experiences the simulated elevator gradually rising to the top floor of a skyscraper and the doors open to reveal nothing but a wooden plank at the edge of the doors. Once the thirty-second recording has elapsed, which includes up to 15 seconds of the participant waiting inside the elevator with the doors open, the individual is told the following: âĂIJThe objective is to walk to the edge of the plank and return to the elevator. You will have one minute to complete this task.âĂİ(see Fig 2.) A one-minute âĂIJVR 2âĂİ recording is initiated at the end of this instruction in which the user is monitored as they step forward onto a real physical plank placed on the floor of the study environment (see Fig. 1). If the participant was unable to exit the elevator or expressed hesitation, they were encouraged to do their best. The recording was ended once the minute elapsed or the user completed the objective. The user is then helped to a seat and asked to record their anxiety again on a Likert scale.

3.4 Rest / Recovery

After the simulation, experimenters assisted the participant in carefully removing the VR headset and guiding the participant to a seat. The last recording was a one-minute interval serving as a recovery measure. Once the recovery recording was completed, the participant was asked to fill their last recording of their anxiety on a Likert scale.

4 DATA ANALYSIS

In analysis, participants were split into two groups, those who scored above or equal to 40 on their total trait anxiety form who are considered to have relatively higher than average anxiety, and those who scored below 40 who are considered to have average or low levels of anxiety. This threshold is based on the state anxiety cut off point of what is considered to be above average [8]. The Trait Anxiety (Y-2) score of 40 also closely represents the median score of the collective trait scores of all 10 included participants. The data was split this way to determine whether there is a significant increase in sensitivity to anxious situations physiologically.

All skin conductance and heart rate data were analyzed in Microsoft Excel and Google Sheets. The baseline heart rate and skin conductance data for each participant was averaged and compared to the maximum values from introduction, virtual reality and recovery phases. This was done to reflect the potential maximum severity in percent differences among all participants in all sensor metrics.

The initial recorded Baseline, Intro, VR and Rest task signals were analyzed for the 10 participants. EEG signals were represented in frequency domains using the FFT (fast Fourier transform) to obtain amplitudes of corresponding EEG bands. Amplitude was then squared so that spectral power could be calculated for alpha (7-15 Hz), low-beta (15-20 Hz) and high-beta (20-30 Hz) frequency bands with averages taken according to the individual tasks. These averages were then log-transformed to normalize the distributions for analysis.

5 RESULTS

The results reflect on the potential for individuals with higher trait anxiety to experience more severe physiological symptoms.

5.1 Heart Rate and Skin Conductance Data

A two-tailed unequal variance (heteroscedastic) t-test statistical analysis was ran between the high trait score and low trait score participants for each phase for heart rate and skin conductance. None of the differences between participants with high trait scores and low/average trait scores indicated statistical significance. During the introduction phase, averages in percent increase for heart rate and skin conductance p values were 0.21 and 0.28 respectively indicating no statistical significance. During the virtual reality phase, p values calculated to 0.24 and 0.87 for heart rate and skin conductance, respectively, again resulting in no statistical significance. Finally, for the recovery phase between those with higher (greater than or equal to 40) trait anxiety scores and those with lower (less than 40) trait anxiety scores, there was no statistical significance. P values between percent changes in recovery phase were 0.10 and 0.72 for heart rate and skin conductance, respectively.

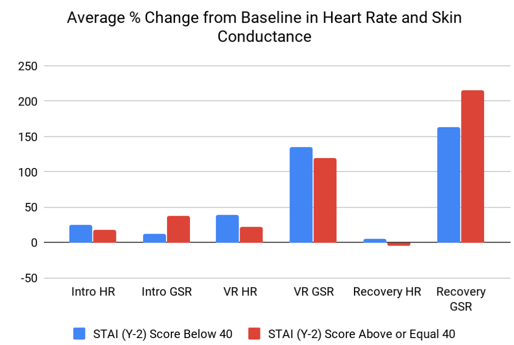

Figure 3: The figure above shows the differences in percent change in heart rate (HR) and skin conductance (GSR) from baseline during introduction, virtual reality (VR) and recovery (rest) phases. There are no noticeable patterns of difference between individuals with trait anxiety scores of above or equal to 40 and below 40.

5.2 Self-Reported Anxiety Scoring

While two-tailed unequal variance (heteroscedastic) t-test results indicated no statistical significance among any populations, more research and a larger sample size would be necessary to draw definitive conclusions on the difference in self-reflected anxiety patterns evident between the two populations.

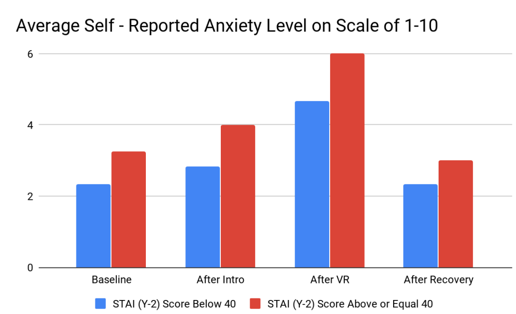

Figure 4: The figure above shows the average of self-reported anxiety levels throughout different phases of the study in participants with STAI (Y-2) Trait anxiety scores of below 40 and participants with scores greater than or equal to 40. The individuals who scored 40 or above on the STAI (Y-2) anxiety scoring also reflected higher levels of anxiety throughout each phase of the study including baseline levels.

5.3 EEG Activity

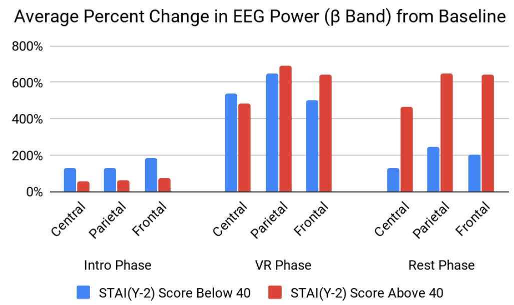

Figure 5: The figure above shows the average percent change in EEG Activity at central, parietal and frontal areas of the skull during introduction, VR and Rest phase. The individuals with STAI (Y-2) scores at or above 40 tend to have higher levels of activity during VR Phase and specifically maintain high levels of activity during the recovery phase of the experiment.

6 DISCUSSION

We hypothesized that individuals who experience anxiety more regularly, and therefore, have higher trait anxiety scores, also experience the same anxious situations as others more intensely, physiologically. The hypothesis that frequently experiencing anxiety makes an individual susceptible to more severe reactions to anxious events and situations could impact the design of person-centered assistive technologies and future anxiety treatment options. The individuals who participated in this study completed form Y-2 of the state trait anxiety inventory corresponding to trait anxiety to indicate their general anxiety levels. To maintain the significance of person-centered data collection, all analyzed biosignals for an individual were calculated as a percent difference from that individualâĂŹs baseline data. While the baseline of an individual with higher trait anxiety may not represent an anxiety-free control, the information is still valuable as a measurement of severity of potential increase in anxiety from their previous state. It is also important to mention that there is potential for the stigma of mental disorders and anxiety to influence participant responses in self-reflected anxiety scoring. To most considerately accommodate potential influence of stigma or fear of judgement, participants were given privacy while completing the trait anxiety form and all participant information was not reviewed until after the individual had left the room.

In this investigative study to better understand how individuals with higher trait anxiety scores react physiologically to anxious situations in comparison to people with lower or average scores, the results determine no statistical significance among average percent differences in heart rate and skin conductance from baseline to all other phases. Considering the large amount of data loss that resulted in a smaller sample size for data analysis among participants with complete data sets, further investigation is required for more definitive conclusions on the relationship of psychophysiological reactions to trait anxiety scores. However, this data does imply that anxious situations can be experienced in many ways.

In the analysis of EEG data, the low amplitude beta (15-30 Hz) wave activity was considered to signify the brainâĂŹs reaction to visually threatening images, active thinking, high alert and anxiety based on previous studies [3]. Thus, when analyzing change in power across central, frontal and parietal areas of the skull, spectral analysis showed increase in power in frontal and parietal areas during the virtual reality and recovery phase for those with higher (greater than or equal to 40) trait anxiety score. The differences in EEG activity among the two groups was not significant in any phase. There seemed to be a pattern of higher sustained EEG activity during recovery phase in individuals with trait anxiety scores of 40 or above, but without further investigation with a larger sample size, the results are inconclusive

The fact that the self-reported Likert scale anxiety scores after every phase were generally higher in individuals who also reported higher trait anxiety scores indicate an alignment of the individualâĂŹs interpretation of their general anxiety levels [9]; however, the physiological reactions of heart rate and skin conductance showed no significant difference between individuals with higher trait anxiety scores and those with lower or average scores. Differences in EEG activity between the two groups revealed no statistical significance in any phase, however a pattern was observed in sustained EEG activity during rest period for individuals with trait anxiety scores at or above 40. This finding implies that varying perceived anxiety scores (STAI Y-2, and Likert scale ratings) are not directly predictive of specific physiological patterns. The evidence from this study indicates that evaluations of an individualâĂŹs anxiety would be more effective if considering the perceived severity of the anxiety over the physiological symptoms of anxiety.

7 CONCLUSION

The results of this research study will broaden the understanding of the manifestation of anxiety in all individuals. Specifically, physiological data patterns such as elevation of heart rate and skin conductance cannot sufficiently determine the state of anxiety an individual may be experiencing. This reaffirms the need for the pursuit of person-centered solutions in which the individualâĂŹs reflected perception of their own anxiety holds the significant value in the appropriate subsequent treatment or intervention options. This study uniquely observes the misalignment with higher trait anxiety scores and perceived likert scale anxiety scores to that of more severe physiological reactions to anxious situations. Additionally, analysis of EEG results indicate a potential pattern of sustained elevated EEG activity after an anxious experience in participants with trait anxiety scores above or equal to 40. The results collected were not statistically significant but further investigation with a larger sample size is required for conclusive patterns to be identified.

This research will serve as the control experiment to future studies on new intervention methods for anxiety symptom treatment. This study also serves as the foundation for further research in using virtual reality simulations to stimulate anxiety while monitoring EEG, skin conductance, and heart rate activity.

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