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## SELF-MONITORING HEART RATE BIOFEEDBACK: A SECONDARY PREVENTION STRATEGY FOR MANAGING ANXIETY IN COLLEGE STUDENTS

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SELF-MONITORING HEART RATE BIOFEEDBACK: A SECONDARY  
PREVENTION STRATEGY FOR MANAGING ANXIETY IN COLLEGE STUDENTS

BY

LOUIS WILLIAM TURCHETTA

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

IN

PSYCHOLOGY

UNIVERSITY OF RHODE ISLAND

2019

DOCTOR OF PHILOSOPHY DISSERTATION

Of

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UNIVERSITY OF RHODE ISLAND  
2019

## ABSTRACT

### **Intro:**

Anxiety is often a chronic condition that will affect approximately 29% of individuals during their lifetimes (Dennis & O'Toole, 2014). Unfortunately, numerous barriers to treatment exist, especially when treating children (Dennis & O'Toole, 2014). Wearable technology, particularly utilizing heart rate monitoring, can potentially aid in the treatment of anxiety, allowing for greater recognition of symptoms and interventions in any setting.

### **Hypothesis:**

Hypothesis one: College students with "mild to moderate" levels of anxiety will be able to utilize self-monitoring heart rate biofeedback (SMHRB) consistently (e.g., respond to at least 70% of Maximum HR alerts utilizing relaxation breathing).

Hypothesis two: participants who consistently implement relaxation breathing in response to a Maximum HR alert will significantly reduce symptoms of anxiety from baseline levels on a global anxiety scale.

### **Methods:**

A series of individual AB designs were used with random assignment to baseline phases to track 7 participants on a global measure of anxiety (CUXOS). Participants with mild to moderate anxiety were measured in pre-baseline, baseline, and intervention phases to examine change due to the self-monitoring heart rate biofeedback intervention. After the baseline phases were completed, participants were trained to use the wrist-worn heart rate monitor to assist with the identification and remediation of symptoms of anxiety. In addition to reporting their weekly CUXOS score through a Google Form via a text message, participants also reported usage information two times daily.

**Results:**

The intervention was considered Effective for four out of seven participants (57%), while it was considered Ineffective for two out of seven (29%) and Minimally Effective for one out of seven (14%). The 4/7 participants who responded well to treatment showed an average reduction on the CUXOS of 15 points. Moreover, most participants (5/7) showed a favorable increase in HRV, which also corresponded to a decrease in CUXOS scores. All seven participants reported the intervention was easy to use, helpful, and that they would continue to use a version of it in the future. However, four out of seven participants stated they had some trouble with the device initially, and three participants noted that the flashing red light (HR alert) sometimes contributed to anxiety. In the reporting of usage information, just under half of all twice daily text message data was submitted by participants on average. This usage data revealed that participants reported wearing the device 90 % of the time during their intervention periods. Of all the heart rate alerts participants received, 37% of them corresponded with subjective feelings of anxiety. Participants intervened with anxiety using the intervention 83% of the indicated times.

**Conclusion:**

Wearable biofeedback interventions may be promising. However, key design features are essential to consider for future research. The ideal design for future research would include using a device compatible with automatic collection of usage and biofeedback data and the use of multiple control groups to verify effective components of an intervention. Lastly, improving the correlation between physiological measures such as heart rate alerts and subjective emotional states is essential. Improving the accuracy of

devices may be accomplished through the use of more complex alert measures such as HRV instead of HR. Alternatively, an extended reporting period, whereby users allow HR measures to become more reliable and provide feedback to researchers in order to select a more accurate beats per minute (BPM) threshold that indicates increased anxiety, could be promising

## **ACKNOWLEDGMENTS**

This research is dedicated to my family; without their support and love none of this would be possible. To my parents, whose emotional support and sacrifice to aid me in everything I do will never be forgotten. To my wife, who endured the long hours and time apart. Her encouragement allowed me to continue to put in the hours necessary to accomplish my professional goals. I am grateful for all of her support, sacrifice, and love.

I must also thank my major professor Dr. Stoner, for all his help and guidance in each stage of this process and throughout the entire program. His words of wisdom always rang true once I was ready to hear them. On occasion it was after he had allowed me to make my own mistakes; however, he was always there to support me.

Lastly, a sincere thank you to my committee for taking the time to be a part of this dissertation and for their guidance along the way. In particular, Dr. Flannery-Schroeder, for her expertise in anxiety research and commitment to this project, and Dr. Brand and Dr. Porto for their time and participation on my committee.

## Table of Contents

ABSTRACT.....	ii
ACKNOWLEDGEMENTS.....	v
TABLE OF CONTENTS.....	vi
LIST OF TABLES.....	vii
LIST OF FIGURES.....	ix
CHAPTER 1: INTRODUCTION .....	1
Summary Statement of the Problem and Overview.....	1
Background and Justification of Study.....	2
Significance of Anxiety.....	3
Theoretical Models of Anxiety and the Connection to HR.....	3
Impediments to Treatment.....	4
Self-monitoring.....	4
Research Questions and Hypothesis.....	6
CHAPTER 2: METHODOLOGY.....	8
Components of SMHRB.....	8
Participants and Recruitment.....	8
Research Design.....	10
Timeline.....	12
CHAPTER 3: RESULTS.....	15
Data analysis strategy.....	15
Individual Participant Results.....	19
Group Summary Results.....	36
CHAPTER 4: DISCUSSION.....	42
Summary of Findings .....	42
Limitations.....	51
Implications for Future Research and practice.....	52
Conclusion .....	54
Appendices:.....	57

Appendix A: Review of Literature.....	57
Appendix B: Measures.....	74
Appendix C: Ethics, Emergency Procedures & Psychoeducation.....	79
Appendix D: Relaxation Breathing Training & Procedure.....	83
Appendix E: Participant Daily Text Message Questions.....	85
Appendix F: Open-Ended Study Conclusion Questionnaire Responses.....	87
Bibliography.....	88

## LIST OF TABLES

TABLE	PAGE
Table 1. Data Analysis Considerations in Evaluating Intervention Effectiveness.....	16
Table 2. Participant 1-James: Fidelity- Usage data.....	21
Table 3. Participant 2-Abby: Fidelity- Usage data.....	22
Table 4. Participant 3-Myra: Fidelity- Usage data.....	24
Table 5. Participant 4-Amin: Fidelity- Usage data.....	27
Table 6. Participant 5-Ginger: Fidelity-Usage data.....	31
Table 7. Participant 6-Belinda: Fidelity- Usage data.....	33
Table 8. Participant 7-Sondra: Fidelity- Usage data.....	36
Table 9. Summary of Treatment Responders.....	39
Table 10. Summary of Participant Usage.....	40

## LIST OF FIGURES

FIGURE	PAGE
Figure 1. Participant 1 Weekly CUXOS Scores.....	20
Figure 2. Participant 2 Weekly CUXOS Scores.....	22
Figure 3. Participant 3 Weekly CUXOS Scores.....	25
Figure 4. Participant 4 Weekly CUXOS Scores.....	27
Figure 5. Participant 5 Weekly CUXOS Scores.....	30
Figure 6. Participant 6 Weekly CUXOS Scores.....	32
Figure 7. Participant 7 Weekly CUXOS Scores .....	35

## **Chapter 1:**

### **Summary Statement of the Problem and Overview**

It is estimated that 32 % of adolescents will be diagnosed with an anxiety disorder at one time in their lives (Merikangas et al., 2010). Furthermore, 22% of adolescents may be suffering from anxiety during a one-year period, which amounts to approximately 13.4 million adolescents in the United States (NIMH, Harvard National Comorbidity Study, 2017). Untreated, anxiety disorders can impair a person's ability to learn, self-regulate, and can severely affect their relationships (Beesdo, Knappe, & Pine, 2009). For a variety of reasons, up to 80% of adolescents with an anxiety disorder do not receive treatment (Taras et al., 2004). Recently, self-monitoring and biofeedback have been used to support relaxation and aid in the reduction of the body's sympathetic nervous system responses to anxiety-provoking stimuli (Prinsloo, Derman, Lambert, & Rauch, 2013). Although there is evidence supporting the use of self-monitoring and biofeedback in the treatment of anxiety, few if any studies have examined the effectiveness of using wearable biofeedback devices for the management of anxiety in natural environments such as an educational setting. Adolescents spend a majority of their time in educational settings; thus, exploring treatment options that are compatible with these settings is essential to improvements in treatment. New technology has made heart rate biofeedback more available, comfortable, convenient, and even fashionable. Although this technology has developed rapidly in recent years, there is a need for more studies examining its use and effectiveness, particularly with youth in schools.

Two central research questions have been investigated in this research study.

Research question one sought to determine: to what extent adolescents with symptoms of

anxiety utilize the self-monitoring heart rate biofeedback (SMHRB) intervention consistently? Within the scope of the first research question, there was an examination of information pertaining to how the intervention (independent variable (IV)) was applied. For example: a) how often did students respond to a HR alert and initiate relaxation breathing, or recognize the alert but not initiate any intervention at all; b) how often did students use relaxation breathing without a maximum HR alert; c) how often did the alert not correlate with subjective self-assessment of anxiety? Participants responded to a Google Form that (submitted via text message, twice daily) provided information about the independent variable in order to substantiate how it was being used.

Research question two addressed the effectiveness of the intervention in reducing symptoms of anxiety as measured by a global anxiety measure, the Clinically Useful Anxiety Outcome Measure (CUXOS).

Hypothesis one: College students with "mild to moderate" levels of anxiety will be able to utilize self-monitoring heart rate biofeedback (SMHRB) consistently (e.g., respond to at least 70% of maximum HR alerts utilizing relaxation breathing). Hypothesis two: participants who consistently implement relaxation breathing in response to a Maximum HR alert will significantly reduce symptoms of anxiety from baseline levels on a global anxiety scale.

### **Background and Justification of the Study**

New technologies and innovations are offering treatment alternatives that utilize wearable technology, biofeedback, and smartphones. The ubiquity, availability, and cross-cultural acceptance of these interventions allow them to traverse traditional barriers to treatment such as cost, accessibility, time commitment and negative stigma (Dennis &

O'Toole, 2014). SMHRB could be a tool that allows users with moderate symptoms of anxiety to effectively intervene in a manner that reduces these traditional barriers, and could be used as an effective adjunct to more traditional therapy. This research centers on symptoms of anxiety, particularly focusing on reducing the specific symptom of increased heart rate in response to stress. Furthermore, a description of the integrated components of SMHRB are included. Together, these integrated components offer promise for a reduction in symptoms of anxiety. The research will also offer a rationale for why there is a need for an effective, portable, on-demand intervention for symptoms of anxiety.

**Significance of anxiety.** Anxiety disorders are the most prevalent of all psychological disorders (Beesdo, Knappe, & Pine, 2009). Anxiety is characterized by chronic symptoms of persistent worry (Parker, 2015) and can manifest with a variety of physical and emotional symptoms (Goldberg, 2014). Evidence suggests that those with the condition are at an increased risk for developing other chronic medical conditions, suffer more severe medical symptoms, and have a higher mortality rate (Parker, 2015).

Anxiety also can interfere with the ability to regulate thoughts, actions, and emotions. These thought disruptions are particularly concerning for adolescents in secondary and postsecondary educational settings. The relationship between poor test performance and anxiety is well-documented. However, less apparent is that anxiety can have a significant impact on education as a whole. Specifically, anxiety may disrupt the short-term memory involved in learning. Moreover, there is evidence to suggest that chronic stress during key developmental periods can change brain structures permanently, thus impairing future learning, behavior, and health (Shonkoff et al., 2011).

**Theoretical models of anxiety and the connection to HR.** There are multiple theories related to heart rate and the etiology and treatment of anxiety. One prevalent theory describes the etiology of anxiety as inherited in and manifested in childhood temperament and heart rate variability (HRV) (Ratanasiripong et al., 2004). There are other theoretical models that describe the relationship between physiology and psychological functioning. For example, the neurovisceral model of anxiety describes a relationship between the cognitions involved in regulating anxiety and the autonomic response. Additionally, the polyvagal theory describes the relationship between deliberate actions by the individual that result in changes in biological states, such as relaxation breathing and relaxation efforts (Quintanna et al., 2012). (See Literature Review in Appendix A for a more in-depth review of biological theories related to stress.)

**Impediments to treatment.** A variety of impediments to quality treatment for anxious youth include treatment costs, time commitment, accessibility (Dennis & O'Toole, 2014), and issues with the acceptability of treatment (Herzig-Anderson et al., 2012). The various obstacles to quality community-based treatment influence approximately 70% of students diagnosed with anxiety to receive some support in schools instead of clinical settings. Although schools offer advantages to obtaining treatment, such as reduced transportation and family costs, in many cases schools are overwhelmed and lack the resources to adequately support students who would benefit most from obtaining treatment for anxiety (Herzig-Anderson et al., 2012; Taras et al., 2004).

### **Self-monitoring**

Many technologies that allow for improvement in symptoms of anxiety utilize some aspect of self-monitoring (SM). Self-monitoring is the act of measuring one's behavior (target) and comparing it to an external standard or goal that can result in lasting improvements to that behavior (Kazdin, 1989).

SM permits students to track their mental states independently, and improvements in behavioral outcomes have been noted with SM without any additional intervention (Shapiro & Cole, 1999). SM has been used to improve a variety of behaviors, including: social skills, work completion, and self-regulating behaviors involved in anxiety. Through self-monitoring, individuals can learn to recognize emotional states and to identify and differentiate various emotions in different contexts (Kauer et al., 2012). Increasing awareness of emotions is an essential step in training individuals to change their cognitions, beliefs, schemas, and behaviors (Kauer et al., 2012; Walker & Shinn, 2002). Additionally, students who efficiently use processes such as self-monitoring typically have higher levels of self-efficacy, motivation, and educational achievement (Zimmerman, 2002).

Self-monitoring has shown utility as an intervention for internalizing disorders; however, students often need assistance to initially begin to self-monitor their emotions, thoughts, and behaviors (Flannery-Schroeder & Lamb, 2009). Technological devices may offer a particular advantage for SM (Craske et al., 1999; Kauer et al., 2012), and Kauer et al. report that tech-enhanced self-monitoring may increase emotional self-awareness (ESA) and reduce symptoms of internalizing disorders.

Using a maximum heart rate alert function on a HR monitor could serve as a prompt to initiate event recording as well as a prompt to initiate restorative behaviors

aimed at self-regulation of emotion. The prompt may permit users to notice their environment, circumstances, feelings, and emotions and then correlate them with HR. The device may also have the capacity to assist in teaching students to recognize distress directly and immediately employ self-regulation techniques to normalize heart rate, emotions, and potentially reduce symptoms of anxiety.

The goal of SMHRB is for users to learn to identify their stress symptoms through recognition of their physiological states and initiate relaxation breathing without outside assistance. However, external prompting is an intermittent step that allows for scaffolding between assisted and organic recognition and relaxation breathing. External prompting may thereby increase the probability of users increasing their emotional and physical self-awareness in the future (Shapiro & Kratochwill, 2000). (See Appendix A Literature Review for more information and previous research on self-monitoring.)

Although there is evidence supporting the use of HR and HRV biofeedback with anxiety, few, if any, studies have examined the effectiveness of a HR biofeedback intervention with anxious adolescents in their natural environment. Interventions using biofeedback are increasing, and there is a need for more studies examining its use and effectiveness, particularly with adolescents in educational settings. Determining whether adolescents will consistently utilize heart rate self-monitoring with fidelity is important and was a focus of this investigation. Moreover, if students do consistently utilize this intervention, establishing how effective the intervention is in reducing anxiety will provide valuable information to the ongoing development of treatments for this chronic problem.

## **Research Questions and Hypothesis**

Two central research questions were investigated. Research question one sought to determine to what extent adolescents with symptoms of anxiety will consistently utilize a SMHRB intervention? Within the scope of the first research question, there was an examination of information pertaining to treatment fidelity, or how the intervention (independent variable (IV)) was applied. For example, how often did participants: a) respond to a HR alert and initiate relaxation breathing, or recognize the alert but not initiate any intervention at all; b) how often did students use relaxation breathing without a maximum HR alert; c) how often did the alert not correlate with subjective self-assessment of anxiety? Participants responded to a Google Form (submitted via text message, twice daily) that provided information about the independent variable in order to substantiate how it was being used.

Research question two addressed if the intervention was effective in reducing the symptoms of anxiety as measured by a global anxiety measure, the Clinically Useful Anxiety Outcome Scale (CUXOS).

Hypothesis one: College students with "mild to moderate" levels of anxiety will be able to utilize self-monitoring heart rate biofeedback (SMHRB) consistently (e.g., respond to at least 75% of maximum HR alerts utilizing relaxation breathing). Hypothesis two: participants who consistently implement relaxation breathing in response to a Maximum HR alert will significantly reduce symptoms of anxiety from baseline levels on a global anxiety scale.

## **Chapter 2:**

### **METHODOLOGY**

#### **Components of SMHRB**

Self-monitoring is the first component of the SMHRB intervention. The act of monitoring behavior and comparing it to an external standard has, in and of itself, demonstrated improvement in the desired outcome behavior (Kazdin, 1989). A benefit of self-monitoring is physiological self-awareness. Through practice with self-monitoring heart rate, an increase in awareness of the relationship between emotional symptoms (i.e., fear, worry, stress) and physical symptoms (i.e., increased heart rate [HR]) of anxiety may be possible. Self-monitoring through the use of a HR alert may improve physiological self-awareness over time and allow a user to recognize and act on their symptoms more frequently and more accurately over time. The second component of the intervention is slow, relaxed breathing. Combining breathing with HR biofeedback may potentially enhance the speed and degree of symptom relief. The combination of these components of SMHRB was tested as one intervention with college students at the University of Rhode Island using a series of individual AB designs. The research study allowed for the collection of quantitative and some qualitative information on the practicality, usability, and future potential of interventions utilizing SMHRB.

The current study utilized an intervention that incorporates self-monitoring and heart rate biofeedback with symptoms of anxiety. This section begins with a description of the participants involved and eligibility procedures. Next, tools and measures used in the research are described. Finally, a description of the research design and timeline is provided.

## **Participants and Recruitment**

After IRB approval was obtained, a convenience sample of seven URI undergraduates was recruited. Recruitment was initiated through posting the IRB approved flyer on social media sites accessible to students and through a General Psychology course email. Students were free to participate without penalty or coercion and could opt out at any time. Prior to obtaining informed consent, participants were provided an in-depth description and full disclosure of procedures. Although unlikely, a participant who did not see improvement could have become frustrated with their participation. As such, students were made aware that they could opt for a referral for counseling at any point during the study.

**Inclusion criteria.** Once recruited, students were administered the CUXOS anxiety inventory and those who met the criteria of having “Mild to Moderate” symptoms of anxiety, defined as a score between 21-40 on the Clinically Useful Anxiety Outcome Scale (CUXOS), were considered eligible. Participants were required to be between the age of 18-25; willing to communicate with the researcher by text message; and willing to complete electronic surveys via Google Forms two times per day throughout their participation in the study.

**Exclusion Criteria.** Students were administered a global screener, DSM-5 Cross-Cutting Symptom Measure (DSM-5 CCSM, in person, paper and pencil version: see Appendix B for detailed administration instructions), to determine the potential for other causal factors of distress besides symptoms of anxiety. The DSM-5 CCSM is a global screening (level 1) measure that indicates whether participants should be screened further for specific disorders. For example, while the screener has several disorder categories, if

a participant endorses any question in a specific category (e.g., depression) on the global (level 1) screener that indicates the potential presence of depression, then a more specific (level 2) depression evaluation screening would be conducted. Participants who indicated mild symptoms or higher on the second, more-specific disorder measure (level 2) would have been extended a referral and excluded from the study (see Appendix B for procedures for students with significant mental health concerns). Participants who endorsed symptoms of a disorder (other than anxiety) on the first general level 1 screen and did not indicate mild symptoms of the disorder on the more comprehensive level 2 screen were still eligible for the study. Once participants were administered the CUXOS and DSM-5 CCSM, the items were scored immediately, and students knew of their eligibility status prior to leaving the initial assessment meeting. Students were eligible if they had not engaged in therapy or taken medication for anxiety for one year before the study, or if they were not receiving pharmacotherapy or psychotherapy for anxiety during the study. Furthermore, no student who was enrolled in classes taught by the researcher participated in the study. Nine students were recruited and screened; two students were found ineligible as they were already participating in treatment for anxiety with mental health service providers. Seven participants remained part of the study for 9 weeks. They were all students attending the University of Rhode Island, and were between the ages of 18 and 23. Two participants were male and five female.

### **Research Design**

A series of seven individual AB designs were used for this research. Seven participants were each randomly assigned to a baseline phase one, two, or three weeks. This design allowed each participant's no treatment phase (BP) data to act as his/her own

control for behavioral comparison with the intervention phase data. Once baseline phases ended, the application of the experimental variable to a participant was expected to produce a change when the intervention was employed (Barlow & Hersen, 1984).

**Independent variables.** The independent variables (IVs) in this study were comprised of two components that make up the SMHRB intervention. The first is self-monitoring of heart rate using a wearable electronic monitor, and the second is the use of relaxation breathing techniques. These components were combined in the study and theorized to more effectively reduce symptoms of anxiety than unaided self-monitoring and breathing.

The relaxation breathing component (slow, relaxation breathing) was taught to participants in individual meetings with the primary investigator. Participants were taught a five-step method of slow, calm breathing (see Appendix C for detailed breathing procedures). After mastering these breathing techniques, participants were taught to use them in conjunction with increased heart rate alerts as indicated via the wearable device described in the next section. Prior to entering into the intervention phase of the study, each participant demonstrated the ability to reduce elevated heart rate by 5 beats per minute as a function of using relaxation breathing.

Participants were also taught to use a wrist-worn heart rate monitor, the Mio ALPHA 2. The HR monitor was used to alert participants, via a flashing red light, if and when they had reached a predetermined max heart rate, indicating a potentially anxious state. The alert was set for 5 BPM above the baseline resting heart rate obtained for each participant (see Appendix B for detailed information on obtaining resting HR). 5 BPM is

within the range observed as a typical spike while experiencing symptoms of anxiety (Stewart, Buffett-Jerrott, & Kokaram., 2001).

Throughout each participant's intervention phase, he/she was asked to wear the device during their waking hours. Furthermore, they were instructed that, in the event of a maximum HR alert that was accompanied by subjective feelings of anxiety, they should begin slow relaxation breathing intended to reduce HR. For each HR alert and breathing intervention episode, participants were instructed to discontinue relaxation breathing when either they felt more relaxed or when their HR-BPM had been restored to a normal range (close to their resting HR). Participants were asked to only engage in relaxation breathing when they experienced feelings of discomfort (i.e. symptoms of anxiety.)

As a check on participant use of these intervention components, brief surveys were administered via text message twice daily. These text messages included five short questions, including: did you wear the monitor?; how many times did the monitor alert you?; and how many times did you use the breathing techniques? (See Appendix E for a complete list of daily questions.)

**Dependent variables.** The present study used two primary dependent variables to measure symptoms of anxiety: one was utilized weekly while the other was used as a pre-post measure only. The weekly measure, the Clinically Useful Anxiety Outcome Scale (CUXOS), was administered to each participant in person during the eligibility meeting and then via a text message link to a Google Form thereafter. The (CUXOS) consists of 20 questions focused on global symptoms of anxiety. It has been shown to be reliable and valid based on multiple studies (See Appendix B for technical adequacy information).

A second dependent variable, heart rate variability (HRV), was measured in each

participant at two points in time: once at the end of the baseline phase and once after the conclusion of the intervention phase. HRV was obtained by using the Polar H10 HR Monitor with chest strap. HRV is measured by analyzing the time between heartbeats. Participants wear the chest strap monitor for approximately five minutes to detect HRV. HRV was measured by using the average of the three, five-minute assessments as an overall indicator of HRV. HRV has been shown to correlate with anxiety and has been used consistently in a variety of studies as a measure of overall stress and psychological functioning (Sharma, Balhara, Sagar, Deepak, & Mehta, 2011).

### **Timeline**

Two groups of three participants began the study simultaneously in a no-intervention baseline phase, and participants within each group were randomly assigned to remain in baseline for differing lengths of time (one, two, or three weeks). Staggered baselines allowed for comparisons both within and between participants, as well as between intervention and baseline phases during the same time period, to allow for observed behavior change to be attributed to the intervention (internal validity). Arranging differing baseline lengths, and as a result having varied treatment lengths allowed for more control and detection of historical events that may influence results. For example, it is conceivable that participants may have an increase on the CUXOS during one week due to a common factor such as midterm exams.

The study lasted nine weeks, with participants remaining in an intervention phase for a minimum of six weeks. Participants' time in the intervention phase ranged from six to eight weeks depending on their randomly assigned baseline phase (one to three weeks). For example, one week in BP resulted in eight weeks in the intervention phase.

Participants were trained on the SMHRB intervention once their randomly assigned baseline phase ended. This time frame is considered realistic for data collection based on standards for interventions performed in education settings (Hixon, 2008). Additionally, this time frame is consistent with other intervention timelines in other research with anxiety and biofeedback (e.g., Houser et al., 2013). Also, McKee (2008) indicates that biofeedback interventions start to show results of training generalization during this time frame as well.

## **Chapter 3:**

### **RESULTS**

This section is organized in the following manner. First, the overall data analytic strategy is presented. Then, the results for each participant are presented, including graphed quantitative data, fidelity of implementation (usage) data and a summary of participant feedback in response to questions asked about the treatment. Next, an overall summary of outcomes is provided followed by summary of all participant usage data. Finally, a summary highlight of qualitative information obtained from participants open-ended questions is provided.

#### **Data Analysis Strategy and Decision-Making Rubric**

The categorical independent variable in this study was the intervention (SMHRB), which was compared to a no-treatment baseline phase (BP) for each participant. Descriptive statistics (e.g., percentage of HR monitor provided alerts that corresponded to subjective anxiety) were used to estimate the accuracy of the HR alert as well as the frequency and type of intervention the college student participants utilized (e.g., relaxation breathing, or no action). The dependent variables were the values obtained on CUXOS and the HRV measure.

For each participant, five metrics were used to determine the effectiveness of the intervention. Four metrics were based on CUXOS scores, and one metric was based on the HRV measure. The metrics used were as follows: average weekly rating score change during the intervention phase (i.e., slope of change over the time of the intervention); percentage of nonoverlapping treatment phase data points between the lowest baseline score and all of the treatment scores; overall quantitative change from last baseline point

to last treatment point; categorical severity level change from the last baseline point to the last treatment point; and change in HRV between the pre- and post-test assessment.

Table one provides a summary of the data analytic strategy for the evaluation of obtained results.

Table 1.

<b>Data Analysis Considerations in Evaluating Intervention Effectiveness</b>			
Method (Criteria) (Metric)	Description	Example Criterion "Met"	Non-Example Criterion "Not Met"
<b>CUXOS Slope of intervention phase data.</b>	Mean weekly change for treatment was calculated by using the formula $(y1 - y2 / x1 - x2)$ whereby the difference between the first and last CUXOS treatment scores are divided by the difference between the corresponding treatment periods. This yields the average weekly change in CUXOS points and this criterion is required to be negative.	Weekly Change = <b>-1.87</b>	Weekly change = <b>.05</b>
<b>CUXOS Percentage of Nonoverlapping data points (PND)</b>	This metric identifies data of similar values across baseline and treatment conditions. First, the lowest baseline CUXOS score is identified. Then the number of treatment phase CUXOS scores falling below the lowest baseline score is identified and calculated into a percentage of total treatment phase scores. The criterion for determining effectiveness is 50% or more of the CUXOS treatment phase scores must be below the lowest CUXOS baseline score.	Participant's lowest CUXOS baseline phase score (30). Treatment scores = 28,24,28 32, 32, 26. 4/6 ( <b>67%</b> ) of the treatment scores are below the extreme baseline score (30).	Participant's lowest CUXOS baseline phase score (27). Treatment scores = 28,24,28 32, 32, 26. 2/6 ( <b>33%</b> ) of the treatment scores are below the extreme baseline score (30).
<b>CUXOS Quantitative Change from Baseline</b>	This metric examines change in participant level of anxiety according to the CUXOS categorical system. A quantitative change requires a <b>decrease</b> in score on the CUXOS of at least <b>5 points</b> between the last treatment score and the last baseline score. 5 points is roughly equal to ½ the distance between 2 levels (e.g. Moderate Anxiety. (31) - Mild Anxiety. (21) Difference = 10).	A participant scored 40 on their last BL CUXOS phase and 35 on their last treatment CUXOS. <b>Change of -5</b>	A participant scored 21 on their last BL CUXOS and 19 on their last treatment CUXOS. <b>Change of only -2</b>
<b>CUXOS Categorical Severity Level Change</b>	A <b>decrease</b> in categorical level on the CUXOS from the last baseline score to the last treatment score. Non anxious      0-10 Minimal anxiety    11-20 Mild anxiety        21-31 Moderate anxiety   31-41 Severe anxiety     41 and above	A participant scored 33 in their last week in a baseline phase and 25 in their last week in the treatment phase. -Change from <b>Moderate to Mild</b>	A participant scored 33 in their last week in a baseline phase and 31 in their last week in the treatment phase - <b>No Change</b> moderate level

<b>Heart Rate Variability (HRV)</b>	This metric provides for a comparison of HRV between baseline and treatment conditions. HRV consists of the variation among the intervals between heartbeats and is measured in milliseconds (ms). More variability between beats is considered better as it indicated more flexibility in responding to stimuli. - Any <b>increase in HRV</b> is counted a positive criterion toward an overall rating of effective.	A participant scored 95 on their Pre HRV measurement and 105 on their Post measurement. <b>+10 difference</b>	A participant scored 95 on their pre HRV measurement and 92 on their post measurement. <b>-3 difference</b>
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**\*Effective**-Four or more criteria met, **Minimally Effective**-Two or three criteria met, **Not Effective**-1 or less criterion met. \*Note: Lower CUXOS scores are desired.

Categories of *Effective*, *Minimally Effective* and *Not Effective* were created based on the number of effectiveness criteria participants met, across the five metrics. The benchmarks used for each criterion are listed in Table 1 and determined the manner in which that criterion was counted toward the overall effectiveness rating. For a rating of Effective, at minimum four out of five of the criteria were required to be met. A rating of Minimally Effective required two or three of the criteria to be met. Lastly, for a rating of Not Effective, one or fewer of the criteria were met.

In evaluating criteria, it was important to consider trends in the outcome data, such as a gradual decline in symptoms from baseline to the conclusion of the intervention, as this may be indicative of the manner in which symptoms of anxiety respond to an intervention and potentially indicate that the intervention is having an effect (Alberto & Troutman, 1990; Barlow & Hersen, 1973; Hixon et al., 2008). Using a trendline (i.e. line of best fit, slope) for visual inspection serves this purpose. The trendline depicted in all figures presented was calculated using Microsoft Excel’s linear regression function. However, for ease of interpretation, a simple slope was calculated that yielded the rate of CUXOS rating change per week. The simple slope was calculated using the formula  $(y_1 - y_2 / x_1 - x_2)$  and entering CUXOS scores and corresponding treatment week. Only the treatment phase slope was calculated, as in some instances

there were not enough data points obtained in baseline phase to establish stability. A negative slope indicates a reduction in CUXOS scores across the intervention phase (i.e., the desired direction).

Further evaluation was accomplished through visual inspection of the CUXOS data to determine the intervention's effects. Determining the percentage of overlapping CUXOS data points between the range of baseline scores and all of the intervention scores also helped determine whether the intervention had an effect. This method is commonly referred to as the percentage of non-overlapping data points (PND). PND is a simple measure of effect size for small subject design research (Riley-Tillman & Burns, 2009) that calculates the percentage of intervention data points that do not overlap with the defined extreme baseline phase data point (Campbell, 2004). According to Scruggs and Mastropieri (1998), a PND less than 50% is considered to warrant a conclusion of "no observed effect". The present study required 50% or more of non-overlapping data points in order to be counted toward the overall effectiveness rating.

In addition to visual inspection, examining the quantitative change in CUXOS scores between the last baseline score and last treatment score is useful for understanding the magnitude of change throughout the intervention. A minimum change of minus 5 points was required to meet the criteria in order to count toward the overall effectiveness rating.

Furthermore, evaluating categorical severity level changes measured on the CUXOS assisted in determining whether the intervention showed practical utility. For example, if a participant who scored in the moderate range of anxiety symptoms on the CUXOS in the final baseline phase, and by the conclusion of the study showed a

reduction of symptoms that could now be classified in the mild category on the CUXOS, this result would indicate a practically significant change and count toward overall effectiveness.

The final evaluation metric, HRV, was assessed using a heart rate monitor and is based on the difference between the pre-intervention- and post-intervention measurements. An increase in HRV over time is desirable indicating more flexibility in responding to environmental stimuli and potentially signifying reduced stress. HRV is measured in milliseconds (ms) and an increase in HRV between the start and end of the treatment phase was considered another positive criterion toward the evaluation of effectiveness.

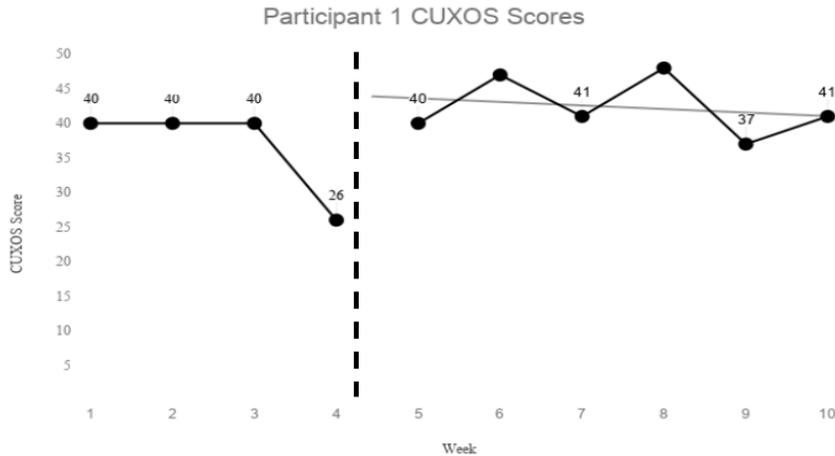
Finally, although not included in the evaluative criteria for formal designation of a category (e.g., effective, ineffective, minimally effective), an analysis of participants' subjective experiences of the intervention was summarized and evaluated. (See Appendix G for a complete compilation of participants' responses.) Participants were assigned pseudonyms to protect their identity, however common gender names are used and are consistent with their actual gender.

### **Individual Participant Data**

#### **Participant #1 - James.**

*Treatment results for James.* Outcome data for James' CUXOS scores are provided in the graph in Figure 1.

Figure 1.



Overall, James’ data met one out of the five evaluation effectiveness criteria, for a resultant overall effectiveness rating of Not Effective. James’ intervention results can be described as follows. To begin, the average weekly change of the CUXOS scores was  $+.20$  during the treatment phase. A percentage of non-overlapping data (PND) evaluation revealed that 0 % of CUXOS scores in the treatment phase fell below the lowest CUXOS baseline score, thus indicating no change due to treatment was detectable. These two indicators suggest insignificant effectiveness of the treatment. Related findings were discovered in comparing the change in score from the last CUXOS baseline score to the last CUXOS treatment score, which showed an increase of 15. Similarly, there was no change in categorical severity level on the CUXOS and his scores remained in the moderate anxiety range across both phases. Finally, on the measure of heart rate variability (HRV), the difference between the baseline measurement and post-treatment measurement was  $-8.9$  ms ( $-10\%$  change), indicating an unfavorable decline in HRV that parallels James’s increase in CUXOS Scores.

***Fidelity of treatment self-reporting.*** Table 2 contains a summary of James’ self-reported treatment usage information.

Table 2.

<b>James: Fidelity- Usage data</b>	
Responses collected out possible reporting periods during intervention (2x daily)	43%
Proportion of daytime device was worn	100%
Alerts with Anxiety "Device Anxiety Accuracy detection"	38%
Usage of SMHRB for Alerts with Anxiety	94%
Breathing w/o Device	0
<b>Determination:</b>	<b>High Usage/ Low Reporting:</b>

James completed 43% of the daily response requests, and of these responses he reported wearing the heart rate device 100% of the time. Out of the total number of alerts reported, 38% corresponded with subjective feelings of anxiety. Of the 38% of alerts that corresponded with self-identified anxiety, James responded to those 94% of the time using the SMHRB intervention. Finally, James did not engage in the relaxation breathing without the heart rate monitoring watch.

*Summary of self-reported subjective experience of the treatment.* James reported the intervention was "very simple to use," aside from getting used to the watch functions initially. Further, he expressed it was difficult to respond quickly to daily questions, especially because these seemed to be asked at times that were inconvenient such as "in the middle of class." He also commented on the red flashing light on the watch that is intended to alert the participant of an elevated heart rate. James noted that the red light in some ways "became a trigger of sorts," alerting the participant to be aware of being anxious when on a number of occasions, indeed, he was not anxious. He also expressed that the intervention was "Definitely helpful overall" and stated that he felt "more relaxed." Finally, James reported he would use the breathing strategies in the future "for

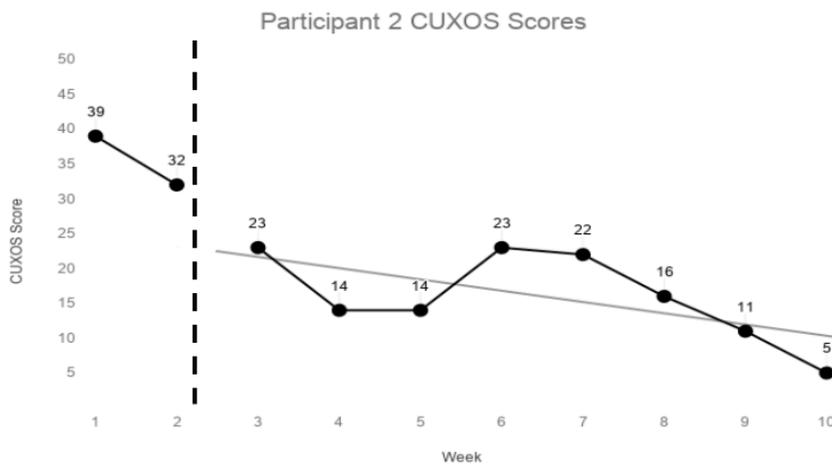
sure” and, while he would not wear the watch as much in the future, he would, however, use it on a more limited basis to assist with anticipated stressful experiences.

The information presented here suggests the treatment was not effective for James even though he appeared to use the treatment with fidelity. Nonetheless, James reported the intervention was easy to use and he further indicated his intent to utilize the strategies in the future.

**Participant #2- Abby.**

*Treatment results for Abby.* Outcome data for Abby’s’ CUXOS scores are provided in the graph in Figure 2.

Figure 2.



Overall, Abby’s’ data met five out of the five evaluation criteria for effectiveness, for a resultant overall treatment rating of Effective. Abby’s intervention results can be described as follows. To begin, the average weekly change of the CUXOS scores was - 2.4 during the treatment phase. A percentage of non-overlapping data (PND) evaluation revealed that 100% of CUXOS scores in the treatment phase fell below the lowest CUXOS baseline score, thus indicating a reliable change due to treatment was detectable.

These two indicators suggest significant effectiveness of the treatment. Related findings were identified in comparing the change in score from the last CUXOS baseline score to the last CUXOS treatment score which showed a decrease of 27. Similarly, there was a substantial change in categorical severity level on the CUXOS and her scores moved three levels from the Moderate Anxiety category to the Non-anxious category. Finally, on the measure of heart rate variability (HRV), the difference between the baseline measurement and post-treatment measurement was +11.5 ms (+11% change), indicating a favorable increase in HRV that parallels Abby’s decrease in CUXOS Scores.

***Fidelity of treatment self-reporting.*** Table 3 contains a summary of Abby’s self-reported treatment usage information.

Table 3.

<b>Abby: Fidelity- Usage data</b>	
Responses collected out possible reporting periods during intervention (2x daily)	78%
Proportion of daytime device was worn	84%
Alerts with Anxiety "Device Anxiety Accuracy Detection"	35%
Usage of SMHRB for alerts with Anxiety	100%
Breathing w/o device	15
<b>Determination:</b>	<b>High Usage/ High Reporting:</b>

Abby completed 78% of the daily response requests, and of these responses she reported wearing the heart rate device 84% of the time. Out of the total number of alerts reported, 35% corresponded with subjective feelings of anxiety. Of the 35% of alerts that corresponded with self-identified anxiety, Abby responded to those 100% of the time

using the SMHRB intervention. Finally, Abby reported engaging in relaxation breathing without the heart rate monitoring watch 15 times.

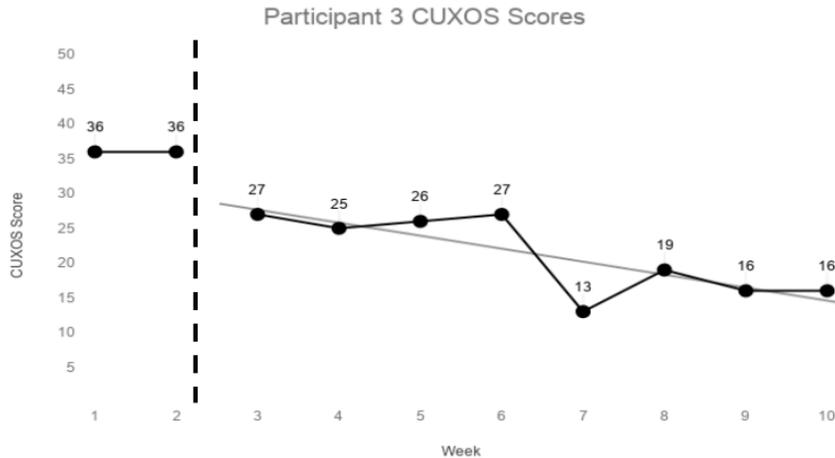
*Summary of self-reported subjective experience of the treatment.* Abby reported feeling as though the intervention was “easy to use,” once she was able to turn the wrist worn device on and off and gained practice tracking heartbeat. Abby expressed that the only difficulty was at first when there was some complication with charging the device. Overall, Abby said there was a large difference between her level of anxiousness at the beginning and end of the study and that she went from “extremely anxious, worrying about little things ....to...barely have[ing] anxiety and much more calm and relaxed”. Additionally, Abby said she would continue to use the intervention, but not every day as she did in the study. Lastly, Abby found the tracking of elevated HR alerts to be difficult to accomplish completely accurately.

The information presented here suggests the treatment was effective for Abby, as all measures showed improvement and her outcomes produce a change of three categorical levels on the CUXOS. She submitted her usage results regularly and reported high levels of usage as well. Abby also reported the intervention was easy to use and that she would keep using it.

**Participant #3- Myra.**

*Treatment results for Myra.* Outcome data for Myra’s’ CUXOS scores are provided in the graph in Figure 3.

Figure 3.



Overall, Myra’s data met five out of the five evaluation effectiveness criteria, for a resultant overall effectiveness rating of Effective. Myra’s intervention results can be summarized as follows. First, the average weekly change of the CUXOS scores was  $-1.5$  during the treatment phase. A percentage of non-overlapping data (PND) evaluation revealed that 100% of CUXOS scores in the treatment phase fell below the lowest CUXOS baseline score, thus indicating a reliable change due to treatment was detectable. These two indicators suggest significant effectiveness of the treatment. Related findings were discovered in comparing the change in score from the last CUXOS baseline score to the last CUXOS treatment score which showed a decrease of 20 points. Similarly, there was a substantial change in categorical severity level on the CUXOS and her scores resulted in a change of two levels from the Moderate Anxiety range to the Minimal Anxiety range. Finally, on the measure of heart rate variability (HRV), the difference between the baseline measurement and post-treatment measurement was  $+25$  ms (75% change), indicating a favorable increase in HRV that parallels Myra’s decrease in CUXOS Scores.

***Fidelity of treatment self-reporting.*** Table 4 contains a summary of Myra’s self-reported treatment usage information.

Table 4.

<b>Participant 3-Myra: Fidelity- Usage data</b>	
Responses collected out possible reporting periods during intervention (2x daily)	26%
Proportion of daytime device was worn	100%
Alerts with Anxiety "Device Anxiety Accuracy Detection"	66%
Usage of SMHRB for Alerts with Anxiety	90%
Breathing W/o Device	32
<b>Determination:</b>	<b>High Usage/ Low Reporting:</b>

Myra completed 26% of the daily response requests, and of these responses she reported wearing the heart rate device 100% of the time. Out of the total number of alerts reported, 66% corresponded with subjective feelings of anxiety. Of the 66% of alerts that corresponded with self-identified anxiety, Myra responded to those 90% of the time using the SMHRB intervention. Finally, Myra reported engaging in relaxation breathing without the heart rate monitoring watch 32 times.

***Summary of self-reported subjective experience of the treatment.*** Myra reported that the intervention was “very easy to use,” and it became part of her “daily routine.” She also liked the text reminders and said having the app on her phone was helpful. She said other than occasionally forgetting to report her daily usage, she had no other difficulties using the intervention. Myra also found the intervention helpful in becoming “more mindful” about her anxiety, describing it as an alternative strategy to “taking a nap

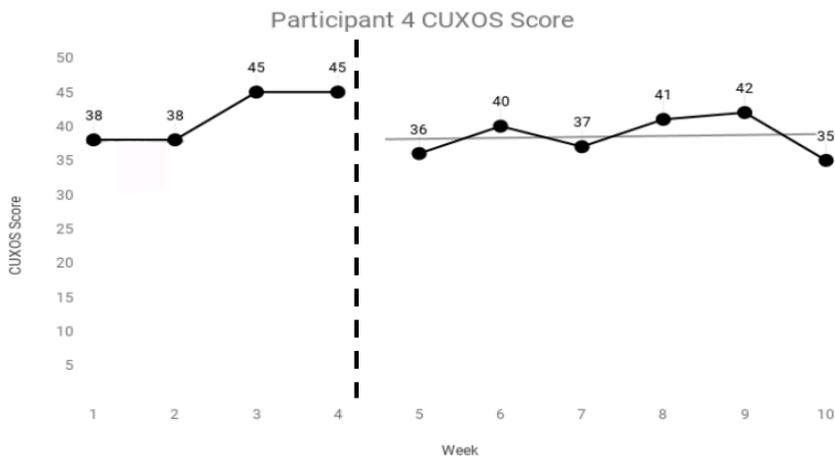
or staying in bed.” Lastly, she reported believing it is “important to keep going with this” and that she will continue to use the intervention.

The information presented here suggests the treatment was effective for Myra, as her results were favorable on all criterion and she improved two categorical levels on the CUXOS that also corresponded to a HRV change of 75%. Although she did not submit her usage results regularly, at the end of the intervention trial she did verbally report extremely high levels of usage. Myra also had a substantially higher concordance between HR alerts and subjective feelings of anxiety (67%) than the other participants. Myra also reported the device was easy to use and appreciated the application and text reminders and said she will use the intervention in the future.

**Participant #4 - Amin.**

*Treatment results for Amin.* Outcome data for Amin’s CUXOS scores are provided in the graph in Figure 4.

Figure 4.



Overall, Amin’s treatment results data met three out of the five evaluation effectiveness criteria, for a resultant overall effectiveness rating of Minimally Effective.

Amin's intervention results can be described as follows. To begin, the average weekly change of the CUXOS scores was -.2 during the treatment phase. A percentage of non-overlapping data (PND) evaluation revealed that 50% of CUXOS scores in the treatment phase fell below the lowest CUXOS baseline score, thus indicating there may have been some change due to treatment. These two indicators suggest potential significant effectiveness of the treatment. Related findings were discovered in comparing the change in score from the last CUXOS baseline score to the last CUXOS treatment score, which showed a decrease of three on the rating scale; this was not substantial enough to count toward an Effective rating. However, the change in CUXOS scores was not substantial enough to produce a change in categorical severity level on the CUXOS. Thus, Amin's scores remained in the Moderate anxiety range across both phases. Finally, on the measure of heart rate variability (HRV), the difference between the baseline measurement and post-treatment measurement was 211ms (400% change), indicating an exceptionally favorable increase in HRV. Although Amin did have some reduction in his CUXOS scores, a corresponding change in HRV of such a large magnitude is unexpected and may be an anomaly that is more related to change in fitness level than stress, or may have resulted from equipment or measurement error.

***Fidelity of treatment self-reporting.*** Table 5 contains a summary of Amin's self-reported treatment usage information.

Table 5.

<b>Participant 4 - Amin: Fidelity- Usage data</b>	
Responses collected out possible reporting periods during intervention (2x daily)	87%
Proportion of daytime device was worn	96%
Alerts with Anxiety "Device Anxiety Accuracy Detection"	31%
Usage of SMHRB for Alerts with Anxiety	60%
Breathing W/o Device	5
<b>Determination:</b>	<b>Moderate Usage/ High Reporting:</b>

Amin completed 87% of the daily response requests, and of these responses he reported wearing the heart rate device 96% of the time. Out of the total number of alerts reported, 31% corresponded with subjective feelings of anxiety. Of the 31% of alerts that corresponded with self-identified anxiety, Amin responded to those 60% of the time using the SMHRB intervention. Finally, Amin engaged in relaxation breathing without the heart rate monitoring watch five times.

*Summary of self-reported subjective experience of the treatment.* Amin reported that the intervention was “overall easy to use” and described the device and breathing techniques as easy to learn and noted that they “did not interrupt” his daily routines. He did feel that wearing the device at all times was difficult and noted that he would use the breathing exercises in the future without the watch now that he has learned to monitor his heart rate. Lastly, Amin noted that the blinking light was not a good indicator and may have added to his anxiety if at the time, indeed, he was not already anxious.

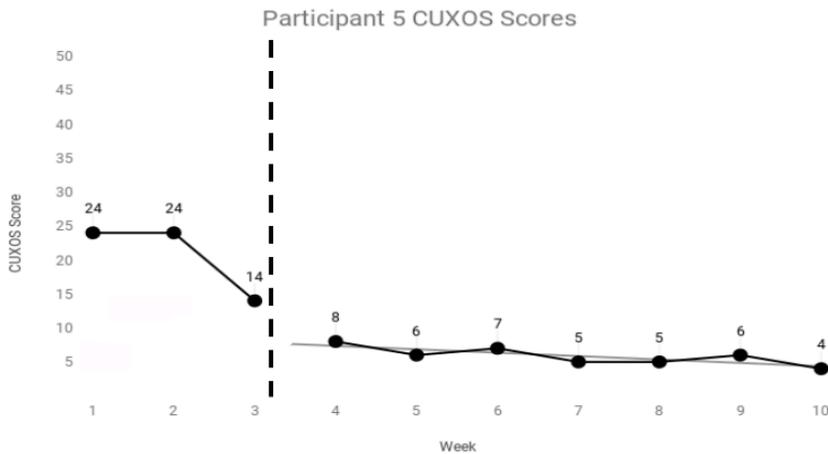
The information presented here suggests the treatment was Minimally Effective for Amin even though he had high reporting and appeared to use the treatment with

fidelity. Finally, Amin reported the intervention was easy to use and he further indicated his intent to utilize the strategies in the future.

**Participant #5- Ginger.**

*Treatment results for Ginger.* Outcome data for Ginger’s CUXOS scores are provided in the graph in Figure 5.

Figure 5.



Overall, Ginger’s data met five out of the five evaluation effectiveness criteria, for a resultant overall effectiveness rating of Effective. Ginger’s intervention results can be described as follows. The average weekly change of the CUXOS scores was  $-.66$  during the treatment phase. A percentage of non-overlapping data (PND) evaluation revealed that 100% of CUXOS scores in the treatment phase fell below the lowest CUXOS baseline score, thus indicating a reliable change due to treatment was detected. These two indicators suggest significant effectiveness of the treatment. Related findings were discovered in comparing the change in score from the last CUXOS baseline score to the last CUXOS treatment score which showed a decrease of 10. Thus, there was a significant change in categorical severity level on the CUXOS, from Minimal to a Non-

Anxious classification. Finally, on the measure of HRV, the difference between the baseline measurement and post-treatment measurement was +2.7 ms (2%), indicating a slight but favorable increase in HRV that parallels Ginger’s decrease in CUXOS Scores.

***Fidelity of treatment self-reporting.*** Table 6 contains a summary of Ginger’s self-reported treatment usage information.

Table 6.

<b>Participant 5 - Ginger: Fidelity- Usage data</b>	
Responses collected out possible reporting periods during intervention (2x daily)	58%
Proportion of daytime device was worn	95%
Alerts with Anxiety "Device Anxiety Accuracy Detection"	28%
Usage of SMHRB for Alerts with Anxiety	94%
Breathing W/o Device	2
<b>Determination:</b>	<b>High Usage/ Moderate Reporting:</b>

Ginger completed 58% of the daily response requests, and of these responses she reported wearing the heart rate device 95% of the time. Out of the total number of alerts reported, 28% corresponded with subjective feelings of anxiety. Of the 28% of alerts that corresponded with self-identified anxiety, Ginger responded to those 94% of the time using the SMHRB intervention. Finally, Ginger reported engaging in relaxation breathing without the heart rate monitoring watch two times.

***Summary of self-reported subjective experience of the treatment.*** Ginger stated that the intervention was easy to use, specifically in keeping track of elevated heart rate alerts; however, she noted that the buttons on the device were unclear and challenging to use. Ginger also noted that she experienced a decrease in anxiety and felt that deep

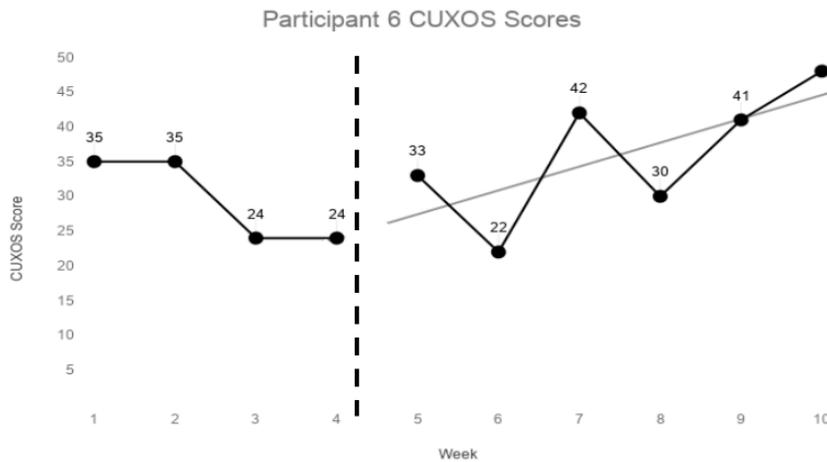
breathing did bring her heart rate down to assist in this effect. She also noted that she will continue to do deep breathing in the future with or without the device.

The information presented here suggests the treatment was Effective for Ginger, as she had favorable results on all of the criteria and was able to reduce her categorical severity ratings on the CUXOS from Minimal to Non-Anxious. This change, however, was not accompanied by a substantial change in HRV. Here, Ginger experienced only a 2.7-point increase (2% change). Ginger had moderate reporting and high usage rates. Finally, Ginger reported the device was easy to use and indicated she will continue to use the intervention with or without the device in the future.

**Participant #6 - Belinda.**

*Treatment results for Belinda.* Outcome data for Belinda’s CUXOS scores are provided in the graph in Figure 6.

Figure 6.



Overall, Belinda’s data met zero out of the five evaluation effectiveness criteria, for a resultant overall effectiveness rating of Not Effective. Belinda’s intervention results can be described as follows. To begin, the average weekly change of the CUXOS scores

was +3 during the treatment phase. A percentage of non-overlapping data (PND) evaluation revealed that 16.6% of CUXOS scores in the treatment phase fell below the lowest CUXOS baseline score, thus indicating no change due to treatment was detected. These two indicators suggest insignificant effectiveness of the treatment. Related findings were discovered in comparing the change in score from the last CUXOS baseline score to the last CUXOS treatment score, which showed an increase of 24 points. Similarly, there was an unfavorable increase in categorical severity level on the CUXOS, for which her scores changed from the Moderate Anxiety range in baseline to the Severe Anxiety range at the end of the treatment phase. Finally, on the measure of heart rate variability (HRV), the difference between the baseline measurement and post-treatment measurement was - 8.9 ms (-21%), indicating an unfavorable decline in HRV that parallels her increase in CUXOS Scores.

***Fidelity of treatment self-reporting.*** Table 7 contains a summary of Belinda’s self-reported treatment usage information.

Table 7.

<b>Participant 6-Belinda: Fidelity- Usage data</b>	
Responses collected out possible reporting periods during intervention (2x daily)	10%
Proportion of daytime device was worn	75%
Alerts with Anxiety "Device Anxiety Accuracy Detection"	31%
Usage of SMHRB for Alerts with Anxiety	80%
Breathing W/o Device	12
<b>Determination:</b>	<b>High Usage/ Low Reporting:</b>

Belinda completed 10% of the daily response requests, and of these responses she reported wearing the heart rate device 75% of the time. Out of the total number of alerts reported, 31% corresponded with subjective feelings of anxiety. Of the 31% of alerts that corresponded with self-identified anxiety, Belinda responded to those 80% of the time using the SMHRB intervention. Finally, Belinda engaged in the relaxation breathing without the heart rate monitoring watch 12 times.

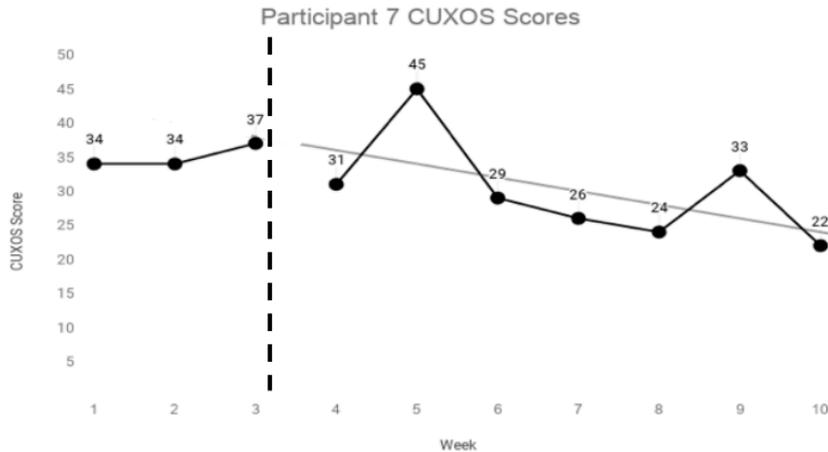
***Summary of self-reported subjective experience of the treatment.*** Belinda reported that the wrist worn device could be confusing at times and that she had trouble syncing with the app. However, she described the breathing exercises as helpful and said the reminders helped her become more aware of her anxiety and how to manage it. Belinda stated it was “most concerning” that the device would sometimes flash red when she was not experiencing anxiety and remain red until her breathing exercises were completed.

The information presented here suggests the treatment was Not Effective for Belinda. Her unfavorable rise in CUXOS severity rating also corresponded to her rise in HRV. Although she reported using the intervention with high fidelity, her reporting was markedly low. While the intervention did not prove effective for Belinda, nonetheless she reported the intervention assisted her in becoming more aware of her anxiety.

**Participant #7- Sondra.**

***Treatment results for Sondra.*** Outcome data for Sondra’s CUXOS scores are provided in the graph in Figure 7.

Figure 7.



Overall, Sondra’s data met five out of the five evaluation effectiveness criteria, for an overall effectiveness rating of Effective. Sondra’s intervention results can be described as follows. To begin, the average weekly change of the CUXOS scores was - 1.5 during the treatment phase. A percentage of non-overlapping data (PND) evaluation revealed that 85% of CUXOS scores in the treatment phase fell below the lowest CUXOS baseline score, thus indicating a reliable change due to treatment was detectable. These two indicators suggest significant effectiveness of the treatment. Related findings were discovered in comparing the change in score from the last CUXOS baseline score to the last CUXOS treatment score, which showed a decrease of 15. Similarly, there was a significant change in categorical severity level on the CUXOS and her scores moved one level from the Moderate Anxiety category to the Mild Anxiety category. Finally, on the measure of heart rate variability (HRV), the difference between the baseline measurement and post-treatment measurement was +71 ms (137% Change), indicating a favorable increase in HRV that parallels Sondra’s decrease in CUXOS Scores.

*Fidelity of treatment self-reporting.* Table 8 contains a summary of Sondra’s self-reported treatment usage information.

Table 8.

<b>Participant 7- Sondra: Fidelity- Usage data</b>	
Responses collected out possible reporting periods during intervention (2x daily)	41%
Proportion of daytime device was worn	80%
Alerts with Anxiety "Device Anxiety Accuracy Detection"	30%
Usage of SMHRB for Alerts with Anxiety	71%
Breathing W/o Device	0
<b>Determination:</b>	<b>High Usage/ Low Reporting:</b>

Sondra completed 41% of the daily response requests, and of those responses she reported wearing the heart rate device 80% of the time. Out of the total number of alerts reported, 30% corresponded with subjective feelings of anxiety. Of the 30% of alerts that corresponded with self-identified anxiety, Sondra responded to those 71% of the time using the SMHRB intervention. Finally, Sondra did not report engaging in relaxation breathing without the heart rate monitoring watch.

*Summary of self-reported subjective experience of the treatment.* Sondra described the intervention as easy to use, with the exception of responding to daily surveys, which she often forgot to do. She felt the intervention was helpful in reminding her to take deep breaths when she saw a spike in heart rate, and also described it as helpful in relaxing during stressful times. Sondra also said she would use the breathing technique in the future if she feels anxiety coming on.

The information presented here suggests the treatment was effective for Sondra, as she met all criteria and moved a categorical level on the CUXOS which corresponded to her favorable change in HRV score. Although her reporting was considered low, she reported high levels of usage. Sondra also reported the intervention was easy to use and she further indicated her intent to utilize the strategies in the future.

### **Summary of Results for Treatment Responders**

Based on the results across the seven individual participants, overall the intervention was considered Effective for 4/7, or 57%, of participants; Minimally Effective for 1/7, or 14%, of participants; and Not Effective for 2/7, or 29%, of participants. Across the five participants in the Effective and Minimally Effective categories who were considered “responders” to the intervention, a comparison of the last baseline CUXOS scores and the last treatment CUXOS scores showed an average decrease of -15 points. Furthermore, 4/7 participants’ CUXOS ratings decreased a categorical severity level between the last baseline phase and the last treatment phase. These findings indicate the intervention had a positive effect for these participants, and the magnitude of the decrease in symptoms is roughly equal to one and a half levels of severity on the CUXOS. The average slope of the trendline in the treatment phase for participants who responded well to the intervention is -1.25, signifying a desired weekly incremental change over the course of the intervention. Furthermore, for the group of responders, the average (PND) percentage of treatment points that fell below the lowest baseline point was 87%. This indicates that participants who responded well had subjective levels of stress which were lower in the intervention phase than the baseline phase a majority of the time, and signifies a trend toward symptom reduction. Lastly, the

average change in HRV for responding participants from the baseline phase (72ms) to the end of the treatment phase (136ms) showed a favorable increase of 64ms for an average HRV percent change of 88%. Participant four showed a HRV change that seemed to be questionable, as it was an extreme outlier. Adjusting for this outlier would still yield a favorable increase of 35% HRV for responders. With or without adjusting for the outlier the increase is favorable and corresponds with the desired decrease in CUXOS scores, indicating the two metrics are negatively correlated as anticipated.

Table 9.

<b>Summary of Treatment Responder Data Results</b>	
Average. Difference Pre-Post CUXOS	-15
Average Slope (weekly reduction in CUXOS ratings)	-1.25
Average (PND) Per Participant	87%
Average HRV Score Change (SDNN)	64ms (88%)
Average HRV Change Excluding Outlier	21ms (35%)
<b>Overall Category Ratings</b>	
<b>Effective</b>	4/7 51%
<b>Minimally Effective</b>	1/7 14%
<b>Not Effective</b>	2/7 29%

### **Group Summary of All Participants' Fidelity and Reported Usage**

Participants' overall reporting and usage data was delineated into two categories, Reporting and Usage, for organizational and evaluative purposes. The categories were also classified by percentage of usage. For example, for both self-reports and collected responses, percentages of reporting and usage were defined for each participant into high, moderate, and low classifications (i.e., above 70% = High, 50-70% = Moderate, Below 50% =Low).

The category of reporting included the percentage of received responses to investigator text messages out of the total responses that were possible. All participants reported wearing the device at a high rate (more than 75% of the day); therefore, for the usage category, classifications were determined by the percentage of instances in which participants responded to HR alerts with subjective symptoms of anxiety.

The participants were asked to report their usage via text message. On average the group of participants responded to a total of 49% (Low reporting) of their text messages. This figure is lower than anticipated and falls just below this studies classification of Moderate responding. The average proportion of time participants reported wearing their device during the day was 90%. This figure was based on the responses received from participants; there was no adjustment made for data not reported in daily texts. On average 37% percent of alerts for each participant corresponded to subjective feelings of anxiety. This number is an indication of the concordance of the devices with subjective feelings of anxiety. This number is lower than anticipated and signifies that the HR alerts did not match participants' subjective feelings of anxiety a majority of the time. Out of the alerts that were reported with anxiety, participants reported using the intervention 83% (High usage) of the time on average. This finding indicates that participants used the intervention a majority of the times when an alert occurred and the participant was experiencing subjective symptoms of anxiety. The group reported using relaxation breathing without the device an average of 9.4 times through the entire treatment phase. This number is comparatively low and likely did not influence symptom outcomes in any direction.

Table 10.

<b>Summary of Participant Reported Usage</b>			
	Range (%)	Average (%)	Category
Responses collected out possible reporting periods during intervention (2x daily)	10 - 78	49	Low
Proportion of daytime device was worn	80 – 100	90	High
Participant Intervention Usage for Alerts w/ Anxiety	60 - 93	83	High
*Proportion of Heart Rate Alerts w/ Anxiety	28- 65	37	Low

\*This is a measure of device accuracy not fidelity

**Summary of all participants’ responses to open ended questions.** An informal thematic and per-question analysis for participant responses was used to support and establish conclusions and insights about the intervention. All seven participants said that the intervention was easy to use, was helpful, and that they would continue to use a version of it in the future (e.g., breathing with a device or without). Two of the seven participants stipulated that they would only use the breathing aspect of the intervention or use it with a different device. These reports are consistent with the study goals to link emotional self-awareness and physiological awareness so participants may intervene with symptoms of anxiety in the future without utilizing a device. Moreover, two participants noted that the text messages were beneficial (“text reminders were great”, “helpful”). Three participants also specifically noted that they believe the intervention helped lower their anxiety overall (participants were not asked explicitly about levels). One participant

described it as a better alternative to “taking a nap or just staying in bed,” and indicated “it [the intervention] helped to try and get through it.” Others noted the “breathing was easy” and they could “do it on the go” and the “quantitative data” (HR) was helpful in relaxing.

The majority of the participant feedback for the intervention was positive. However, there were also applicable constructive criticisms as well as some concerning themes in the data. First, as previously mentioned, two participants found the text messages helpful; however, three others indicated that they consistently forgot to respond to them. Additionally, four participants suggested they had some trouble acclimating to the watch functions initially and some difficulty using it effectively at first. Lastly, and of particular concern regarding the intervention use and effects, three participants suggested that when the red light on the watch was flashing, and they did not feel anxious, it was bothersome enough that it seemed to prompt subjective feelings of anxiety. It is notable that the three participants who found the flashing red light intrusive also achieved the most unfavorable results on the CUXOS.

## **Chapter 4:**

### **DISCUSSION**

#### **Summary of Findings**

This research examined two primary questions and hypotheses. The first was to examine to what extent were college students with “mild to moderate” levels of anxiety able to utilize self-monitoring heart rate biofeedback (SMHRB) consistently (e.g., respond to at least 70% of maximum HR alerts utilizing relaxation breathing). The second, and related, question examined to what extent did participants who consistently implemented relaxation breathing in response to a Maximum HR alert significantly reduce symptoms of anxiety from baseline levels on a global anxiety scale?

Self- reports for each individual indicate that all participants wore their devices more than 70% of time during the day. Additionally, six participants utilized the intervention more than 70% of the time and one participant utilized it 60% of the times when a HR alert corresponded with subjective feelings of anxiety. These self-reported results indicate that participants used the intervention in a manner consistent with the hypothesis. Furthermore, these results also indicated that future research utilizing interventions with wearable technology with college students in real world settings is viable.

Moreover, four participants showed improved measurements in HRV and CUXOS ratings. Additionally, all of their results also revealed a progressive trend toward improvement in anxiety symptoms during the intervention phase. Taken together these results indicate the intervention had a significantly positive effect for a majority of the participants.

All participants wore their devices a majority of the time, and the group reported wearing their wrist monitor an average of 90% of the daytime as indicated by their twice daily responses. Further, they utilized self-monitoring to intervene with subjective feelings of anxiety consistently (83% percent of instances as indicated by self-report).

Although participants generally reported high usage, they also noted that many false positives occurred. That is, participants reported that 64% of HR alerts did not correspond to subjective feelings of anxiety across participants. This means if a participant received ten alerts in one day, approximately three of them would correspond to subjective feelings of anxiety. These reported estimates, however, should be interpreted with caution, first, because they are based on self-reports and, second, because of the lower-than-anticipated rates of reporting in response to text message prompts (49%).

Furthermore, the majority of participants who had a decrease in CUXOS ratings also exhibited an average improvement in HRV scores from baseline. These results indicate that the intervention did have a significantly positive effect for most participants and also suggest that the measure of HRV is correlated with symptoms of anxiety as measured by the CUXOS.

**Interpretations of results in the context of missing and unverifiable data.** One of the challenges of an “in vivo” research study relative to a more controlled environment type of study is adequately ensuring participant engagement in specified activities and reporting of self-monitoring information. Although difficulties with ensuring participant treatment fidelity is a limitation of this study, it is nonetheless pertinent to the

investigation. Determining whether a participant can consistently follow the procedures is another measure indicating whether this type of intervention is viable.

Although the importance of determining viability is not in question, the determination of how to consider intervention protocol adherence is difficult to resolve. A critical consideration in this study is the limitations of the usage data. Participants on average responded to 49% of all text messages (range of 9.5%-77.6%). This result leaves a great deal of uncertainty as to how to interpret missing data (non-responses to texts for daily usage). One possible interpretation may generate the question: does the lack of reporting negate participant estimates of usage and equate to a lack of intervention usage? Another question that could be generated is, does this lack of usage correlate with lower CUXOS scores? This conclusion may be plausible, as both of the participants with ineffective outcomes had a low percentage of reported data (43% and 9.5%). However, two other participants who had effective outcomes also had low reporting (26% and 41%), making that conclusion questionable especially with such a small number of participants.

The previous question about equating the lack of participant responses to lack of intervention usage requires a consideration of the aims of the study. The intention of this exploratory study using a small *n* design is to use participant self-report and outcomes to make recommendations for similar research in the future. Thus, interpreting results using the information provided by participants, with caution, seems to be the most viable option. Additionally, in the open-ended questionnaire, some participants expressed concern with their ability to keep accurate records of alerts. A potential difficulty in

overall reporting accuracy, combined with higher than anticipated rates of missing data, call for even more caution in the interpretation of the results of this study.

It is clear that the limited quantity and verifiability of usage data warrant caution in the interpretation of results. However, the finding that the collection of usage data was limited and difficult to verify is also valuable, as part of the research question was to determine the ability of college students to be able to execute such an intervention. Additionally, this being one of the earliest studies to examine self-monitoring using heart rate biofeedback in vivo rather than in a laboratory setting, there was an expectation that there would be some loss of control and verifiability over the independent variable.

**Importance of using multiple outcome measures.** The analysis of this research differs somewhat from typical anxiety treatment research for a variety of reasons. First, the present work used an innovative approach to treatment using a secondary prevention intervention methodology that is relatively novel (SMHRB). Second, using multiple techniques to examine the intervention's utility is necessary to determine effectiveness. In an effort to avoid type one error and concluding the intervention is effective when it is not, or a type two error concluding the intervention is not effective when it actually is, multiple outcome assessment methods were employed to help increase confidence that the intervention was evaluated fairly.

Lastly, best practices in the interpretation of research using small  $n$  design encourage the use of multiple evaluation strategies for examining the data. These include, for example, analyzing a line of best fit and slope of that line. Other recommended techniques include the use of total values for participants or mean values for groups as well as percentage of non-overlapping data, PND (Scruggs and Mastropieri, 1998). The

present research also utilized a less-studied experimental measure of HRV as an added measure of stress. Using *both* the HRV and the CUXOS measures was intended to provide for a more comprehensive assessment of treatment effectiveness.

**Significance of the results in a secondary prevention framework.** The SMHRB intervention was intended, as intervention at the secondary level of prevention, and therefore was designed to prevent and manage milder symptoms of anxiety. Within this context, it seems fitting that the three participants experiencing the least favorable results, Minimally Effective and Ineffective, experienced on average baseline scores in the Moderate range of severity on the CUXOS. Additionally, one of the participants had average baseline scores on the higher end of the moderate range (37), and one participant had an average baseline score that ended up in the severe range (41.5) before the baseline period ended. This information may point to the limitations of the intervention's effectiveness with participants experiencing more moderate to severe anxiety symptoms.

As previously mentioned, the SMHRB intervention research study yielded some favorable outcomes for a majority of participants and an average decrease across those responding participants of approximately 15 points on the CUXOS between the final weeks of each phase. This is substantial in that 15 points is roughly equal to one and a half of a severity levels on the CUXOS (e.g., Moderate (30) – Mild (20) = 10). A decrease of 15 points represents a tangible change for someone with symptoms of anxiety.

**SMHRB anxiety outcomes compared to previous work.** The results of the present study are consistent with those of Vitasari et al. (2011) who found that university students significantly improved their scores on an anxiety measure using HRV as a

mechanism to support biofeedback training in a laboratory setting. Although Vitasari et al. (2011) used heart rate biofeedback as an intervention tool to reduce stress, they used HRV in a laboratory setting rather than HR in real world settings as did the present SMHRB work. SMHRB research extends the work of Vitasari et al. (2011) through the expansion of interventions using biofeedback measures in the context of activities of daily life. Thus, the present work suggests that biofeedback measures may be viable for use outside of the laboratory for anxiety treatment research.

Other studies also have found similar results to those of the present study, but again in laboratory settings (Ratanasiripong et al., 2012; Reiner, 2008). For example, Reiner (2008) found in his twenty-four-participant pilot study that a majority of participants reported that using HR biofeedback reduced anxiety levels and increased relaxation more than mindfulness, yoga, and breathing. Such research indicates the strong potential of biofeedback to reduce stress in comparison to other established interventions. However, Reiner (2008) did not use a formal anxiety scale to measure participants' change, and similar to Vitasari et al. (2011) the research was also conducted primarily in laboratory settings. Unlike Vitasari et al. (2011) the present study did not pair the intervention against a control or an alternative intervention. Nonetheless, the present work does add to the body of work supporting the use of biofeedback measures to reduce symptoms of anxiety.

**Implications for future use of rating scales using mobile technology.** In addition to the effectiveness of SMHRB and the implications for future practice there were also some positive implications for the research methods employed in the study that extend previous work. As an example, Turner et al. (2014) studied the effectiveness of

combining HR biofeedback with didactic instruction for students enrolled in a university stress management course. The results showed significant decreases in anxiety and a large effect size on a pre-post Beck Anxiety Inventory (BAI) as compared to a control group. The present SMHRB study found results that were less robust; however, the results extended the work of Turner et al. (2014), with the utilization of HR in real world settings and the successful employment of an established rating scale, the CUXOS. The usage of the CUXOS by participants was impressive as all participants submitted 10 out of 10 rating scales outside of the lab via text messages. This finding indicates the viability of using weekly online ratings scales for future research to measure symptom change in a reliable, consistent and convenient way in real world settings. Thus, a larger study may be able to employ text-message-linked forms on a weekly basis to collect self-report measurement data rather than the more common pre- and post-measurement methodology.

**Implications of the correlation between HRV and CUXOS.** Another noteworthy finding of the present work was that participants who showed a favorable reduction in symptoms on the CUXOS also showed a favorable HRV increase of 35% compared to baseline, on average. Likewise, participants who had less favorable results showed an unfavorable HRV decline of 23% on average. This finding is important as it provides additional validation of the self-reported CUXOS outcomes. This finding also lends further support for continued use of HRV as a measure of stress in future work of this type. Finally, the finding is consistent with other research findings, showing significant correlations between HRV and symptoms of stress and anxiety in a variety of populations (Kim et al., 2018).

**Analysis of treatment utilization data.** Treatment utilization (i.e., usage) data was also favorable; however, the limited amount of text message reports collected was somewhat disappointing. Just under half of all twice daily text message questionnaire responses were submitted by participants on average. This is not consistent with other research utilizing daily self-reporting. Chung et al. (2018) collected daily self-reports of depression symptoms in a study in South Korea and reported 100% daily compliance from all 20 participants for two weeks. It also is not consistent with another depression and anxiety research study, using self-reports of treatment-seeking adults for 10 days, where only 3% of participants had reporting less than 80% (Naragon-Gainey, 2019). One explanation for these differences may be that, relative to the present work, these studies had substantially shorter required reporting periods and were conducted with different populations. Additionally, Chung et al. (2018) recruited treatment-seeking adults and paid participants approximately \$1 per self-report submitted, which likely contributed to the higher rates of responding. The more consistent participant reporting in the previous studies warrant greater consideration of compensation and treatment length in future work in order to improve reporting of and use of prescribed treatments.

**Implications of treatment phase length.** Treatment phase length is another factor that potentially influenced the participants' outcomes. A comparison of the length of time participants spent in a treatment phase and their final CUXOS outcome ratings suggested the three participants with the least favorable outcomes (Ineffective, Minimally Effective) were all randomly assigned to be the only participants in phase three of the intervention. Participants in phase three of the intervention had six weeks in the

intervention phase, compared with the other participants who spent seven or eight weeks in the intervention and whose results were Effective.

Relatedly, two of the three participants with the least favorable results, Amin (Minimally Effective) and James (Ineffective), both began to show some minimal improvement in scores on their final two weeks' (weeks five and six) CUXOS ratings. While Amin's best rating on the CUXOS was his last week (week six), James had relatively improved (low) scores on his last two ratings, causing a downward-sloping trendline.

Further support for the potential effect of treatment length is illustrated by the participants that had the best results. Abby and Myra were among those with the greatest decline in symptom ratings from baseline on the CUXOS and had been randomly assigned to phase one (eight weeks in treatment phase). Ginger and Sondra were randomly assigned to phase two (seven weeks in intervention phase) and showed slightly more modest results than Abby and Myra (phase one, eight weeks in intervention). All of the participants with Effective ratings also showed a relatively stable decline in CUXOS score, including their final measurement. Overall, those who participated in the intervention phase for longer lengths of time experienced better outcomes than those who participated for shorter lengths.

It is interesting to conjecture that a longer intervention period may have yielded improved results for Amin and James. Finally, future research studies with in vivo biofeedback interventions should consider using a longer eight week intervention period, rather than a shorter, intervention timeframe.

## Limitations

**Heart rate alert accuracy.** One of the discouraging, yet important, outcomes of this study was the reported lack of concordance between the heart rate alert (red flashing light) and reported subjective feelings of anxiety. Results from participant-reported usage estimates show just 37% of alerts corresponded with subjective feelings of anxiety; said another way, 63% of alerts seemed to be inaccurate from the participants' perspectives. Although subjective appraisals of anxiety do not necessarily wholly verify accuracy, a higher percentage of concordance would be more desirable. This perceived heart rate alert inaccuracy could be due to several factors. First, participants may have had difficulty keeping track of alerts, and, in fact, three participants stated that keeping track of the alerts accurately was difficult for them. This is especially likely as the alert indicator is an unobtrusive flashing light and unless a participant happens to be looking at the indicator, they may not notice it. This could result in some HR alerts resulting in no response from a participant. Second, participants' baseline heart rate data may not have been as accurate as necessary. For example, in obtaining the initial baseline heart rate, the circumstances or the measurement procedure may have led to a baseline heart rate that was too high or low and did not represent their true resting relaxed heart rate. Additionally, there may have been discrepancies between participants' subjective emotional states and their anxious heart rate. For example, when some participants experienced anxious symptoms, their heart rate may have been higher or lower than the threshold of 5 bpm fluctuation, used to trigger the HR alert, thus leading to relatively inaccurate HR alerts.

The inaccuracy between the HR alert and participants' subjective symptoms of anxiety is especially concerning for future research, predominantly because of the qualitative information disclosed in the open-ended question responses, in which three participants expressed their frustration with the inaccuracy of the HR alert. Specifically, the three participants implied that when the alert was active (red), and they felt they were not experiencing symptoms of anxiety, they then experienced stress. Moreover, it is not surprising that these three participants who experienced this discomfort were also the participants whose results were least favorable. Prior to conducting future research in this area with a similar device and method, it is imperative to improve the concordance of the alert or improve training in how to deal with alerts that don't correspond to subjective feelings of anxiety. Although not conclusive, it seems plausible that the intervention was not as successful for participants at least partially because of the mismatch between alerts and subjective symptoms.

**Missing data and challenges with verification of data.** As previously mentioned, a critical challenge in this study is the limitations of the usage data. Participants on average responded to 49% of all text messages (range of 9.5%-77.6%). This finding generates questions as to how to interpret missing data (i.e., non-responses to texts for daily usage). Critical examination could lead one to interpret that it is likely that if a participant is not reporting data than they are also likely not using the intervention. The SMHRB interpretation of results did not make the assumption that reporting and usage were equivalent. Rather, it was assumed that the participants' own estimates of their usage were the most accurate reflection of their usage data. Therefore,

the inability to verify data, coupled with higher than anticipated rates of missing data, call for an abundance of caution in the interpretation of the results of this study.

### **Implications for Future Research and Practice**

**Possible solutions to the accuracy of HR alert to predict subjective symptoms of anxiety.** Just prior to the start of this research study some heart rate devices and applications (Apple watch) have shown that prolonged data collection over time (several days) can yield a more accurate measure in relation to a user's typical resting heart rate. Therefore, wearing a watch continuously for several days and nights during a pre-treatment phase would allow for a more complete assessment of when a user's heart rate would be considered in a resting state and when it would be considered in an anxious state. Through collection and utilization of this more extensive cardiac data, researchers may be able to obtain more precise baseline data and more accurately determine a threshold HR alert for participants.

Furthermore, with the reduction in cost and increase in availability of a variety of devices, researchers can more easily utilize existing third-party applications to collect HR data. Whether researchers customize or use existing applications, users could report their subjective emotional states as soon as a detected change in HR occurs. Over time the application would match self-reports of emotional states to physiological states, building a profile that would allow for a more accurate tailored alert and intervention system.

**Possible solution to collection and verification of data in future research.** The present study does employ relatively recent technologies in its design (e.g., text message delivery, Google Form survey collection, optical heart rate monitoring); however, it

lacked the advanced technology that the most recent, more expensive devices employ to allow for optimal integration in data collection.

In addition to the previously mentioned enhancements to improve heart rate and anxiety detection, new devices and technology recently released will allow for a marked improvement in the ability to verify and monitor the use of the independent variable (usage data) instead of relying on self-reports. Newer, more expensive devices (e.g., Apple watch) permit the use of third-party applications which will allow for a common platform for physiological data measured by a device to be collected automatically. An application of this nature would allow consumer devices (e.g., Apple watch) to share heart rate and other data with researchers on a common platform. A platform would allow researchers to collect almost all of the data more seamlessly and accurately. For example, with participant permission, the researcher would have access to more objective data, such as: frequency of use; duration; and a record of heart rate throughout the day, which would include the number of HR alerts, to name a few. In future research, choosing a device that has the capability and compatibility to accommodate the previously discussed functions will be essential in obtaining generalizable results. Additionally, a reduction in the cost of these devices and the availability of these features will likely make them more accessible for use in future research.

## **Conclusion**

The results of the research study are mixed in terms of finding the experimental treatment to be effective, with four of seven participants experiencing improved symptoms of anxiety linked to the intervention. Although the intervention showed a reduction in anxiety for the majority of participants, the limited responses of participants

and difficulties with verification of intervention usage limits the ability to conclusively attribute intervention usage to results. Nonetheless, participants reported they were able to wear the heart rate monitoring device a majority of the time prescribed, and respond to a majority of alerts that correlated with subjective feelings of anxiety. Results also showed that participants were able to provide weekly data using an online self-report measure (CUXOS) through text messages extremely consistently (100%) and using the CUXOS as weekly collection method is viable for future research with anxiety.

Viewing the results within the scope of a secondary prevention and management framework, it seems to fit that on average the most severely affected participants had the least favorable outcomes. However, there are also results that point to intervention shortcomings, such as alert accuracy as well as discrepant time in intervention phases between participants, which may have led to lower anxiety symptom ratings. In future research, potentially standardizing and increasing the length of intervention phases, along with recruiting a larger sample size and utilizing multiple groups, will allow for isolation of interventions component effects as well as identifying effects on specific sub-groups of our population. For example, it will be important to investigate treatment effects as a function of age, gender, and ethnicity, which could yield more nuanced and generalizable results.

Moreover, before conducting future research on HR biofeedback utilizing an alert function, a more reliable method of establishing participants' baseline levels of heart rate will be necessary. Although wearable device technology is still in its infancy, it has reached a point that its substantial, reliable, and positive influences on human functioning

are possible. Wearable technology has tremendous potential for the future treatment of mental health concerns, and it continues to be an important area for future research.

## **Appendix A**

### **Review of Literature**

#### **What is Anxiety?**

“Anxiety disorders include disorders that share features of excessive fear and anxiety and related behavioral disturbances. Fear is the emotional response to real or perceived imminent threat, whereas anxiety is the anticipation of future threat. Obviously, these two states overlap, but they also differ, with fear more often associated with surges of autonomic arousal necessary for fight or flight, thoughts of immediate danger, and escape behaviors, and anxiety more often associated with muscle tension and vigilance in preparation for future danger and cautious or avoidant behaviors... Sometimes the level of fear or anxiety is reduced by pervasive avoidance behaviors” (DSM-5).

#### **Variations by Age and Culture**

Worry seems to become prominent in the elementary years, at approximately age 4, and varies in complexity. During the typical course of development, the quantity and intensity of worry and fears decline with age (Schultz et al., 2005). A majority of children who develop anxiety during childhood will remit in 3 or 4 years (Gullone, 2005). Sex differences in development also exist. Evidence indicates that girls exhibit more intense as well as a greater number of fear responses than boys (Gullone, 2000). However, gender differences need to be interpreted with caution, as gender role differences may skew presentation and reporting of fears, phobias, and anxiety (Ginsburg & Silverman, 2000). Children seem to have common fears at specific age ranges. For example, in the pre-school years between 6-9 months, children fear strangers; 2-year-olds fear monster-type creatures; at four years of age, children are afraid of the dark; and typically, in the

middle school and high school years, older children and adolescents exhibit social fear and fear of failure (Gullone, 2000; Miller, Barrett, & Hampe, 1974).

Additionally, there is evidence that the most common fears in children are similar across cultures. There may, however, be some cultural variations as to the specific content feared in each category type (Portman, 2009). For example, in high school, stress and worry related to acculturation and discrimination may be more prevalent in populations who have recently immigrated. There is additional evidence of variation for individuals from collectivist cultures. Collectivist cultures (i.e. those found in some Asian countries) emphasize the needs and goals of the group as whole over the needs and wishes of each individual (as is the focus in individualist cultures, i.e. the U.S.). Research indicates that individuals from collectivist cultures report increased internalizing disorders, and in some Asian cultures people are also more likely to present with somatic symptoms of anxiety such as stomach pain (Valerla et al., 2004).

The developmental period of childhood is marked by varying fear and worry which can be considered typical (McKay & Storch, 2011). Additionally, some degree of apprehension, fear, and anxiety serve essential adaptive functions. Fear in response to an actual life-threatening event can prepare our body for a vital "fear" response, initiating a life-saving flight or fight response. Moreover, some apprehension or anxiety about an upcoming event, an exam for example, can serve as motivation to prepare. Alternatively, if the fear or anxiety creates significant enough discomfort as to interfere with functioning, this could be considered atypical, and assessment and intervention may be warranted (Fonesca, Yule, & Erol, 1994).

### **Why is Anxiety a Problem?**

Anxiety disorders can impair a child's ability to learn and self-regulate and may severely affect their relationships (Beesdo, Knappe, & Pine, 2009). For a variety of reasons, up to 80% of children with an anxiety disorder do not receive treatment (Taras et al., 2004). The most prevalent of all psychological disorders (Beesdo, Knappe, & Pine, 2009), anxiety is characterized by chronic symptoms of persistent worry (Parker, 2015) and can manifest with a variety of physical and emotional symptoms (Goldberg, 2014). Evidence suggests that as many as 29% of the population will be affected by an anxiety disorder and those with the condition are at a greater risk of developing other chronic medical conditions. The relationship between poor test performance and anxiety is well documented; however, less apparent is the reality that anxiety can have a significant impact on the education and development of children. Anxiety interferes with the ability to regulate thoughts, actions, and emotions, and disrupts short-term memory involved in learning. There is also evidence to suggest that chronic stress during critical developmental periods can change brain structures more permanently than acute stress, thus impairing future learning, behavior, and health (Shonkoff et al., 2011).

### **Theories of Anxiety Etiology and Maintenance**

**Cognitive theories.** One of the most influential theories relating to anxiety is Beck's Cognitive Theory. The underlying premise of this theory is that pathological anxiety is derived from a misperception of danger which results in distortions in the perception of information and stimuli. Beck's approach describes negative automatic thoughts and schemas about the world, self, and other (the cognitive triad) as the maintenance of anxiety (Chambless & Ollendick, 2001).

Contemporary models based on Beck's work integrate the learning process of behavioral models (associative and non-associative) with cognitive perspectives. The behavioral view assumes that learning takes place through classical conditioning to stimuli and through behavioral reinforcement (operant conditioning). The cognitive approach assumes that anxiety is a result of an overestimation of danger, threat, and fear, as well as an underestimation of self-efficacy to cope with potential threats (Portman, 2009). Cognitive Behavioral Therapy (CBT) is designed to improve coping skills to leverage improvement in behavioral, emotional and cognitive processes in a reciprocal manner to improve affect. Essentially, positive change in cognition fosters improvement in behavior and emotions in a continually enhancing cycle (Mckay, 2011).

**Biological theories.** Cognitive and behavioral theorists acknowledge the influence of biological factors on anxiety disorders. Individual temperament is one such factor that may be largely inherited. Family studies indicate children whose parents have an anxiety disorder are at a greater risk of developing an anxiety disorder themselves (Merikangas, 2005). Although the prevalence of anxiety in families is high, twin studies suggest the genetic heritability component of the disorder is only moderate (Eaves et al., 2010). This may be due to strong environmental influences operating in families.

Biological influences also include neurotransmitters, autonomic nervous system functioning, brain circuitry and more. Structural and functional imaging studies have implicated the amygdala, often called the emotional brain, in anxiety disorders (Labuschagne, Phan, Wood, et al., 2010). The ventromedial prefrontal cortex (involved in explicit cognitions) also plays a role in anxiety disorders, as there is decreased activation in fMRI studies when subjects with anxiety are exposed to fear stimuli (Greenberg et al.,

2003). A simplified explanation is that the combination of increased activation of the amygdala, coupled with decreased activation of the ventromedial prefrontal cortex, is implicated in the neurobiological experience of anxiety (Pine, Guyer & Levenluft, 2008). Interventions such as positive self-talk have shown an increase in activity between these areas, which is linked to a decrease in fear response. Hypothetically, increasing positive self-talk may cause the increase in the connection between these two areas and serve to down-regulate (influence from prefrontal cortex to limbic regions) the anxiety and the fear response.

There is also substantial ongoing research investigating the role of neurotransmitters in anxiety. The dysregulation of GABA-involved circuits has been implicated in the etiology of anxiety (Nutt, 2001). Medications such as benzodiazepine are designed to treat anxiety and calm or inhibit transmission of neurotransmitters that act on GABA receptors. Additionally, glutamergic neurotransmission, an excitatory pathway, may also be involved in the biological mechanisms underlying stress response and anxiety-related disorders. Moreover, although not well understood, it is widely accepted that serotonin plays a crucial role in anxiety, as the anxiolytic effects of selective serotonin reuptake inhibitors (SSRI's) are considered the first line of treatment for anxiety disorders (Portman, 2009).

Furthermore, the autonomic nervous system, divided into the sympathetic and parasympathetic system, plays a significant role in the physiology of anxiety disorders. Increased heart rate is commonly recognized as a symptom of anxiety and is produced by the mechanisms of the sympathetic response that prepares the body for a flight or fight response. Children with anxiety disorders are said to have a dominant sympathetic

system. The parasympathetic system restores relaxation to the body, such as reduced heart rate, restoration of digestive functioning, and reproductive functioning, among other things (Thayer et al., 2012). In the last decade a greater emphasis has been placed on the bidirectional potential of interventions to act on the autonomic system with the use of biofeedback in anxiety disorders. For example, heart rate biofeedback may have the potential to increase parasympathetic functioning, thus reducing heart rate and returning calm to the individual.

*Biological theory and Heart Rate Variability.* An extension of the biological theory is described through the use of heart rate variability. One prevalent theory describes anxiety's roots in childhood temperament and heart rate variability (HRV) (Ratanasiripong et al., 2004). Multiple theoretical models attempt to explain the relationship between physiology and psychological functioning. For example, the neurovisceral model of anxiety describes a relationship between the cognitions involved in regulating anxiety and the autonomic response. Additionally, the polyvagal theory describes the relationship between deliberate actions by the individual that result in changes in biological states, such as deep breathing and relaxation efforts (Quintana et al., 2012). When examining heart rate as a marker of reactivity, anxious and non-anxious individuals initially respond similarly to environmental stressors with temporary increases in beats per minute (BPM) of approximately 5-10 (Stewart, Buffett-Jerrott, & Kokaram., 2001). Although BPM is a crucial marker of normal acute environmental stress, the measure that distinguishes between those who struggle with chronic stress and anxiety and those who do not is the rate at which HR is returned to its resting state after experiencing a stressor. Those who experience a stressor and can more quickly recover

their heart rate to a resting state exhibit higher heart rate variability (HRV). HRV is negatively correlated with overall stress level. More precisely, HRV is the variation in the time interval between heartbeats. Thus it is preferable to have higher HRV as it shows more versatility in responding to environmental stimuli such as the ability to more quickly reduce heart rate in response to a benign threat. It is measured by the variation in the beat-to-beat interval (Ratanasiripong et al., 2004). Moreover, many studies have found that the relationship between HR and anxiety is bi-directional, indicating that interventions that promote more effective cardiac control can facilitate improved emotional regulation and anxiety reduction (McKenna, Gallagher, Forbes, & Ibeziako, 2015; Ratanasiripong et al., 2004; Quintanna et al., 2012; Vitasari et al., 2011).

### **Impediments to Treatment**

Although anxiety in adolescents is well-documented, anxious youths are frequently under-identified. Unlike students with externalizing disorders, those with internalizing disorders such as anxiety usually do not outwardly express behaviors. By not posing an immediate disruption in the classroom, students with internalizing disorders thus present a less-perceptible concern (Herzig-Anderson, Colognori, Fox, Stewart, & Masia Warner, 2012). Correctly identifying adolescents with anxiety is only one obstacle to treatment. Additional impediments include treatment costs, time commitment, accessibility (Dennis & O'Toole, 2014), and issues with the acceptability of treatment for students with anxiety, such as social stigma and over-use of unsupported treatments in community settings (Herzig-Anderson et al., 2012).

The various impediments to quality community-based treatment influence approximately 70% of students identified as needing services to obtain them through their

educational institution. Schools may have fewer barriers for students to receive treatment, such as the need for transportation and added family costs. Additionally, schools offer unique opportunities to practice real exposures and directly engage with particular stressors, such as tests and peer interactions (Herzig-Anderson et al., 2012).

Although schools may offer advantages for treatment, many are notably overwhelmed with students who need mental health services. Moreover, many institutions, especially those in K-12 settings, are lacking the necessary funding and resources to treat students with mental health concerns such as anxiety (Taras et al., 2004). While challenges will persist for many populations in need of mental health treatment, new technologies and innovations are offering alternatives to traditional treatment methods. Many of these options utilize wearable technology, biofeedback, and smartphones. The ubiquity, availability, and cross-cultural acceptance of these interventions allow them to traverse traditional boundaries to treatment such as cost, accessibility and negative stigma (Dennis & O'Toole, 2014).

### **Self-monitoring**

Most technologies that allow for improvement in symptoms of anxiety utilize elements of self-monitoring (SM) as an essential feature. Self-monitoring is the act of measuring one's target behavior and comparing it to an external standard or goal that can result in lasting improvements to that behavior (Kazdin 1989).

SM has been used as a stand-alone intervention and permits students to track their mental states independently. Improvements in behavioral outcomes have been noted with SM, without any additional intervention (Shapiro & Cole, 1999). SM has been used to influence a variety of behaviors such as helping individuals: maintain appropriate social

skills; mitigate work competition; and as self-regulate behaviors involved in anxiety. Use of self-monitoring is primarily based on the behavioral principle that the act of measuring one's target behavior and comparing it to a standard can result in enduring improvements to that behavior. Self-monitoring can be described as having reactive effects, in that those who utilize it often react to this monitoring information to change behaviors in the desired direction (Kazdin 1989).

Through self-monitoring, individuals can learn to recognize emotional states and to identify and differentiate various emotions in different contexts (Kauer et al., 2012). Learning to recognize emotional states has been termed emotional self-awareness (ESA). Possessing ESA has been hypothesized to predict symptomology in mental illness. Self-monitoring is considered to be one of the first phases of self-regulated behavior (Rafferty 2010). Increasing awareness of emotions is an essential step in training individuals to change their cognitions, beliefs, and schemas (Kauer et al., 2012). Students who learn to utilize self-monitoring strategies efficiently can potentially manage a variety of behaviors (Walker & Shinn, 2002). Additionally, students who efficiently use processes such as self-monitoring typically have higher levels of self-efficacy, motivation, and educational achievement (Zimmerman, 2002). Moreover, engaging in SM and practicing ESA has been correlated with more appropriate help-seeking behaviors (Newman, 2002). Learning how to use self-monitoring strategies effectively allows youth to manage a variety of behaviors and emotions (Cooper et al., 2007). This is true not only for typically developing peers, but also for students with cognitive disabilities.

**Specific self-monitoring strategies.** Specific SM strategies have been utilized for the treatment of anxiety. For example, both event and interval recordings are commonly

used for self-monitoring panic and anxiety. An interval recording strategy involves observing whether a behavior occurs or does not occur during specified time periods. Once the length of an observation session is identified, the time is broken down into smaller intervals that are all equal in length (Craske, Michelle, Jennie & Tsao, 1999). Event recording is a process for documenting the number of times a behavior occurs. An observer using event recording makes a tally mark or documents in some way each time a student engages in a target behavior. The observer also records the time period at which the behavior is being observed.

Event recording is tied to data regarding a particular situation or event, such as test anxiety. For each anxious event, students recorded the location, time of day, behavioral response, and degree of distress, using a self-assessment procedure. This procedure is highly useful for situations and specific instances such as phobias (Beidel, Neal, & Lederer, 1991). Manualized CBT programs for anxiety frequently ask participants to rate their systematic units of distress (SUD), which quantifies feelings of distress and can be a marker of progress.

Interval recording is the most common method for self-monitoring for generalized anxiety disorder, given the chronic nature of worry and anxiety that characterizes this disorder. A version of momentary time sampling is common to self-monitoring the severity of panic and anxiety (Craske et al., 1999). For example, Hiebert and Fox (1981) instructed students and volunteer participants to record 0-100 ratings of subjective distress every waking hour for one week. Barlow et al. (1989) asked clients with panic disorder to record their daily anxiety levels (0-8-point scale) at four specified times during the day. Other researchers, such as Borkovec, Grayson, and Cooper (1978),

required college students experiencing stress to complete daily records for six weeks, each night. Using self-monitoring as a treatment for anxiety has resulted in significant declines in both the percentage and severity of tension (Craske et al., 1999).

Researchers have also found that handheld devices offer a particular advantage for momentary time sampling in that mechanized prompts to enter data at specific points in time may preclude the delay in self-monitoring that probably occurs otherwise (Craske et al., 1999).

Using SM to promote ESA may also provide a suitable framework for initial intervention programs by supporting students in becoming aware of their emotions as a prerequisite for learning more adaptive coping strategies (Kauer et al., 2012). Moreover, self-monitoring strategies can be differentiated to meet the needs of students. They are typically less invasive (Fantuzzo, Polite, Cook, & Quinn, 1988) and potentially more effective than those administered by an adult such as a teacher (DuPaul & Stoner, 2002).

**Technology in self-monitoring.** Studies utilizing mobile phone applications for self-monitoring found that they increased positive mood and coping strategies while decreasing negative mood in individuals with stress (Kauer et al., 2012). Additionally, participants in this and similar research increased their ESA and were able to internalize the questions and therapies used in the mobile programs to treat internalizing disorders (Kauer et al., 2012). For example, Kauer et al. (2012) examined self-monitoring using mobile phones for mild or moderate mental health concerns related to mood and stress with a sample of 114, 14 - 24-year-olds. The randomized control trial indicated that self-monitoring increases ESA and can decrease symptoms of internalizing disorders. These

results suggest that mobile phone self-monitoring programs may be an ideal first-step intervention for internalizing disorders.

Although self-monitoring has shown utility as an intervention for internalizing disorders, students often need assistance to initially begin to self-monitor their emotions, thoughts, and behaviors (Flannery-Schroeder & Lamb, 2009). It may be the case that wearable technology such as a heart rate monitor can be applied as an effective initial self-monitoring technique. Using the heart rate alarm function could serve as a prompt in event recording to notice the environment and circumstances as well as correlate SUD feelings, emotions, and heart rate. The device may also have the capacity to assist in allowing students to directly recognize distress and immediately employ self-regulation techniques to normalize heart rate, emotions, and potentially anxiety.

The ultimate goal of recognizing one's emotions is paramount; however, external prompting is an intermittent step that allows for the scaffolding of this behavior (Shapiro & Kratochwill, 2000). An external prompt such as a high heart rate alarm can serve as a teaching tool to signal awareness and prompt remedial behavior.

New technologies and innovations are offering treatment alternatives that utilize wearable technology, biofeedback, and smartphones. The ubiquity, availability, and cross-cultural acceptance of these interventions allow them to traverse traditional boundaries to treatment such as cost, accessibility, time commitment, and negative stigma (Dennis & O'Toole, 2014). SMHRB could be a tool that allows users to effectively intervene when experiencing moderate symptoms of anxiety in a way that is least restrictive and/or could be used as an effective adjunct to more traditional therapy.

### **The Influence of Biofeedback on Anxiety**

Biofeedback includes utilizing various biomarkers, which can consist of brain activity, blood pressure, muscle tension, heart rate, skin temperature and sweat gland activity (Ratanasiripong, Sverduk, Prince, & Hayashino, 2012). When examining heart rate as a marker of reactivity, anxious and non-anxious individuals initially respond similarly to environmental stressors with temporary increases in beats per minute (BPM) of approximately 10 (Stewart, Buffett-Jerrott, & Kokaram., 2001). Although BPM is a crucial marker of normal acute environmental stress, the measure that distinguishes between those who struggle with chronic stress and anxiety and those who do not is the rate at which HR is returned to its resting state after experiencing a stressor. Those who experience a stressor and can more quickly recover their heart rate to a resting state exhibit higher heart rate variability (HRV). HRV is negatively correlated with overall stress level. More precisely, HRV is the variation in the time interval between heartbeats. It is measured by the variation in the beat-to-beat interval (Ratanasiripong et al., 2004). Moreover, many studies have found that the relationship between HR and anxiety is bi-directional, indicating that interventions that promote more effective cardiac control can facilitate improved emotional regulation and anxiety reduction (McKenna, Gallagher, Forbes, & Ibeziako, 2015; Ratanasiripong et al., 2004; Quintanna et al., 2012; Vitasari et al., 2011). Vitasari et al. (2011) used biofeedback training to help students prepare themselves mentally and physically for anxiety. Their biofeedback training program focused on quickly alleviating the increase in beats-per-minute psychophysiological arousal associated with stress and anxiety. Thirty-five university students participated in HR biofeedback training in the research laboratory. The results showed a significant

decrease in beats-per-minute mean scores after BPM biofeedback training, even though the participants were not permitted to use the devices outside of the lab.

### **Biofeedback and Heart Rate Monitoring as an Intervention**

**Recent technological trends in HR biofeedback.** Tracking fitness has become a significant part of popular culture. There are many ways we can now track fitness. There are applications such as “My Fitness Pal” that allow us to track our calorie consumption. These applications can combine with a “fitness tracker,” often a wrist-worn device for monitoring and tracking health, and fitness-related metrics, such as distance traveled walking or running, heartbeat, and quality of sleep. The latest iteration of heart rate trackers has a more comfortable design, compared to older heart rate detection devices that were expensive, bulky, and required the use of a chest strap. The ability to measure HR, activity, and sleep, and store this data has not been immediately, directly, and discreetly available to consumers until very recently. Its potential for use with monitoring and understanding anxiety is growing.

**How biofeedback works.** Biofeedback has been used to support relaxation and aid in the reduction of the body's sympathetic responses to anxiety-provoking stimuli (Prinsloo et al., 2013). Ratanasiripong et al. (2012) conceptualize biofeedback's impact as a three-step process involving awareness of the physiological response, controlling their response, and generalizing the response to daily life. Recognition of the physiological response is attained through the use of sensors. These sensors relay information to a smartphone or the built-in display on the wrist-worn HR tracker which provides timely, functional feedback to the user. The feedback assists users in associating awareness of body feelings with measured physiological indicators affecting their level of arousal. As

users gain awareness, they can use relaxation techniques to reduce arousal and more effectively control their autonomic responses to anxiety-provoking stimuli.

Using these methods outside of a therapeutic or research setting to implement real change is perhaps one of the most substantial hurdles to overcome. The ultimate goal of biofeedback is for the individual to be able to recognize physiological symptoms of arousal and be able to eventually implement interventions without the use of the biofeedback technology (McKenna, Gallagher, Forbes, & Ibeziako, 2015).

**Research supporting Heart Rate Biofeedback.** Turner et al. (2014) studied the effectiveness of combining HR biofeedback with didactic instruction for students enrolled in a university stress management course. His results showed significant decreases in anxiety. The participants were randomly assigned to 2 groups, treatment and control, for four weeks. They measured pre- and post-data using the Beck Anxiety Inventory (BAI) and found significant results with a .77 effect size.

Several studies have demonstrated that biofeedback is superior to controls in studies of HRV (Ratanasiripong et al., 2012; Reiner, 2008). Reiner examined the clinical usefulness of HRV with 24 subjects. He reported 75% of participants using HRV found it reduced their stress levels. 80% reported increased relaxation. 73-77% of study participants found HRV-biofeedback more helpful than breathing, yoga, and meditation (Reiner, 2008). Although a small pilot study, this is a strong representation in that HRV-Biofeedback was found more potent than three well-documented intervention techniques.

Moreover, in a study of college-age students, results showed a significantly greater reduction in anxiety when HRV was added to weekly counseling. Thirty participants were randomly assigned to a treatment or control group. Both groups utilized

identical weekly counseling; however, the treatment group added HRV-biofeedback measures as an adjunct. While both intervention groups yielded a large effect size, the added effect of introducing HRV-biofeedback yielded a  $.77 d$  effect size over the counseling group (Ratanasiripong et al., 2012).

Potentially, the most convincing evidence in support of further examination of heart rate biofeedback comes from one of the few, and potentially only, meta-analyses on the topic conducted by Goessl, Curtiss and Hofmann (2017). They included 24 studies totaling 484 participants (ages 18-63) who received HRV biofeedback training for stress and anxiety. A random-effects meta-analysis resulted in pre-post within-group effect size (Hedges'  $g$ ) of 0.81. Additionally, a between-groups analysis comparing biofeedback to a control condition yielded Hedges'  $g = 0.83$ . The authors concluded that HRV biofeedback training is associated with a large reduction in self-reported stress and anxiety. They also maintain the intervention offers a promising approach for treating stress and anxiety with wearable devices.

**HR-V vs. HR-BPM biofeedback.** Heart Rate Variability (HRV) has been used as a global measure of cardiac health and an overall measure of autonomic responsiveness to stress and anxiety (Quintana et al. 2012; Ratanasiripong et al., 2004). Measurement of HRV includes BPM in its calculation and uses a relatively complex algorithm compared to the simple tracking of BPM (calculations on HR & HRV). In contrast with heart rate (BPM), HRV is the variation in the time interval between heartbeats and has the potential to distinguish between typical individuals those who struggle with chronic stress (Ratanasiripong et al., 2004).

Although HRV has been used in interventions, it is a more global measurement of stress. In contrast, a beats-per-minute (BPM) heart rate biofeedback intervention is immediate and can more easily be influenced in real time. Vitasari et al. (2011) found that a HR BPM intervention was useful to measure and reduce stressor-induced elevated heart rate more quickly and was also effective in overall long-term anxiety reduction. Training individuals to recognize and more quickly reduce their heart rate (BPM) consistently, in response to a stressor, could have beneficial effects on HRV (increase) and reduce overall stress and anxiety (Vitasari et al., 2011)

## Appendix B

### Measures

#### Clinically Useful Anxiety Outcome Scale (CUXOS)

The Clinically Useful Anxiety Outcome Scale (CUXOS) is a brief, 20-item self-report measure designed to assess the severity of anxiety symptoms in adults with a diagnosed Anxiety disorder or Depression (D'Avanzato et al., 2013; Zimmerman, Chelminski, Young, & Dalrymple, 2010). The CUXOS can be used as a screening tool or to monitor and evaluate symptom changes over the course of treatment, as it is sensitive to change (Beidas et al., 2015).

Developed in 2010, the CUXOS item content is based on the *DSM-III-R* and *DSM-IV* descriptions of Generalized Anxiety Disorder and Panic Disorder (Zimmerman et al., 2010). The items are derived from the Hamilton Rating Scale for Anxiety (1959), whilst the structure of the measure is based on the Clinically Useful Depression Outcome Scale (2008). The CUXOS is comprised of two subscales: the psychic anxiety subscale, consisting of 6 items ("I felt scared"), and the somatic anxiety subscale containing 14 items ("I was sweating"). Each item is rated on a Likert-type scale from zero ("not at all true") to four ("almost always true"), with total scores ranging from zero to 80 (<10 non-anxious; 11-20 minimal anxiety; 21-30 mild anxiety; 31-40 moderate anxiety; 41+ severe anxiety). On average, clients completed the measure within two minutes and clinicians scored the scale within 15 seconds (Zimmerman et al., 2010). The efficient nature of this measure is an advantage when considering using it as a screening tool or to monitor symptom change over time.

The CUXOS' solid psychometric properties are also an advantage. The initial validity study included 963 patients, 556 with a diagnosed non-comorbid anxiety disorder and 407 with no current anxiety disorder (Zimmerman et al., 2010). The study demonstrated strong internal consistency for the total scale (Cronbach  $\alpha = 0.95$ ) and each subscale ( $\alpha = 0.90$  for the psychic anxiety subscale, and  $\alpha = 0.93$  for the somatic anxiety subscale). The test re-test reliability of the total scale was also strong ( $r=0.90$ ).

In terms of convergent and divergent validity, the CUXOS correlated more highly with other measures of anxiety (median  $r=0.54$ ) than with scales measuring other symptom domains (median  $r=0.32$ ). The CUXOS' ability to discriminate between severity levels was also investigated via an analysis of variance conducted with the Social Avoidance and Distress Scale (SADS) severity ratings in relation to the CUXOS' ratings. Higher SADS severity ratings correlated significantly with higher CUXOS ratings of severity.

Whilst the psychometric properties reported in the Zimmerman et al. (2010) study are promising, little research has been conducted on different demographic features and varied clinical populations. At this stage there is only one other validity study concerning the CUXOS. Jeon et al. (2017) conducted a study with 838 psychiatric outpatients during intake, using a Korean adaptation of the CUXOS. The study found similar psychometric properties as reported by the original study, with a high internal consistency (Cronbach  $\alpha = 0.90$ ) and a test re-test reliability of  $r=0.74$ . Jeon et al. also found that the CUXOS was

more highly correlated with other measures of anxiety (mean  $r= 0.74$ ) than with measures of the other symptom domains (mean  $r= 0.53$ ).

Based on the current literature, the CUXOS is a valid and reliable brief assessment tool. The CUXOS can be readily incorporated into clinical practice, given the efficiency and ease of administering and scoring. However, there are limitations. The scale is not extensively researched and the impact of individual difference factors has not been explored rigorously. Additionally, clinicians should be mindful that item content is based on the *DSM-III-R* and *DSM-IV* definitions of anxiety disorders and some symptoms of distress may be underreported if triggers are being avoided by the client, e.g. phobic objects may not have been encountered that week.

### **DSM-5 Self-Rated Level 1 Cross-Cutting Symptom Measure—Adult**

The DSM-5 provides *cross-cutting symptom measures* (CCSMs), which are utilized for consideration across diagnostic symptoms. Level 1 is concise, including 1–4 items on each domain, while Level 2 is more comprehensive, including a measure for each domain. The Level 1 CCSMs are more general measures that include symptoms across domains consistent with common diagnostic categories (e.g., depression, anxiety) and assess a wider scope of time (i.e., two weeks). The Level 1 CCSMs are designed for adults to complete as a self-report. The Level 1 measure contains 23 items across 13 domains.

The Level 2 CCSMs are utilized after finding threshold scores from Level 1 measures. Level 2 measures contain a more detailed symptom investigation that can help with diagnosis and treatment, including assessment of a shorter time period (i.e., 7 days). Level 2 measures include such symptoms as depression, anger, mania, anxiety, somatic symptoms, sleep disturbance, repetitive thoughts and behaviors, substance abuse, inattention, and irritability. Certain measures address how often the individual has been bothered by a symptom within a time period of 7 days, and others ask the individual to pick a statement in a cluster that best represents the way he or she has been feeling within the past 7 days. Similar to the Level 1 measures, adults and children/adolescents between the ages of 11 and 17 may complete a self-report version; these measures can be used at the early stages of treatment and throughout the treatment process (American Psychiatric Association, 2013).

Evidence supports the use of the DSM-5 Cross Cutting measures with a college population. Bravo et al. (2018) conclude that the DSM-5 CCM have acceptable internal consistency across multi-item DSM–5 domains and moderate to strong correlations among domains (internal validity). Further, several DSM–5 domains were positively associated with longer, validated measures of the same mental health construct and had similar strengths of associations with substance use outcomes compared to longer measures of the same construct (convergent validity), a large, diverse sample of non-treatment-seeking college/university students. This conclusion was based on data from 7,217 college students recruited from 10 universities in 10 different states across the United States. The authors assert the DSM–5 Level 1 measure is a viable tool for identifying and addressing psychopathology in college students (Bravo, Villarosa-Hurlocker, Pearson., 2018).

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### **Instructions to Clinicians**

Participants will complete the first general, Level 1 DSM-CCM measure in person using paper and pencil. The DSM-5 Level 1 Cross-Cutting Symptom Measure is a self or informant-rated measure that assesses mental health domains that are important across psychiatric diagnoses. It is intended to help clinicians identify additional areas of inquiry that may have a significant impact on the individual's treatment and prognosis. Also, the measure may be used to track changes in the individual's symptom presentation over time.

This adult version of the measure consists of 23 questions that assess 13 psychiatric domains, including depression, anger, mania, anxiety, somatic symptoms, suicidal ideation, psychosis, sleep problems, memory, repetitive thoughts and behaviors, dissociation, personality functioning and substance use. Each item probes how much (or how often) the individual has been bothered by the specific symptom during the past two weeks. The measure was found to be clinically useful and to have good test-retest reliability in the DSM-5 Field Trials that were conducted on adult clinical samples across the United States and Canada.

### **Scoring and Interpretation**

The investigator will score the general, Level 1 cross cutting measure immediately to determine if a second, Level 2 disorder-specific measure is needed. Each item on the measure is rated on a 5-point scale (0=none or not at all; 1=slight or rare, less than a day or two; 2=mild or several days; 3=moderate or more than half the days; and 4=severe or nearly every day). The score on each item within a domain should be reviewed. Because additional inquiry is based on the highest score on any item within a domain, the clinician is asked to indicate that score in the "Highest Domain Score" column.

A rating of mild (i.e., 2) or greater on any item within a domain (except for substance use, suicidal ideation, and psychosis) will be used to indicate a required follow

up with a disorder specific Level 2 cross cutting measure. For substance use, suicidal ideation, and psychosis, a rating of slight (i.e., 1) or greater on any item within the domain may serve as a guide for additional inquiry and follow-up to determine if a more detailed assessment is needed (suicide will require a risk assessment, see Emergency Protocols in Appendix D).

Scoring procedures are unique for each of the Level 2, disorder-specific measures. Each procedure will be followed explicitly, and participants will be offered referrals if, after scoring, individuals indicate mild or greater in any disorder other than anxiety. Each disorder-specific Level 2 screen provides individual guidance as to what meets the mark of mild symptom severity. The link to the measure can be accessed here:

<https://www.psychiatry.org/psychiatrists/practice/dsm/educational-resources/assessment-measures>

### **Procedures used with Measures**

**CUXOS.** The repeated measures design included ten total assessment points, including the pre-and post-measures using the CUXOS which was primarily remotely administered using a survey link (Google Form) and delivered by text message on Sunday evenings. With the exception of the initial baseline CUXOS measure, the pre-intervention and post-intervention data from the preplanned CUXOS measure was obtained on Sunday evenings each week via Google Form. The CUXOS measurements obtained on Sunday at the end of each HRV of the participant was also be measured at three-time intervals during the study (First meeting-baseline, pre-intervention, and post-intervention).

**Final survey.** Additionally, a qualitative style survey was administered using Google Forms or in person (based on convenience for participant and their response to times offered by the researcher or filling out a link) during the final assessment of the CUXOS and HRV measures. The survey obtained information about the subjective usefulness of the device and intervention. Information was collected to assess the likelihood that future users would find this intervention useful. Sample questions from the survey include: Was the device easy to use? Please explain. Was the device difficult to use? Explain. Did you feel the SMHRB intervention was helpful? Explain. Did you feel that the SMHRB intervention was not helpful or would not help you in the future? Explain. Would you continue to use it? Explain. Is there anything else you want to tell me about the experience?

While automatically collected electronic data indicating adherence to fidelity protocols provides the most reliable information, self-reports are valid and recommended methods to collect treatment fidelity data for mental health interventions (Belleg et al., 2014).

**Biofeedback measures and devices.** The Self-Monitoring Heart Rate Biofeedback (SMHRB) includes the use of Maximum HR alerts used to alert users of the presence of a raised HR, a symptom of anxiety. SMHRB may also assist with relaxation breathing by guiding users to reduce HR more effectively with guided HR biofeedback. The device used to measure HR-BPM featured a wrist-based optical heart rate monitor (The Mio Alpha 2) that can measure heart rate continuously as well as a feature to alert the user when their heart rate reaches a certain threshold. In general, wrist-based heart rate monitors have shown reliability and accuracy. The percentage of error measured

across a variety of devices is small (range: 1–9% < 5bpm) (Wallen et al., 2016). The wrist-based feature is essential, as the usability and social validity of the intervention rest on this premise. The Mio Alpha and Polar HR devices are examples of devices that have the requisite features and have shown good accuracy, according to Wallen et al. (2016). In order to establish an accurate resting heart rate and max heart rate, a systematic procedure (See Appendix B) was followed (Palatini 2009). The average resting heart rate for each participant served as a target for the SMHRB intervention. Participants experiencing anxiety were told to use SMHRB to initiate relaxation and attempt to lower heart rate and reduce anxiety symptoms. Furthermore, setting a maximum HR threshold for participants signaled that their heart rate was elevated and that the user may be experiencing anxiety, which would prompt them to gain more insight into ESA and prompt the use of SMHRB.

In the intervention phase of treatment, participants demonstrated the ability to use relaxation breathing to reduce HR in the initial training session. For example, the participants followed the relaxation breathing techniques and initiated these techniques to verify they feel a sense of relaxation from relaxation breathing or a reduction in HR of three-five beats per minute in response to relaxation breathing (See Appendix D for more details about the intervention and training).

HRV was obtained by using a more accurate chest strap HR monitor. This was required to take baseline, pre- and post- measures of HRV. HRV was measured for each participant at baseline, pre- and post-intervention using the average of three trials for each measurement period. HRV is measured by analyzing the time between heartbeats. This measure is used to gain another aspect of emotional distress. HRV has been shown to correlate with anxiety and has been used consistently in a variety of studies as a measure of overall stress and psychological functioning (Sharma, Balhara, Sagar, Deepak, & Mehta, 2011). The HRV measure is a supplemental comparison to the final post-CUXOS measures and aided in determining effectiveness of the intervention.

**Calculating resting HR.** Resting heart rate is an easily measurable cardiovascular parameter but is subject to high variability. There are many sources of variability, including the resting period before measurement, environmental conditions, method of measurement (pulse palpation versus electrocardiogram), number of readings, duration of measurement, position of the body, and nature of the observer.

According to the Consensus Panel of the European Society of Hypertension, the following information should be provided in studies reporting heart rate data: (i) resting period before measurement; (ii) environmental conditions; (iii) method of measurement; (iv) number of measurements; (v) duration of measurement; (vi) body position; and (vii) nature of the observer (Palatini, 2009).

Electrocardiographic (ECG) recording is the most precise method of heart rate measurement and is routinely carried out in many clinical settings. However, use of electrocardiography implies greater financial costs, and it is not known whether increased measurement precision actually translates into more meaningful data. According to Houser et al. (2013), measurements between commercial electronic devices and ECG are highly correlated ( $R > 0.9$ ) and provide similar information. For this reason, electrocardiographic measurement is not required for the measurement of resting heart rate, even in research.

Electronic pulse meters consist of two parts: a transmitter placed over the artery and a receiver for display. A digital system is usually accurate to within 3-4 bpm of an electrocardiographic recording (Wallen et al., 2009). The Polar HR monitor selected for this study has been shown to be accurate to within 1 beat per minute of an electrocardiogram (Wallen et al., 2009).

In an attempt to minimize the effects of confounding factors, the process of measuring HRV at baseline was standardized. Participants were asked about exercise, alcohol, nicotine and coffee intake. They were instructed to avoid these activities in the hours preceding measurement, and they were asked if they complied before being measured. They were also asked to abstain in the hours preceding the final HRV measurement at the conclusion of the study. No readings required postponement, as was recommend if participants answered in the affirmative (Palatini, 2009). Readings were taken using the monitor while the patient was comfortably seated in a chair with legs uncrossed. The room was at a comfortable temperature and background noises were limited. The patient was asked to refrain from talking during the procedure, and at least 5 minutes elapsed in this setting before the first reading was taken. A quiet, private room in the instructor suite on the URI campus was reserved for these purposes as well as to maintain confidentiality. If the student was taking any medications, we asked if they had been taking them consistently through all measures in order to ensure continuity of results.

Prior to administering any measurements, the participant was asked to rest for at least 5 minutes. However, if participants reported feeling highly anxious in the moment or had disclosed a pronounced “white-coat reaction” (medical anxiety), a longer waiting period was employed. The duration of measurement ranged from 15 seconds to 1 minute in different studies. The aforementioned European consensus panel recommends 30 seconds to obtain a reliable estimate of heart rate, and this timeframe (30 seconds) was adopted as a consistent waiting period to measure resting HR for this study. Two measurements have been shown to be sufficient for a reliable estimate of resting heart rate in most patients (Palatini, 2009). The Polar H10 Heart Rate Monitor was used as the device to measure the baseline HR following the aforementioned procedures.

For comparison purposes, the following guideline values were utilized: The average resting heart rate of adults can range from 60-100 BPM. The Centers for Disease Control (CDC) estimate that the average resting heart rate for the adolescent population (age 16-19) is 75 BPM. In typical adolescents and adults, HR-BPM has been shown to fall at the following values (5<sup>th</sup> percentile = 54) (25<sup>th</sup>= 64)(50<sup>th</sup>=73)(75<sup>th</sup>= 82)(95<sup>th</sup>= 95) (Osthega et al., 2011).

**HRV calculation.** All HRV measurements were obtained by the Polar strap worn device and taken at pre- and post-study assessments. One of the standard measures used for calculating HRV is SDNN, which stands for standard deviation of the inter-beat intervals of normal sinus beats. SDNN and measures of HRV have been hypothesized to be associated with the strength of the parasympathetic component of the autonomic system. SDNN is considered one of the most relevant and accurate measures of the autonomic nervous system. The SDNN is the "gold standard" for medical stratification of cardiac risk. SDNN values predict both morbidity and mortality. Based on 24-hour monitoring, patients with SDNN values below 50 ms are classified as unhealthy, 50–

100 ms have compromised health, and above 100 ms are healthy (Shaffer and Ginsberg, 2017). SDNN will be automatically calculated on the *Polar* application.

HRV is measured using a chest belt or photo-plethysmography to measure HRV, and both have been shown to provide reliable HRV measurement ( $>.98r$ ) compared to ECG (Flatt and Esco, 2013).

For accuracy, students were asked not to participate in sports or any activity more rigorous than walking for 12 hours before the HRV measurement. Participants used a chest strap and sat and waited five minutes after it was put on to get an accurate HRV measure. All the standard procedures previously mentioned for obtaining heart rate were followed for HRV, with the addition of a chest strap and recommendations for reduction of physical activity before the assessment.

## **Appendix C**

### *Ethics, Emergency Procedures and Psychoeducation*

#### **Ethics/Informed Consent**

The research has been presented and approved by the Institutional Review Board (IRB). One of the protections for the subjects is a clear description of research protocols and procedures. Research participants' information was protected in an encrypted, password-secured protected file. Another benefit to participants includes psychoeducation with respect to the physiological aspects of anxiety. Additional benefits include practice with coping mechanisms (relaxation breathing); potential reduction of symptoms of anxiety; and a fitness tracker/ heart rate monitor.

The URI students were free to participate without penalty or coercion and were allowed to opt out at any time. Prior to obtaining informed consent, participants were provided an in-depth description and full disclosure of procedures. Although unlikely, participants who did not see improvement could have become frustrated with their participation. Students were made aware that they could opt for a referral for counseling at any point during the study.

#### **Emergency Procedures**

In the extremely unlikely event that a participant disclosed that they may be at risk of self-harm, a more thorough risk assessment (SAFE-T) would have been conducted. SAFE-T includes questions and guidance to assess any ideation, intention, means or a plan to harm oneself. The SAFE-T plan could be implemented by the investigator who has training on risk assessments and experience conducting them. See SAFE-T plan at this website:

[https://www.integration.samhsa.gov/images/res/SAFE\\_T.pdf](https://www.integration.samhsa.gov/images/res/SAFE_T.pdf). If any of the essential risk questions were answered in the affirmative, or if the student felt unsafe, campus emergency personnel would have been alerted, and the student would not be left alone. If there is no immediate danger but the potential participant endorsed symptoms of moderate depression or other symptoms of disorders as indicated on the DSM-5 measures, a referral for counseling would have been provided.

#### **Psychoeducation Protocol**

Participants who did not meet inclusion criteria or were excluded were provided guidance for how to access psychoeducation media after they had been given measures determining their eligibility status. This was accomplished by sending them an email and instructions to access a website on their own or in the form of a brief guided tour through a comprehensive website on anxiety in person at designated times. The in-person option was offered to interested individuals; however, if in-person attendance was not possible, web options described above were offered. The website includes an overview of typical anxiety presentations, normalization of anxiety, and possible uses of coping mechanisms. A short video on the same webpage can be viewed so participants have coping strategies modeled for them. Those who were not included in the study were encouraged to download the accompanying mobile app that is associated with the page that may help them.

Ineligible participants were extended a referral for counseling if their anxiety symptoms were severe (anxiety above 41 on the CUXOS) and/or their symptoms were indicative of another disorder as described previously in exclusion criteria. Students were given a global screener, DSM- 5 Cross-Cutting Symptom Measure (DSM-5 CCSM, in person, paper and pencil version), (see Appendix B for administration instructions) to determine the potential for other causal factors of distress besides symptoms of anxiety. The DSM-5 CCSM is a global screening (Level 1) measure that indicates if participants should be screened further for specific disorders. For example, while the screener has several disorder categories, if a participant endorses any question in a depression category on the global (Level 1) screener that indicates the potential presence of depression then a more specific (Level 2) depression evaluation screening was conducted. Participants who indicated mild symptoms or greater on the second, more-specific disorder measure would be extended a referral and excluded from the study. If participants endorsed symptoms of a disorder (other than anxiety) on the first, general Level 1 screen and did not indicate mild symptoms of the disorder on the more comprehensive level 2 screen they were still eligible for the study. Once participants were administered the CUXOS and DSM-5 CCSM, the items were scored immediately, and students learned of their eligibility status prior to leaving the initial assessment meeting.

Scoring procedures for DSM-5 Screening tools (individual domain screeners have their own scoring): <https://www.psychiatry.org/psychiatrists/practice/dsm/educational-resources/assessment-measures>

*Psychoeducation Website:*

<https://www.anxietybc.com/parenting/generalized-anxiety-disord>

## **Appendix D**

### *Relaxation Breathing Training & Procedures*

Participants were asked to follow instructions below to implement relaxation breathing when they receive a maximum HR alert (excluding physical activity, including walking). The procedure to implement calm breathing was also accompanied by an audio guide that was played for participants. During this initial introduction to the audio, they practiced for a short time (1 minute and 43 seconds). This was repeated as needed until participants indicated they could undertake this protocol on their own and could reduce HR by 3-5 BPM. If they needed more practice time, that was allowed by the researcher. The website with accompanying audio is provided here:

<https://www.anxietybc.com/adults/calm-breathing>

Furthermore, once a HR alert had occurred a participant was to engage in further self-monitoring which included HR biofeedback using the wrist-worn digital HR monitor display. Although HR monitoring is used during relaxation breathing (altering breaths to ensure a reduction in HR), it may also act as an SM intervention by increasing physiological awareness while allowing more efficient reduction in HR. The combination of the HR alert and relaxation breathing enhanced by HR biofeedback comprises the SMHRB intervention package. Relaxation breathing to initially train individuals to reduce HR may help to confirm they are executing the breathing in an effective way to relax and improve symptoms.

Once participants demonstrated in training that they could perform relaxation breathing, by showing a small reduction in HR (3- 5 bpm) or indicating they felt more relaxed after breathing, they may no longer needed to monitor their HR after a maximum HR alert. Relaxation breathing after a HR alert without viewing the HR display may be

enough for participants in-vivo. Participants could still confirm their HR is below the Max HR threshold when the red light has changed to green.

### **How to Do Calm Breathing**

Calm breathing involves taking smooth, slow and regular breaths. It is best to 'take the weight' off your shoulders by supporting your arms on the side-arms of a chair, or on your lap.

1. Take a slow breath in through the nose, place your hand on your lower abdomen and feel it rise with the in breath.
2. Hold this breath at the end of the inhale for approximately 3-4 seconds.
3. Exhale slowly through the mouth (for about 5-7 seconds).
4. Wait a few seconds before taking another breath.
5. During your breathing, watch the HR display on your monitor confirm that your breathing is reducing HR-BPM. If HR-BPM is not being reduced, alter breathing by lengthening outbreaths by a second or 2. Find the rhythm that's comfortable and reduces HR for you.
6. About 6-8 breathing cycles per minute are often helpful to decrease anxiety, but find your own comfortable breathing rhythm. These cycles regulate the amount of oxygen you take in so that you do not experience the fainting, tingling and giddy sensations that are sometimes associated with over-breathing\*.

\*Over-breathing is similar to hyperventilating. Over-breathing involves taking quick shallow breaths and essentially taking in excess air which depletes valuable CO<sub>2</sub>, an important regulator of many functions in the body. This behavior is often associated with anxiety and occurs more frequently when one is anxious.

## Appendix E

### Participant Daily Text Message Questions

#### Afternoon and Evening Daily Text Message Questions:

1. Did you wear the monitor device (AM) or (PM)?
  1. If you wore the device for more than 75 % of this period, respond yes.
2. How many times did the device alert you?
3. Of the alerts you counted above, how many of those times did you feel **anxious**?
4. Out of the times you were alerted and felt anxious how many times did you engage in relaxation breathing?
5. Were there any times you did relaxation breathing w/o an alert? If yes, how many sessions?

\*AM Text period (Awake – 3pm), PM Text period (3pm – 10 pm)

- **Anxious** means: Definition: a feeling of worry, nervousness, or unease, typically about an imminent event or something with an uncertain outcome.
- If you experience two or more of the following symptoms simultaneously, you may likely be experiencing anxiety: feeling physically tense or 'wound up'; a sort of frightened feeling like 'butterflies' in the stomach; a sort of frightened feeling as if something awful is about to happen; restlessness as if you have to be on the move; worrying thoughts going through your mind; you can't sit at ease and feel relaxed; you get sudden feelings of panic; feeling irritable; having trouble concentrating or focusing on what you're doing (Based on the Hospital Anxiety Scale, adapted for use in describing momentary feelings).

**Appendix F**  
*Open-Ended Study Conclusion Questionnaire Responses*

Participant#	Open Ended Questions & Participant Responses
<b>Q1</b>	
<b>Was the intervention easy to use? Please explain.</b>	
1	I felt as though the intervention was very simple to use. I struggled at first using the watch and figuring out all of the basic functions it had. I always seemed to turn on some sort of workout or fitness thing and it wouldn't really turn off until the watch was switched off at the end of the day. The breathing techniques were extremely simple and not hard to figure out. They were not at all a challenge even when I found myself having anxiety on the go (library, class, driving, etc.).
2	Yes, the intervention was easy to use. Once I learned more how to turn it on, turn it off, charge it, and track my heartbeat, it was much easier to use.
3	Yes! It was very easy to use it really became a part of my daily routine to charge it at night like my phones and to answer the survey as much as I could daily. Having it texted to me made it much easier to remember to fill it out as well as having the app on my phone.
4	Yes, I would consider the intervention overall easy to use. The device and breathing techniques were both very easy to learn and it did not interrupt my daily life. The surveys were not time consuming either, and were very thorough in their explanations.
5	Yes, it was easy in the way of recording my heart rate and knowing when it flashed red or green.
6	The device was not hard to use but it was confusing and at times I couldn't get it to sync to the app. I feel like if I knew how to correct this error it would have been easier for me.
7	It was very easy to use, recording what the heart monitor read twice a day was not difficult at all. When I saw my heart rate spike, I used the breathing exercises I was taught.
<b>Q2</b>	
<b>Was the intervention difficult to use? Please explain.</b>	
1	The only thing I struggled with was simply responding to the questions after each time slot. I found that the time slot always seemed to end while I was in class or in the middle of something else. Besides that, nothing was too difficult.
2	It was only difficult to use at the beginning when I was unsure how to track my heart beat after charging it.
3	I never had any difficulties using it. There were only a few times it would slip my mind to fill it out on a busy day but other than that no issues!
4	The only difficult parts of the intervention were wearing the device at all times. There were several times like dinners or formal events when I did not want to wear the device and had to remember to be aware of my heart rate without it and remember to bring it for wearing after.
5	The heart monitor was hard to use sometimes because the buttons were unclear and hard to push
6	The difficult part was know how to navigate the watch with the app. At times it would say it was syncing but nothing else would happen and then I would not be able to use it.
7	No it was not difficult at all. I sometimes forgot to respond to the daily surveys but that was it.
<b>Q3</b>	
<b>Do you feel the intervention was helpful? Explain.</b>	
1	I definitely helpful overall. I seemed to be much more relaxed and my overall anxiety seemed to be decreased. The breathing really seemed to help me calm down especially when my anxiety was keeping me from doing things like studying or doing homework.
2	I definitely helpful overall. I seemed to be much more relaxed and my overall anxiety seemed to be decreased. The breathing really seemed to help me calm down especially when my anxiety was keeping me from doing things like studying or doing homework.
3	I found it to be very helpful it helped me be more mindful about my anxiety and taking the time to try and calm myself down in a different way rather than taking a nap or just staying in bed that day. It helped me want to try and get through it and see if this could really be something that worked for me.
4	I absolutely consider my participation in the study helpful to myself. It increased my awareness of my heart rate, anxiety and their interrelation. It was helpful to see the quantitative data when I was anxious and having the goal of lowering it gave me a way to see how well or not I could calm myself down.
5	Yes, I felt that my anxiety decreased and the deep breathing brought my heart rate down.
6	Yes, I started using the breathing exercises more often and even did them with my friend who suffers from anxiety when she would have panic attacks and they helped her as well. At times I wouldn't be anxious and the watch would turn red, which was concerning cause sometimes it would remain red unless I did the breathing exercises.

7	I think it was helpful because seeing my heart rate spike reminded me to take a couple deep breaths and relax. Also if I was ever feeling anxious the breathing exercises really helped.
<b>Q4</b>	<b>Did you feel the SMHRB intervention was not helpful or would not help you in the future? Explain.</b>
1	The biggest thing I struggled with was the flashing on the watch. If I was not feeling anxious and looked down to see the watch flashing red. It would make me feel as though I should be anxious because my heartrate was up. If the light was either constant or not there at all and there was another way of being notified when my heartrate was up that would be great. The flashing red light was like a reminder to “be anxious” and that I need to calm down. In the end it kind of became a trigger of sorts.
2	I feel that the SMHRB intervention was definitely helpful. I know that it will help me in the future when I am stressed about something, I will use the breathing exercises to help me calm down and focus.
3	I never felt like it was not helpful. I think it is important to be aware of my heart rate and the things that may give me more anxiety on a daily basis to see if I can somehow change my day even a little to avoid that.
4	I did not feel this way. There were no lasting negative effects from my participation
5	No, it was very helpful.
6	N/A
7	I think it will help me in the future if I ever feel anxious or overwhelmed, I can take a minute to do the breathing exercise and keep my heart rate down
<b>Q5</b>	<b>Do you plan to continue to use the intervention now that the study is completed? Explain.</b>
1	I do plan to continue with the breathing for sure. I don’t know if I will continue wearing the watch as much as a do now. But, I do plan on wearing it on days that I know I will be stressed or anxious, in order to, help me better manage it.
2	I do plan to continue to use the intervention. I will not use it every day like I did during the study but will continue to use it.
3	I have already continued to use it! I think it is important to keep going with this even without the survey tracking daily to see if I can make a change for myself even if it is just a slight change.
4	I do plan to continue practicing the breathing exercises in the future. I may not wear the monitor all day but plan to monitor my heart rate myself since I now know how to.
5	Yes, I do deep breathing everyday now even when I don’t see my heart rate
6	I will probably not use the watch since I have an apple watch already that monitors my activity and heart rate.
7	I will definitely keep using the breathing technique if I ever feel anxiety coming on.
<b>Q6</b>	<b>Anything else you want to tell me about the experience?</b>
1	Overall, I definitely enjoyed the experience and thank you for letting me partake. I hope to be involved in any other studies that you do, if you will have me. If you have any further questions from me please let me know.
2	The HRV watch is difficult to track all of the red flashes, but it is better than a watch that alerts you every time. I tried my best to count all of the red flashes but I might have missed a few. Overall, my experience with this study was great.
3	Thank you
4	I’m glad that I participated. I was not the biggest fan of the color, size and blinking of the watch, which is why I did not wear it to formal events. Also I feel the blinking red light is not the best indicator. Seeing the two blinking red lights often made me more anxious when I saw it, more so than just seeing the number. For some reason seeing the blinking red light made me feel more anxious if I was not already. Thank you for letting me participate.
5	Nope! It was very helpful and I plan on doing deep breathing more often!
6	The reminders were helpful because it made me more aware of when I was anxious and helped me learn how to better manage it.
7	It was very helpful in finding ways to relax during stressful times!

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