# DESIGN AND EVALUATION OF A WEARABLE TECHNOLOGY USING BIOMEDICAL SENSING FOR STUDENTS WHO EXPERIENCE ANXIETY

by

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Dedicated to my wife Sun and my son Sun.

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# ABSTRACT

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The present study evaluated the feasibility and social validity of using a wearable technology to detect anxiety for educational purposes. Twenty college student who planned to take a Graduate Study Exam (GRE) for attending graduate school were recruited to participate in the study. Each participant completed a practice GRE with quantitative and verbal reasoning sections. The participants were asked to complete a demographic questionnaire and State and Trait Anxiety Inventory before the practice exam. An acceptability questionnaire was administered after the practice exam to collect data on the social validity of the wearable technology. During the practice exam, the participants were asked to tap a button on the wearable device to report stressful incidents (SI) when they felt the exam questions were causing them to feel stressed. The participants' heart rate and skin conductance data were collected and analyzed with the timing of their self-reported SI. The data indicated that significant heart rate changes were detected in 66% and 70% of the self-reported SI in the quantitative and verbal reasoning sections, respectively. The results indicated heart rate data could be used for short-term anxiety monitoring for educational purposes in the real classrooms. The social validity data indicated polarized results for the acceptance of an anxiety monitoring technology for educational purposes. Participants with higher familiarity with wearable devices in general reported the wearable device used in the study less distracting during the practice exams. Participants with higher levels of anxiety reported being less comfortable with their physiological signals monitored during the practice exams. Implications and suggestions for future research studies are discussed.

# CHAPTER 1. INTRODUCTION

This chapter provides an overview to this study and establish the significance of anxiety in education, particularly to students with learning disabilities (LDs).

## 1.1 Background

Research studies have shown that anxiety hinders learning outcome and academic performances (Alloway & Alloway, 2010; Eysenck & Calvo, 1992). Additionally, in the United States, test anxiety has increased in elementary education since No Child Left Behind (NCLB) achievement testing was introduced because students experience more cognitive and psychological symptoms of test anxiety in high-stake academic tests (Segool, Carlson, Goforth, von der Embse, & Barterian, 2013). Students with LDs are at higher risk of experiencing anxiety and susceptible to its adverse effects (Bryan, Burstein, & Ergul, 2004; Huntington & Bender, 1993). Very little has done in educational settings for those who experience high levels of anxiety using technology. Other aspects of special needs in education often benefit from the use of technology. Children with autism can benefit from technology-based learning ( Fletcher-Watson, 2015). People with cognitive dysfunction can benefit from a variety of assistive technologies that support their cognitive functions. Examples include prompting, navigating, reminding or storing. According to Gillespie, Best, and O'Neill (2012), "there is increasing evidence for the efficacy of assistive technology for cognition to support attention, emotion-regulation, experience of self in relation to place, and memory." There have been clinical devices that help people who experience anxiety disorder to monitor and manage their anxiety (Reiner, 2008). However, most are designed and used in a more general context and as self-help devices. They do not address the context in which the anxiety occurs. For example, the device tells the user when anxiety is detected and reminds the user to practice calming techniques such as taking a deep breath. They do not address where the anxiety occurs. In educational settings, students could experience anxiety because the content or instructions given are overwhelming to the students. In such cases, interventions or adjustments are much needed. Currently, there's no technology that detects anxiety and enables educational facilitators, teachers, or computers to provide intervention or adjustment for the students. This research study proposes an educational and assistive technology that monitors learning related anxiety and helps fill the gap in the current use of technology in education.

## 1.2 Statement of Purpose

This research study aims to design and evaluate a technology that supports the emotional needs of students who are at risk of experiencing anxiety. The target group of the anxiety monitoring technology includes individuals with LDs, individuals with general anxiety disorder, and the general population who experience anxiety from time to time. This technology has two potential applications. First, it could enable teachers to provide intervention to the students when potential indicators of anxiety are detected. Second, it could be integrated with intelligent tutors who deliver adaptive learning content based upon the cognitive load of the students. Furthermore, this technology attempts to fill a gap in current assistive and educational technology. Most current assistive technology for LDs focuses on helping students complete specific tasks but does not address anxiety. Additionally, unlike human tutors, current educational technology has no or very limited ability in observing and knowing the student's emotional status while delivering content. Finally, this technology is designed to be mobile so it can be easily used at any learning environment.

## 1.3 Scope

This research attempts to study the effectiveness of an anxiety monitoring technology for students who experience anxiety while engaging in learning activities.

## 1.4 Significance

Research studies have shown that high levels of anxiety have negative impacts on cognitive and academic performances. High levels of anxiety consumes the limited amount of working memory, disrupts information processing, and hinders learning outcome (Alloway & Alloway, 2010; Baddeley, 1992; Eysenck & Calvo, 1992)

## 1.5 Research Questions

- Can a wearable technology use heart rate variability and skin conductance response to identify a student's anxiety resulting from engagement in a potentially distressing learning activity?
- Is the use of wearable technology for educational purposes, such as intelligent tutoring and classroom intervention, socially acceptable?

## 1.6 Assumptions

The assumptions for this study include:

- The wearable device used in the study is as accurate as the manufacturer's specification and other independent researchers' studies.
- Participants of the study used the wearable device as designed and intended.
- The participants of the study were taking the practice exam seriously, meaning that the participants engaged in the exam as they would outside of laboratories.
- the participants of the study truthfully and accurately reported their stress during the study.

## 1.7 Limitations

The limitations for this study include:

- This study is limited to the wearable technology available.
- This study is limited to the accuracy of the sensors used.
- This study uses wearable technologies available at the time the study is conducted.

## 1.8 Delimitations

The delimitations for this study include:

- This study focuses on anxiety. Other emotions such as excitement or happiness are not included.

## 1.9 Definitions

In the context of this dissertation, the following terms are defined as:

*Learning Disabilities:* ”Learning disabilities is a general term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities” (NJCLD, 1990).

*Anxiety:* ”Anxiety is a state of uneasiness, accompanied by dysphoria and somatic signs and symptoms of tension, focused on apprehension of possible failure, misfortune, or danger” (Coleman, 2001). Anxiety is a reaction to stress.

*Academic Engagement:* ”Academic Engagement means that the student is appropriately engaged in working on assigned academic material that is geared to her or his ability and skill levels. While academically engaged, the student is (a) attending to the material and the task, (b) making appropriate motor responses (e.g., writing, computing) and (c) asking for assistance (where appropriate) in an acceptable manner. Interacting with the teacher or classmates about academic matters or listening to teacher instructions and directions are also examples of academic engagement. Nonexamples of academic engagement would include such things as not attending to or working on the assigned task, breaking classroom rules (out of seat, talking out, disturbing others, etc.), or daydreaming" (Walker et al., 1990).

## 1.10 Summary

This chapter provided an overview of the research study. It included scope, significance, research question, assumptions, limitations, delimitations, and definitions.

# CHAPTER 2. REVIEW OF RELEVANT LITERATURE

This chapter provides a review of the literature relevant to learning disabilities, assistive technology, anxiety, sensors, and mobile applications.

## 2.1 Definition and Characteristics of Learning Disabilities

About 6 million students from age 6 to 21 are served under the Individuals with Disabilities Education Act (IDEA). This number represents 8.4 percent of the resident population for the age group. About 40 percent of the 6 million students fall into the category of learning disabilities. Therefore, learning disability (LDs) is the largest special education category with about 2.4 million students under IDEA (U.S. Department of Education, 2014). The definition of LDs has long been discussed and debated by parents and professionals. The term LDs was first invented by Betts (1936)and made known by Kirk (1963). A widely adopted early definition of LDs was developed by the National Advisory Committee on Handicapped Children (NACHC) and was defined in Public Law 94-142 in 1975. The early definition of LDs provided a basis for legislation and funding opportunity for the establishment of educational programs for children with LDs. PL 94-142 defines children with specific learning disabilities as:

> Those who have a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or to do mathematical calculations. The term includes such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include children who have learning problems which are primarily the result of visual, hearing, or motor handicaps, of mental retardation, or emotional disturbance, or of

> environmental, cultural, or economic disadvantage (Public Law 94-142, 1975).

This early federal definition however, was often misinterpreted. People often erroneously concluded that people with LDs are a homogeneous group of individuals, and this further led to the misconception that there exists a standard approach in the identification, remediation, and assessment of people with learning disabilities. In fact, learning disabilities should be understood as an umbrella term for a range of learning related disorders. According to NJCLDs, learning disabilities should be a general term that refers to a heterogeneous group of disorders. Furthermore, the old definition uses the term learning disabilities alongside the term children. This usage confines the definition of LDs to children and thus fails to acknowledge that learning disabilities is a lifelong condition. The new definition of learning disabilities by IDEA in 2004 is as follows:

> The term specific learning disability means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which disorder may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations. Such term includes such conditions as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. Such term does not include a learning problem that is primarily the result of visual, hearing, or motor disabilities, of mental retardation, of emotional disturbance, or of environmental, cultural, or economic disadvantage.

The newly developed definition of LDs made references to heterogeneity, underachievement, CNS dysfunction, process clause, life span, exclusion clause, spoken language disorders, academic disorder, and thinking disorders (Bryant, Bryant, & Ok, 2014). One common misunderstanding of LDs is its relationship with behavioral or social problems. Individuals with LDs often demonstrate problems in self-regulate behaviors and may develop altered social perception and problems in social interaction. However, the newly developed definition clarifies that the manifestation of those problems are not considered sufficient evidence in constituting learning disabilities. In other words, although behavioral and social problems often coexist with LDs, they do not constitute LDs. Furthermore, while learning disabilities could concurrently occur with other types of disabilities or psychological disorders such ADHD, LDs are not the consequence of those conditions. The coexistence of LDs and other behavioral or emotional problems might be due to the central nervous system dysfunction. While LDs might be a consequence of the dysfunction in central nervous system, its identification is not restricted to a physician's diagnosis. Instead, according to NJCLDs,"the critical elements in the diagnosis of learning disabilities are elicited during psychological, educational and/or language assessments".

### 2.1.1 Learning Disabilities in Reading, Writing & Mathematics

Bryant et al. (2014) summarized the characteristics of LDs in terms of reading, writing, and mathematics. The characteristics were identified through a survey designed by 36 experts and sent 15000 randomly selected professionals. The results were rated by over 500 professionals for over 2000 students with LDs across the United States (Bryant, Bryant, & Hammill, 2000; Bryant et al., 2000, 2014). The following includes some examples. For reading, individuals with LDs tends to have trouble reading words correctly such as omitting or adding words when reading out loud, or have trouble distinguishing words that appear similar. For writing, individuals with LDs tend to write awkwardly or spell poorly. They use unconventional pencil grip or spells words with the correct letters but wrong orders. For math, individuals with LDs have troubles with calculations such as not recognizing operator signs or failing to carry numbers when appropriate.

## 2.2 Anxiety and Cognitive Performance

The relationship between anxiety and cognitive performance has been widely studied. Anxiety is an important subject within the field of cognition as it interferes with cognitive performance. Anxiety is defined in the Dictionary of Psychology by Coleman (2001) as:

> Anxiety is a state of uneasiness, accompanied by dysphoria and somatic signs and symptoms of tension, focused on apprehension of possible failure, misfortune, or danger. (p.46)

Anxiety is essentially an emotion, and its conditions can be long-term or short-term. Spielberger, Gorsuch, and Lushene (1970) categorized anxiety into state anxiety and trait anxiety. State anxiety refers to the short-term condition and trait anxiety describes the long-term condition. As Spielberger et al. (1970) described:

> State anxiety may be conceptualized as a transitory emotional state or condition . . . that varies in intensity and fluctuates over time. This condition is characterized by tension and apprehension, and activation of the autonomic nervous system . . . Trait anxiety refers to relatively stable individual differences in anxiety proneness, that is, to differences between people in the tendency to respond to situations perceived as threatening with elevations in [state-anxiety] intensity. (p. 3)

The intensity of state anxiety rises when the person perceives the encountered situation as threatening. The person would feel tense, worried, or uneasy. Trait anxiety, on the other hand, implies that people with high intensity of trait anxiety are more prone to perceive situations as threatening and therefore respond with negative emotions. The relationship between anxiety and cognitive performance was explained by the processing efficiency theory. According to the processing efficiency theory, anxiety has two main effects on performance (Eysenck & Calvo, 1992). First, it reduces the storage and capacity of the working memory available for performing a task. Second, anxiety increases the effort required to improve performance. Therefore, anxiety could potentially cause adverse effects on cognitive performance if it takes up the working memory available for the cognitive tasks.

Working memory, also called short-term memory, was first proposed by Atkinson (1968). It is the stage in which information is held, processed, and prepared for long-term memory. As a result, limited working memory implies that there is not enough space for the information to be held and processed into long-term memory. Working memory has been known to play a vital role for complex cognitive activities such as comprehension, learning, and reasoning (Baddeley, 1992).

Recent research studies have shown a more direct and positive correlation between working memory and academic performance. A study investigated 308 children with low working memory scores and their academic performance. The majority of the children with low working memory in the study struggled with both cognitive and behavioral difficulties. Their major barriers included short attention spans and poor academic performance (Alloway, Gathercole, Kirkwood, & Elliott, 2009).

Another recent study yielded similar results. The results of the study suggested that memory capacities determine one's ability to direct attention to or ignore information (Fukuda & Vogel, 2009). Expectedly, a recent study showed that working memory is an accurate predictor of one's academic success. According to Alloway and Alloway (2010),

> Working memory at the start of formal education is a more powerful predictor of subsequent academic success than IQ during the early years (p. 26).

Therefore, because anxiety causes adverse effects to working memory, it makes sense that anxiety also has negative impact on a student's overall learning outcome. In short, high levels of anxiety consume the limited amount of working memory, disrupts information processing, and hinders learning outcome (Eysenck, Derakshan, Santos, & Calvo, 2007).

### 2.2.1 Anxiety and Learning Disabilities

A large body of literature has examined socio-emotional aspect of LDs. Research studies have shown that students with LDs demonstrated a higher anxiety level and other emotional problems (Huntington & Bender, 1993). Studies that compared students with and without LDs have indicated that students with LDs are more likely to experience negative emotions, including depression, anxiety, and loneliness (Bryan et al., 2004). A meta-analysis of 53 studies on the relationship between anxiety and learning disabilities confirmed similar findings (Nelson & Harwood, 2011). According to Nelson and Harwood:

> Sufficient research evidence exists to conclude that students with LDs are at greater risk for experiencing problems with anxiety than are non-LDs students. Future researchers should direct their focus to determining the mechanisms that underlie this increased risk rather than determining whether students with LDs are at risk. Furthermore, protective factors that may prevent students with LDs from developing problems with anxiety should be explored. Finally, it would likely be beneficial to investigate the effects of treatments for anxiety problems on the academic achievement of students with LDs. (p. 11)

Theoretical explanations have been proposed to address the relationship between LDs and anxiety. First, anxiety and LDs are due to a shared neurological dysfunction. Second, a high level of anxiety causes learning disability. Third, anxiety is a product of learning disability. However, none of the theories sufficiently explains the relationship between anxiety and learning disabilities (Spreen, 1989).

A majority of studies on anxiety and LDs have focused on the aspect of test anxiety. Test anxiety could occur before or during the test. It could cause both physical and emotional symptoms. Common physical symptoms include headache, diarrhea, excessive sweating, shortness of breath, or rapid heartbeat. Feeling of fear, helplessness, and disappointment are also common emotional symptoms (Anxiety and Depression Association of America, 2015). Several studies have shown that people with LDs are more likely to experience test anxiety due to cognitive interference (Swanson & Howell, 1996; Whitaker Sena, Lowe, & Lee, 2007). According to Whitaker Sena et al. (2007), "Cognitive interference is the task-irrelevant thoughts that disrupt students' thinking when they take tests" (p. 370). However, it is unclear whether cognitive interference could be a result of anxiety in the first place. People with high anxiety often have intrusive thoughts and concerns, which is a type of cognitive interference.

Another common explanation of test anxiety for students with LDs comes from the belief that students with LDs are more fearful of failure and negative perception of peers because of their poor academic history. It is likely believable that anxiety is a result of LDs when it comes to test anxiety because students with LDs often have weaker academic performance history and therefore are more fearful of failing a test. However, people with high trait anxiety are also more prone to view a situation as threatening. Students with LDs could simply be more fearful of tests because they have a higher intensity of trait anxiety. Therefore, in the case of test anxiety, whether anxiety is a cause or result of LDs remains elusive.

### 2.2.2 Anxiety Intervention for Students with Learning Disabilities

While the theoretical explanation for anxiety and learning disabilities remain inconclusive, it can be assumed that reducing anxiety would help improve learning outcomes for individuals with LDs because anxiety has negative impact on working memory. Some research studies have shown the relationship between reduced anxiety and improved academic performance in students with LDs. One research study applied five-week mindfulness meditation (MM) to 34 adolescent students indicated results with reduced anxiety and improved academic performance (Beauchemin, Hutchins, & Patterson, 2008). The 34 participating student ranged from age 13 to 18, among them 29% were female and 71% were male. There were one male and one female participating teacher. MM training by a professional MM instructor was given to the high school teachers and the principle investigator of the study. Additional MM educational materials were also supplied. The teachers and the PI then gave two 45 minute sessions of MM training to two separate groups of students. After the initial training, the intervention for the study was a 5 to 10 minutes meditation session before each class. The intervention lasted 5 weeks. Pretest and posttest results were compared. Both trait and state anxiety scores were significantly lower after the intervention. The students' pre and post social skills, problem behaviors, and academic performance were evaluated by the teacher. The results indicate significant improvement from pretest to posttest.

Another study applied an eight-week integrative treatment of muscle relaxation, guided imagery, self-instruction training, and test-taking skills to a group of students with LDs. The treatment group showed significant improvement while the controlled group showed no significant difference in academic engagement (Wachelka & Katz, 1999). The participants' age ranged from 17 to 52 years old with an average of 28.72. Twenty-seven students completed the study; fifteen were in high school and twelve were in junior college. Participants were randomized into control and treatment groups. Eleven students actually completed the treatment. The students in the treatment group receive individual one-hour training each week for eight weeks. With one topic every two weeks, four total topics were covered throughout the eight-week intervention period. Three measures were used for pretest and posttest: Test Anxiety Inventory, Survey of Study Habits and Attitudes, and Coppersmith Self-Esteem School Scale. The results for the treatment group indicated statistically significant improvement for all three measures.

## 2.3 Assistive Technology for Students with Learning Disabilities

Challenges faced by students with LDs varied in reading, writing, and mathematics. A large proportion of students with LDs have difficulties in multiple areas. However, not all students with LDs have challenges in all three areas. Teachers have to find effective approaches to compensate for the challenges faced by the students with LDs. Having varied and multiple disabilities suggests there is no standard or cure-all approach in remediating the students' weaknesses. Alternatively, in order to compensate for the weaknesses posed by students with LDs, teachers make adaptations; that is, they make changes to their instructional method, material, or content and ensure the students can access the general education curriculum (Bryant, Smith, & Bryant, 2008). Teachers make setting-specific adaptations to meet the needs of the students, such as allowing students more time when given a test. The adaptation is based upon specific classroom activities. Consequently, the use of assistive technology (AT) is also determined by the settings. Another factor that determines the adoption or use of AT is the student's specific characteristics. As mentioned earlier, students with LDs have varied challenges; the use of AT therefore is also dependent upon the particular characteristics of the student. Students with LDs may have varied strengths and weaknesses. For example, a student can benefit from audio reading software if he has poor reading capabilities but good listening skills. Therefore, what's considered "Assistive Technology depends on whether the device or technology helps the student circumvent his or her particular barriers. For example, a math calculator becomes an AT device if it enables the student with math LDs to learn math that might otherwise be impossible. According to Individuals with Disabilities Education Act (IDEA),

> In general, the term 'assistive technology device' means any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain, or improve functional capabilities of a child with a disability. (IDEA, 2004)

With this definition, various technologies have been used to increase, maintain, or improve functional capabilities of a child with a disability. Table 2.1 on page 15 illustrates some examples of AT for LDs and their advantages and disadvantages.

As seen in Appendix A, most AT for LDs are adopted to help students cope with reading, writing, or mathematics difficulties. They focus on helping the students to circumvent their challenges. As a result, two important aspects that the current AT fails to address are the mental states of the students and the teachers' ability to intervene in time. Students with LDs often show a higher level of anxiety and emotional and behavioral problems (Huntington & Bender, 1993). Studies that compared students with and without LDs have indicated that students with LDs are more likely to experience negative emotions (Bryan et al., 2004). A meta-analysis of 53 studies on the relationship between anxiety and learning disabilities confirmed similar findings (Nelson & Harwood, 2011).

Although various assistive technologies had been used to help individuals with learning disabilities, few research studies have examined the effect of using wearable technology in reducing anxiety and improving academic engagement for individuals with LDs. With the emergence of affordable wearable technologies available on the market, wearable technology can be used to monitor and reduce anxiety for people with LDs. The proposed technology allows teacher to identify when a student with LDs is struggling in class, and the teacher can therefore intervene in a more timely and appropriate manner. This proposed technology and study will fill the research gap and examine the effect of using assistive technology to address the mental and emotional needs of student with LDs.

Table 2.1. *Assistive Technology for LDs*

| Technology | Description | Advantages | Disadvantages |
|---|---|---|---|
| Text-to-speech system (TTS) / Speech synthesis | Convert text to speech by producing computerized voice-output. | Helps student with reading disability to understand text through listening. | Produces computerized voice; requires a quiet environment to use the software program. |
| Optical character recognition (OCR) | Convert printed materials into machine-coded text. | Allows printed material to be read out loud by text-to-speech software. | Scanning large amount of printed materials can be cumbersome. |
| Word processor | Computer software application that supports composition of documents. | Helps students to write without worrying about making spelling or proofreading errors. | Is not available when the person can only write on paper. |
| Speech recognition | Software applications that convert speech to text. | Particularly useful for students with writing disability whose oral ability exceed writing ability. | Requires a quiet environment to use the software program. |
| Electronic math worksheets | Software applications that allow student to organize and work through math problem on a computer screen. | Useful for students with challenges in organizing math problem with pencil and paper. | Is not available when the person can only work through the math problems on paper. |

## 2.4 Intelligent Tutoring Systems

Intelligent Tutoring Systems (ITS) are intelligent educational technology that delivers personalized instructions and responses based upon the student's personal characteristics. ITS is a part of the field of artificial intelligent and education, which is grounded in the disciplines of computer science, psychology, and education (Woolf, 2010). Because ITS is highly adaptive and sensitive to the needs of individual students, it can act the role of a human tutor and serve as an effective aid beyond traditional classrooms for students with special needs (Woolf, 2010).

ITS can recognize and accommodate individual student's personal learning style (Yannibelli, Godoy, & Amandi, 2006), cognitive abilities, and emotional state (DMello et al., 2010; Graesser et al., 2008).Woolf (2010) categorized seven key intelligent features of ITS, including generativity, student modeling, expert modeling, mixed initiative, interactive learning, instructional modeling, and self-improving. The following paragraphs will provide explanations and examples for each above-mentioned ITS features.

Generativity refers to the ability to generate appropriate content and feedback to the student's individualized learning needs. An example of such ability is AnimalWatch. AnimalWatch is a mathematics tutor that provides hints to students based on gender and cognitive abilities. In evaluation study of AnimalWatch, the researchers found that math symbols that were less abstract were more effective for students with lower cognitive abilities, and the opposite is true for students with higher cognitive abilities (Arroyo, Beck, Woolf, Beal, & Schultz, 2000).

Student modeling refers to the ability to gauge the students' knowledge and provide educational content accordingly. Student modeling is a personalization that can be initiated by the student or the ITS; Students can provide information regarding their own learning style or preferences prior to the course, or the ITS can dynamically gather interaction data from the student and determine the students' learning needs and style (Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003). For example, ActiveMath provides the functionality to allow the students to decide their goals and preferences before the course begins (Melis et al., 2001). For dynamic student modeling, SQLT-Web is a Web-based ITS for teaching Structured Query Language. SQLT-Web has the ability to analyze the students' solutions and provide intelligent feedback to student. This capability helped students focus on the areas in which they needed the most practices (Mitrovic, 2003). Another example is the Wayang Outpost. It is a web-based ITS for the math section in Scholastic Aptitude Test. Wayang Outpost collects student's data during the interaction with the ITS, for example, latency, choices answered, and hints requested. The data resulted from the interactions can be logged and analyzed to build an intelligent model to provide the right level of questions for students. Evaluation of Wayang outpost indicated the system was effective in helping students improve performance from pre to post tests (Arroyo, Beal, Murray, Walles, & Woolf, 2004). Although dynamic student modeling is efficient and intelligent, it can sometimes result in inaccurate student models if the data collected are insufficient to make correct inferences for the student's learning style and needs (Brusilovsky & Millán, 2007).

Expert modeling refers to the ability to think and respond like an expert in the subject area. There are domains in a subject area that students find most challenging. Designers of ITS should take the subject area into consideration when building the learning environment. It is beneficial for the ITS to have the expert's model in mind when delivering the content (Koedinger & Anderson, 2013). Some ITS offers problem solving support that helps the students to reach solutions and mimic how experts would solve the same problems (Melis et al., 2001). Mixed initiative refers to the abilities to initiate interaction and respond usefully to the student-initiated interactions. ActiveMath is a web-based ITS that generates interactive content based on the student's goals, preferences, and knowledge. The students can choose the math concepts in which they want to learn. ActiveMath also allows the students to pick their preferred colors and languages. (Melis et al., 2001). Such capabilities provides more flexibilities to the students' learning style and preferences. Interactive learning refers to the ability to engage students. Instructional modeling refers to the ability to adapt instructional methods based on the student's learning. These two features are generally present in most ITS as they're part of the instructional design (Lepper, Woolverton, Mumme, & Gurtner, 1993). Self-improving means that ITS have the ability to improve itself based on its previous experience with the students. The self-improving feature is accomplished through the data logged during the students' interaction with the system. Statistical techniques can be used to derived insight from the log data and improve the system's intelligence (Arroyo & Woolf, 2005).

## 2.5 Sensors and Detection of Anxiety

Physiological sensors measure physiological processes that are influenced by the autonomic nervous system. According to Kent (2006), the autonomic nervous system is

> a division of the peripheral nervous system that controls what are normally involuntary activities, such as heart rate, respiration, body core temperature, blood pressure, and urinary output. The autonomic nervous system includes the sympathetic nervous system and the parasympathetic nervous system, which innervate cardiac muscle, smooth muscles, and glands.

The sympathetic system controls the body's fight-or-flight response, and the parasympathetic system regulates the body's rest-and-digest functions (McCorry, 2007).

Examples of such measurements include electrodermal, cardiovascular, and respiratory activity (Rehg, Rozga, Abowd, & Goodwin, 2014). Fear and anxiety trigger physiological responses such as increased respiratory activities, blood pressure, heart rate, and sweating (Davis, 1992). Eletrodermal activity (EDA), also referred to as galvanic skin responses, is the phenomenon that the skin's conductance changes with sweat gland activity. Because sweat is a good conductor, an increase in sweating will also increase the conductance of the skin. According to Critchley (2002), "EDA is a sensitive psychophysiological index of changes in autonomic sympathetic arousal that are integrated with emotional and cognitive states" (p. 132). As a result, EDA is a convenient indicator of changes in emotional and cognitive activities.

Respiratory psychophysiology studies have shown that an individual's level of anxiety affects respiratory frequency. There is an increase in respiratory rate that correlates with the person's trait-anxiety (Masaoka & Homma, 1997). Currently, there is a wearable sensor on the market called Spire (Spire, n.d.) that monitors an individual's respiratory frequency. Spire monitors continuous respiratory activity and is capable of detecting a person state of mind as tensed, focused, or relaxed depending on the detected breathing pattern. The wearable sensor sends a notification to the user through an iPhone when it detects a notable change in the respiratory pattern. It reminds the user to take a deep breath or a walk in order to calm and relax.

### 2.5.1 Heart Rate Sensors: ECG vs PPG

The heart rate sensors used on smart watches are different from those used on the chest straps. The sensor used on a chest straps is an electrocardiography sensor, also called EKG or ECG. The optical sensor used on a smart watch or wearable fitness device is a photoplethysmography sensor, also called PPG. ECG sensors measure heart rate by directly using the electrical signals produced by the heart activity. ECG is more accurate and is the standard used by health-care providers, whereas PPG sensors detect heart rate through reading the blood flow of the body by illuminating the skin and measuring the wavelengths of light reflected from the skin (Allen, 2007).

Theoretically, a PPG sensor can be placed at any part of the body with blood flow. However, because it measures heart rate through reading the blood volume, its accuracy decreases when it's placed on a part of body where blood concentration is low. Moreover, because a PPG sensor measures blood flow by emitting light and receiving the reflected light, it suffers from the canceling effect of the skin and potential light leak. As a result, PPG sensors receive a lot of noise when the person wearing the device is moving or the device is not tightly attached to the body. In other words, PPG is susceptible to motion artifact (Rhee, Yang, & Asada, 2001).

PPG sensors are still being widely used because they are much less intrusive to wear than a chest strap. Chest straps have to be worn on the chest, whereas a PPG sensor can be placed at any part of the body with blood flow. It is widely used on smart watches and fitness devices because it could be comfortably worn on the wrist.

### 2.5.2 Heart Rate Variability

Measures of heart rate variability (HRV) is an extensively discussed topic in cardiovascular physiology. One of the relevant fact to this research is that high-frequency heart rate variability is known to be related to respiratory sinus arrhythmia (RSA)

(Berntson, Cacioppo, & Quigley, 1993). RSA is a natural variation in heart rate that corresponds with respiration. Naturally, heart rate increases during inspiration and decreases during expiration, and the magnitude of RSA variation corresponds with the parasympathetic (vagal) control of the heart (Berntson et al., 1997). The psychological meaning of the low-frequency HRV is less clear and more controversial. High-frequency HRV is known to decrease during mental stress (Nickel & Nachreiner, 2003) or state anxiety (Jönsson, 2007). However, there are other factors that could influence base levels of RSA such as age, fitness, and postures (Berntson, Quigley, & Lozano, 2007). As a result, heart rate data from subjects of different ages or fitness levels should not be directly compared. Within subjects' data are more reliable; however, factors such as posture still need to be taken into consideration.

Two of the most commonly used methods to assess HRV includes the time domain and frequency domain methods. Commonly used time domain measures include inter-beat-interval (IBI), also known as RR or NN interval. See Figure 2.1 for an illustration of a RR interval on an electrocardiogram. Measures of the variability of IBI

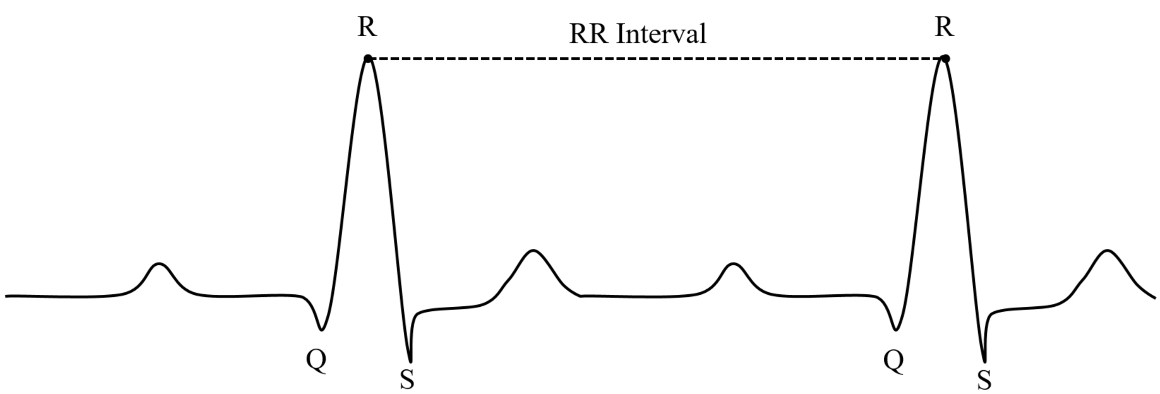


*Figure 2.1.* Graphical representation of RR Interval

includes SDNN, RMSDD, and pNN50; see Table 2.2 for their definitions. Frequency domain methods convert the overall heart period variance into frequency bands. While a time-domain graphs show how signals change over time, a frequency-domain graph illustrates how much a particular band of frequency (variance) occurs. Commonly used measures and expected change are listed in Table 2.2.

Table 2.2. *Commonly used HRV measures and expected change under stress*

| Commonly used HRV measures | Expected change under stress |
|---|---|
| MEAN IBI | Decrease |
| SDNN | Decrease |
| RMSSD | Decrease |
| pNN50 | Decrease |
| Total Power | Decrease |
| LF | Increase |
| HF | Decrease |
| LF/HF | Increase |

MEAN IBI - Average inter beat interval
SDNN - Standard Deviation of all IBI
RMSSD - Square root of the mean of the squares of differences between adjacent IBI
pNN50 - Percentage of differences between adjacent IBI that are greater than 50ms
Total Power - Total spectral power of all IBI interval up to 0.04 Hz
LF - Total spectral power of all IBI betwen 0.04 and 0.15 Hz
HF - Total spectral power of all IBI between 0.15 and 0.4 Hz
LF/HF - Ratio of low to high frequency power

### 2.5.3 Electrodermal Activity

Electrodermal activity (EDA) refers to the variation of the skin conductance (SC) in response to sweat secretion. EDA is a sensitive index of sympathetic nervous system activity (Dawson, Schell, & Filion, 2007). Two main components of EDA include skin conductance level (SCL) and skin conductance response (SCR). SCL refers to the tonic level of electrical conductivity of skin, which is the slower acting components of the SC signal. SCL can be understood as a constantly changing baseline within an individual (Braithwaite, Watson, Jones, & Rowe, 2013). SCR refers to the phasic increase in conductance shortly after stimulus onset, the faster changing part of the SC signal. SCR includes two groups: specific SCR and non-specific SCR. Specific SCRs are event related and caused by external or internal aversive stimuli. Non-specific SCRs are spontaneous responses without stimuli. However, it is not possible to completely differentiate specific or non-specific responses unless all possible stimuli and body movements are recorded (Dawson et al., 2007). Commonly used SC components and expected change under stress are listed in Table 2.3. See figure 2.2 for a graphical representation of SCR components. When a stimulus occurs, there is an interval between the stimulus and the SCR initiation. This interval, also called latency, typically ranges from 1 to 3 seconds. The time from the start to the peak of the SCR is called rise time. The magnitude of the increase of SCR is amplitude. The time it takes the SCR to fall back is called recovery time.

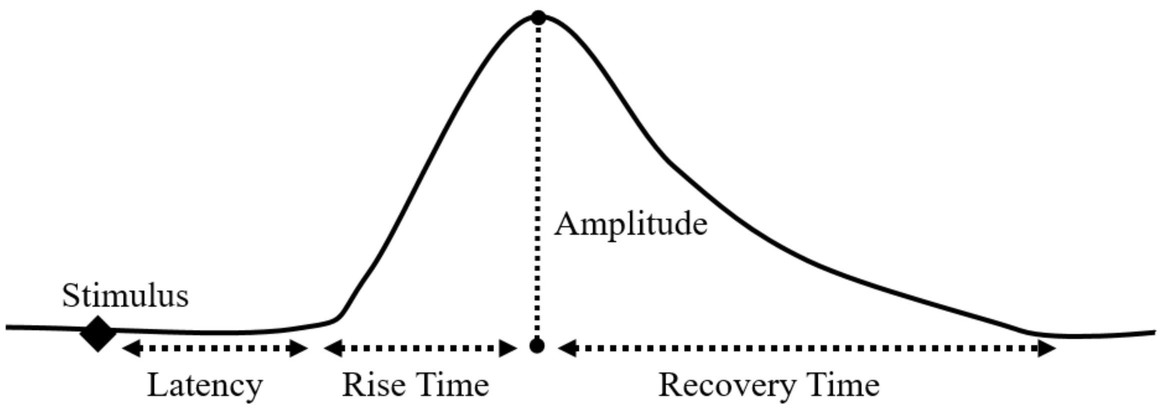


*Figure 2.2.* Graphical representation of SCR

Table 2.3. *Commonly used SC measures and expected change under stress*

| Skin Conductance measures | Expected change under stress | Typical Value |
|---|---|---|
| SCL | Increase | 2 - 20 microsiemens |
| SCR Amplitude | Increase | 0.1 - 1.0 microsiemens |
| SCR Rise Time | Decrease | 1 - 3 s |
| Number of SCR | Increase | n/a |

One of the disadvantages of using EDA in anxiety detection is that SCR is sensitive to a wide variety of stimuli such as anger, surprise, and anxiety. It is therefore impossible to identify the psychological meaning or significance without considering the context in which the stimulus occurs. However, unlike HRV, EDA has shown to be independent of physical posture in stress detection (Sun et al., 2012).

### 2.5.4 Considerations for Academic Environment

Students with LDs are more prone to experience emotional problems and anxiety which could lead to elevated heart rate, sweat, and respiratory activities. However, elevated heart rate, sweat, and respiratory activities are not only caused by anxiety; they could be induced simply by increase in activities. One of the most salient symptoms of ADHD is excessive activity. A clinical study that analyzed 119 children from ages 8 to 16 showed that about 70% of children with ADHD had LDs in one or more areas (Mayes, Calhoun, & Crowell, 2000). This is due to the high coexistence of learning disability and Attention Deficit Hyperactivity Disorder (ADHD). Many students with LDs often also experience ADHD. Although ADHD is not considered a learning disability, their coexistence is common. In addition to biomedical sensing challenges, mobile application inherits numerous constraints, such as more limited computational capability and power supply. The constraints are discussed in the following section.

## 2.6 Mobile Application Development and Performance Considerations

Computational performances of mobiles devices can refer to either the hardware or the software of the device, or it could refer to a combination of both. For the purpose of this study, the researcher refers to performance as the software application performance or the performance of the mobile app. This research study concerns mainly the performance of the software application because the hardware will be obtained commercially off the shelf. Therefore, hardware specification is one of the limitations of this research study. There are several reasons why the researcher is more concerned about the software than the hardware. First, hardware specifications of mobile devices improve rapidly over time. By the time the research study is completed, the most recent specification of the hardware will have changed. Second, the hardware capability of the device commonly refers to its processing power, memory space, battery life, and available sensors. For the purpose of helping students of learning disabilities, the processing power of the hardware is not the most relevant. The most pertinent aspect of mobile device for this study is application development. In the following, the researcher will review the current literature in mobile app development and discuss the design practices pertinent to this research study.

### 2.6.1 Mobile Application Overview

Mobile apps are applications running on mobile devices such as smartphones, tablet computers, and smart watches. Mobile apps are typically downloaded and installed through app stores which are the distribution platforms operated and owned by the company that developed the mobile operations system. Due to the growing popularity of smartphones, mobile apps have grown significantly over the past few years. According to Statista, as of July, 2015, Google Play offers over 1.6 million apps, Apple App Store offers 1.5 million apps, Amazon Appstore offers 400,000 apps, and Windows Phone Store offers 340,000 apps. The total number of mobile app downloads was approximately 2.52 billion in 2009, and it estimated to reach 269 billion downloads in 2017 (Statista, 2016).

Mobile apps can be divided into three main categories: native, web-based, and hybrid. Native mobile apps are coded for specific platforms such as Android or iOS. Web-based apps, on the other hand, are generic and can be accessed from a browser on a mobile device. Hybrid apps are hosted inside a native application and use web-based technology to access content. Mobile app developers have a number of decisions to make before actually programming the apps, including choosing the platform and the development approach. The main platforms include Google Android and Apple iOS. Examples of web-based technology include HTML5, CSS, and JavaScript. Platform specific software development kit include Android SDK, Apple Xcode, and Universal Windows Platform. Other cross-platform tools include Appcelerator, DojoMobile, jQueryMobile, PhoneGap, and Sencha Touch. Developers need to consider schedule, budget, and requirement of the app such as whether the app needs to access camera, sensors, or GPS when making a decision on the development approach (Masi, Cantone, Mastrofini, Calavaro, & Subiaco, 2013).

The main advantage of choosing web-based technology is that they can be targeted for multiple platforms with relative ease since web-based apps are accessed from a browser. However, web-based apps have limited ability to access the device features, such as the sensors. Furthermore, because a web-based app requires the use of a browser, its performance is likely to be worse than a native app (Charland & Leroux, 2011).

The biggest advantage of developing native apps is that it ensures the developers access to all the features available on the mobile device, for example, a finger print reader. Native apps follow the official user interface libraries and guidelines provided by the platform; as a result, they will also provide a more native look and feel. However, the biggest disadvantage of a native app is that it only runs on a specific platform. If the owner of the app chooses to offer the same app on multiple platforms, the app will have to be developed repeatedly and separately. This increases the development cost as well as the difficulty of maintaining a standardized user experience across platforms (Wasserman, 2010).

A qualitative research study interviewed twelve professional mobile app developers indicate that most developers are in favor of building native apps because they believe the user experience of native apps are superior and hybrid apps “look and behave much more like webpages than mobile applications.” Participant of the study who favored hybrid apps argued that “it really depends on the complexity and type of the application,” for example, “information sharing apps can easily adopt the hybrid model to push news content and updates across multiple platforms” (Joorabchi, Mesbah, & Kruchten, 2013). The argument that the best development approach depends on the purpose and type of application is also found in other literature (Masi et al., 2013). The differences of opinion on the choice of native app and web-based app are also documented by other research studies (Wasserman, 2010).

### 2.6.2 Challenges in Mobile Application Development

The challenges of mobile computing come from the nature of mobility. Satyanarayanan (1996) argues that there are four fundamental constraints of mobile computing. First, given the same cost, mobile devices always have more limited resources. Second, mobile devices are more vulnerable to loss and damage and therefore raise more security concerns. Third, mobile devices inherit the nature of wireless connectivity that is less reliable than wired communication. Fourth, mobile devices depend on limited energy sources and thus are more sensitive to power consumption. Most literature in mobile application also discusses the above-mentioned constraints and often refers them as non-functional requirements or qualities. Those qualities include efficiency, responsiveness, scalability, reliability, robustness, connectivity, stability, usability, and security (Masi et al., 2013; Muccini, Di Francesco, & Esposito, 2012; Wasserman, 2010).

Other factors that make mobile app development differ from traditional software development include sensor handling, complexity of testing, and the ability to support varied devices and versions of operating systems (Masi et al., 2013; Wasserman, 2010). Because mobile devices vary in hardware specifications and versions of operation systems, developers of mobile apps must ensure their apps run correctly in terms of functionality and user experience. In other words, mobile app platforms are becoming fragmented instead of unified. A survey study indicates that the majority of mobile app developers see multiple mobile platforms as a challenge (Joorabchi et al., 2013). Fragmentation occurs across and within platforms. As discussed earlier, each mobile platform is different in terms of its user interface and experience guideline. Even within the same platforms, devices varied in hardware such as processor, memory, screen size, and graphical resolutions. In addition, within the same platform, developers find versioning and upgrading a major concern. User testing therefore becomes a more important aspect in mobile app development.

Despite the importance of user testing, automated testing is quite limited for native mobile app development. Lack of automation in user testing poses great challenge for mobile app developers. For example, currently emulators do not support testing for hardware sensors or geo locations services (Wasserman, 2010). In addition, graphical user interface (GUI) testing is difficult to automate. Unit testing is only popular in Android and Windows platforms but limited in iOS (Joorabchi et al., 2013).

User experience is also a widely discussed topic in the literature. Because mobile devices have limited screen space, the design of the interface and the ability to make best use of the screen become more critical. Furthermore, a mobile app should function and behavior identically across all platforms. Given the different GUI guidelines, it is challenging for developers to deliver the same user experience for a native app across platforms. To ensure consistency among multiple devices, currently the common practice among developers is screen by screen review. The testing are done manually to ensure the apps work consistently across devices and platforms (Joorabchi et al., 2013).

### 2.6.3 Implications for this Research

For the purpose of classroom intervention, two mobile devices are needed to help the teacher and student to manage the potential anxiety associated with learning. A smartphone and a smartwatch can be used. The student with LDs will wear a smartwatch for anxiety detection. The teacher will use a smartphone to receive notifications when the smartwatch detects anxiety. Therefore, communication between the two mobile devices are required. As a result, one of the key functionality of the technology is to integrate the two devices.

A smartwatch is a relatively new category of mobile device. The two major platforms for smartwatches are Android Wear and WatchOS which are also based on Android and iOS. The challenges faced by smartphone app developers are likely to be the same or expectedly worse for smartwatch app developers because the constraints inherited from mobility discussed earlier are only greater with smartwatches. These constraints include limited resources, vulnerability, unreliability of wireless communication, and a limited energy source. User experience can be more challenging as well since the screen sizes on smartwatches are significantly smaller than those on smartphones. In summary, the major challenges of mobile app development include cross-platform implementation, user testing and consistent user experience.

## 2.7 Summary

This chapter provided a review of the literature relevant to LDs, anxiety, anxiety detection methods, and mobile application. The next chapter provides the framework and methodology to be used in this research study.

# CHAPTER 3. FRAMEWORK AND METHODOLOGY

The purpose of this research study was to design and evaluate a wearable technology that help teachers and students monitor learning related anxiety. To fulfill the purpose, this research study needed to investigate the relationship between the physiological signals (heart rate and skin conductance) and the student's self-reported levels of stress in an educational setting. This research study also served the purpose of testing and validating the accuracy of the proposed technology in detecting anxiety in real classrooms. If the proposed technology could accurately identify the participants' mental stress, it meant that the technology could be beneficial for those who need classroom interventions such as students with learning disabilities. Please see Figure 3.1 for an illustration of such an application. Additionally, this technology can be used for anyone who can benefit from the use of intelligent tutoring. As discussed in the literature review, intelligent tutoring systems deliver educational content based on the student's individualized needs, which provide advantages for students with special needs. Given the ability to collect physiological data in real time, the proposed technology can be used as a feature of an intelligent tutoring system. This research study attempted to answer the following two questions.

- Can a wearable technology use heart rate variability and skin conductance response to identify a student's anxiety resulting from engagement in a potentially distressing learning activity?
- Is the use of wearable technology for educational purposes, such as intelligent tutoring and classroom intervention, socially acceptable?

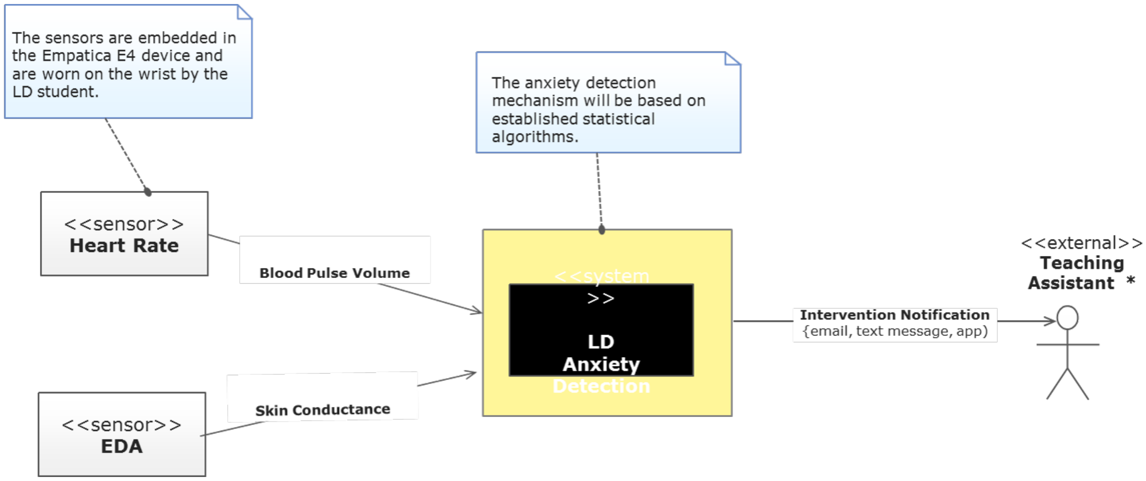


*Figure 3.1.* Illustration of in-classroom application of the technology

## 3.1 Ethical Considerations

The target population for the proposed wearable technology includes the general student population and those with learning disabilities. The main goal of the technology is to help students who are at higher risk of experiencing anxiety and more susceptible to the adverse effect of anxiety. Instead of studying the technology on subjects from the vulnerable population, the researcher adopted an approach that tested the technology on the general population at scale with only one piece of the wearable device. The study was reviewed and approved by the Institutional Review Board at Purdue University.

## 3.2 Research Design

This study used a mixed method design (Creswell, 2009) to answer the two research questions regarding the anxiety-detecting wearable technology. The quantitative approach included testing the feasibility of the proposed wearable technology in detecting anxiety within educational settings. The researcher compared the relationships among the physiological signals, the participant's proneness to anxiety and their self-reported stressful incidents (SI) during a simulated academic exam. The qualitative approach included the acceptability questionnaire in the Appendix A, which was used to answer the question concerning the social validity of the wearable technology. The acceptability questionnaire was modified from Treatment Acceptability Rating Form (Reimers & Wacker, 1988). It used both Likert scale and open-ended questions.

## 3.3 Expected Outcomes

The researcher expected that the proposed physiological signals were viable predictors for anxiety detection in educational settings. The following outcomes were expected.

- High levels of state and trait anxiety leads to more prominent changes in IBI, RMSDD, and SDNN.
- Participants with high levels of state and trait anxiety would report more SI during the exam.
- Mean IBI decreases during the time interval of SI.
- RMSSD decreases during the time interval of SI.
- SDNN decreases during the time interval of SI.

## 3.4 Participants

The researcher recruited twenty (20) participants who were above eighteen (18) years old. To qualify for the study, the subjects needed to be planning to take the official GRE within one year and had never previously taken any official or practice GRE. The rationale for recruiting participants who were planning to take GRE within one year is that the participants were more likely to take the practice exam serious. Participants who had previously taken any official or practice GRE were excluded from the study because they were more likely to be prepared for the exam and as a result less likely to experience cognitive stress from the exam. The researcher aimed to recruit twenty (20) participants because most studies related to emotion detecting in the literature included about ten (10) to twenty (20) participants in the study (Healey & Picard, 2005; Henelius, Hirvonen, Holm, Korpela, & Muller, 2009; Hernandez, McDuff, & Picard, 2015; Ming-Zher Poh, Swenson, & Picard, 2010; Miranda, Favela, & Ibarra, 2015; Sun et al., 2012; Tharion, Parthasarathy, & Neelakantan, 2009). A recruitment email was sent out to 893 undergraduate students at Purdue university. This group of students had previously indicated interests in pursuing graduate studies in a survey collected by the Purdue Graduate School. Forty-eight (48) students initially indicated interests in the participating in the study, but only twenty students eventually were willing to take time to participate in the study and take the practice GRE. See Table C.1 for participant's detailed demographic information.

## 3.5 Demographic Questionnaire

Prior to the study, the researcher collected basic demographic information from the participants. The questionnaire was intended to find out whether the participant was planning to take GRE within one year or had previously taken an official or practice GRE before. Additionally, it asked the participant whether they are familiar with fitness wearable devices because familiarity could influence the participant's acceptability towards the proposed technology. Please see appendix for the complete demographic questionnaire.

## 3.6 Settings

The experiment was conducted at a university building in a room with minimal noises and a computer for the practice exam. This study consisted of several components listed below.

Before participating in the practice exam, the participant was asked to complete the State-Trait Anxiety Inventory (STAI) (Spielberger, 1983) consisting of a total of forty (40) questions. This was for the researcher to know whether the participants were prone to have test anxiety. The STAI consisted of two sub-tests; one was the State Anxiety Scale that evaluated the participant's levels of anxiety "at the moment. The other was the Trait Anxiety Scale that evaluated the participants' levels of proneness to anxiety. The STAI is one of most widely researched and used measures of general anxiety (Julian, 2011). The STAI requires about ten (10) minutes for adults to complete. The total score ranges from twenty (20) to eighty (80); a higher score indicates higher level of anxiety. Test-retest reliability of STAI is high, ranging from 0.86 to 0.95 (Spielberger, 1983).

During the practice GRE exam, the participants were asked to wear the Empatica device on the wrist. The practice exam that was used in this study was published by McGraw-Hill Education and is accessible at `http://www.mhpracticeplus.com/gre.php`

The participants completed both the quantitative reasoning and verbal reasoning sections on the GRE. To mitigate the ordering effect, the first section to take for each participant was randomly decided prior to the study. Half of the participants took the verbal reasoning section first, and the other half took the quantitative reasoning section first. Each of the two sections consisted of twenty (20) questions; the maximum time allowed for each section was thirty-five (35) minutes.

During the exam, the participant was asked to push a button on the wearable device when he or she felt the content was distressing. The device kept track of the time the participant pushed the button by using timestamps. The timestamps were used as self-reported SI during the practice GRE exam. The timing of the self-reported incidents was compared with HRV using the anxiety detection methods detailed in the Anxiety Detection Method section.

Finally, following the practice exam, the participant completed an acceptability questionnaire regarding how they felt about the technology. Please see the Social Validity Section below for more details.

## 3.7 Social Validity

The use of wearable technology in educational settings is not prevalent. There is little known about how it is perceived from the perspective of students. As a result, it is important for the researcher to conduct an analysis of social validity that assesses "the social significance of the goals, the social appropriateness of the procedures, the social importance of the outcomes"(Kazdin, 1977; Wolf, 1978). In the acceptability questionnaire, the researchers attempted to find out whether the participants felt physically and physiologically comfortable and safe to wear the device during the study. These questions provided insight on the usability of the Empatica. Additionally, there were questions addressing the potential concerns about whether the device could distract the students from focusing on the educational tasks or attract unwanted attention from peers. The goal of these questions were to assess the social appropriateness of the technology. Finally, there were a few questions about whether the participant felt there is a need for anxiety monitoring during engagement in learning. The goal of these questions was to gain insight on the students' perceived importance of anxiety monitoring and the need for potential interventions. The acceptability questionnaire helped the researcher answer the important questions regarding social validity of the device. The mean and range of the Likert scale answers were summarized. Gender differences were compared. The Pearson's correlations between the levels of anxiety and prior familiarity with wearable devices were calculated. See the Appendix for the complete acceptability questionnaire.

## 3.8 Sensor Data Collection

The student's physiological data including heart rate and skin conductance were collected by a commercially available wearable device, the Empatica. This research study used the most current version available at the time of the study, E4. Empatica was chosen for the following reasons. First, it's a research grade wearable device that offers more granular heart rate and skin conductance data including a PPG sampling frequency of 64 Hz and an EDA sampling frequency of 4 Hz. Second, the device had previously been approved by the IRB of Massachusetts Institute of Technology for a study that required twelve (12) participants to wear the device. In this study, the investigators collected more than thirty (30) hours of sleep data from Empatica, and its accuracy was compared with the gold standard FDA approved, a chest worn ECG device with an Alive Technologies sensor at a sampling rate of 300 Hz. A total of 26.94 hours of heart recording during sleep across twelve (12) subjects indicated that the mean absolute error for Empatica sensor was 1.08 beat per minute (Hernandez et al., 2015). The results indicate that the Empatica is fairly accurate as a non-intrusive mobile device; it has under-explored applications in settings outside of laboratory given the combination of its portability and accuracy.

Other examples of the Empatica being used in peer-reviewed publications includes the following. Empatica was used in an acceptability study of using wearable devices for chronic pain management (Felipe, Singh, Bradley, Williams, & Bianchi-Berthouze, 2015), as a biosensor for a collaborative learning study of forty-eight (48) high school students (Pijeira-Díaz, Drachsler, Järvelä, & Kirschner, 2016), and in a study of detecting anxiety for the caregivers of people with dementia wherein the investigators collected physiological data from ten (10) participants (Miranda et al., 2015).

Empatica detects heart beats by using a PPG sensor. As mentioned earlier, PPG sensors measure heart rate differently than ECG sensors. ECG sensors measure heart rate by directly using the electrical signals produced by the heart activity. ECG sensors are the gold standard used by health care providers. PPG sensors, on the other hand, detect heart rate through reading the blood flow of the body by illuminating the skin and measure the wavelengths of light reflected from the skin (Allen, 2007). Therefore, PPG sensor can be placed at any part of the body with blood flow. The primary disadvantage of PPG sensors is the fact that it is susceptible to motion artifact (Rhee et al., 2001). Because a PPG sensor measures blood flow by emitting light and receiving the reflected light, it suffers from the cancelling effect of the skin and potential light leak. As a result, PPG sensors receive a lot of noise the person wearing the device is moving or the device is not tightly attached to the body. Empatica E4 uses two lights to counterbalance this disadvantage. It uses a green light to detect heartbeats and a red light to sense movement. If provides a mechanism to remove the noise created by movement.

The heart data provided by Empatica are IBI timing. IBIs are also frequently referred as NN or RR intervals in the literature of HRV. R is the point corresponds to the peak of a QRS complex of a ECG wave. Thus, RR refers to the interval between success peaks (Rs). NN is used to indicate they are ”normal” beats. However, the terms are synonymous as they simply refer to the time interval between adjacent beats. The IBI sequence data provided by Empatica includes interval and timestamps. In addition, Empatica offers a built-in feature that automatically removes the wrong peaks caused by motion artifacts. The following section discusses the procedure used for anxiety detection.

## 3.9 Anxiety Detection Method

The researcher originally proposed to use both HRV and SC for anxiety detection because they have been more widely studied for mental stress or anxiety detection. (Bernardi et al., 2000; Healey & Picard, 2005; Hjortskov et al., 2004; Miranda et al., 2015; Ogorevc, Podlesek, Gersak, & Drnovsek, 2011; Pijeira-Díaz et al., 2016; Sun et al., 2012; Tharion et al., 2009). However, after the data collection, the researcher found that the Empatica failed to reliably collect SC data because of issues associated with the electrodes. According to Emaptica’s manufacturer, similar issues have been reported by other researchers (Empatica Inc., 2017). As a result, the researcher decided to exclude the SC data from the study given the data was not reliable and the fact that SC can only be supplementary. There are many factors that could influence SCR such as excitement and surprise (Dawson et al., 2007).

Traditional HRV analysis can be divided into two main categories: time domain and frequency domain methods. This research used the time domain methods for three reasons. First, it is less computational intensive, which serves better the purpose of mobile application. Second, the detection mechanism is less likely to be triggered by emotions other than anxiety when using the time domain method is used. Additionally, the time domain method has been shown to be accurate in detecting stress (80% accuracy) but rather poor at other emotions such as happiness and sadness (Sung-Nien Yu & Shu-Feng Chen, 2015). Finally, time domain method is more suitable than frequency domain method for short-term stress monitoring (Tharion et al., 2009). The time domain measures used in this study included RMSSD, SDNN, and MIBI (Mean IBI). Other time domain measures such as pNN50 was not included because it is essentially redundant measurements with RMSSD. In addition, RMSSD is more independent of heart rate as it is not affected by the change of heart rate (Electrophysiology, 1996). The LF/HF ratio in frequency domain method are relatively independent of the time domain measures. However, they are susceptible to posture change (Sun et al., 2012) and might not be a significant predictor in short-term stress monitoring (Tharion et al., 2009). Furthermore, MIBI is the most sensitive measure for short-term stress classification (Henelius et al., 2009). Finally, frequency domain methods are more computational intensive than time domain methods, which makes it less suitable for mobile application.

## 3.10 Data Analysis

The heart rate measures included MIBI, SDNN, and RMSSD. The HRV data were divided into two groups. The first group of data is under stress which included HRV data that were observed within two-minute intervals of the participant's SI. The second group of data is before stress, which included the HR data that were observed within the two-minute intervals prior to the SI intervals. The two-minute intervals range from one minute before to one minute after the SI. The non-stress intervals range from three minutes to one minute before the SI. See Figure 3.2 for an illustration.

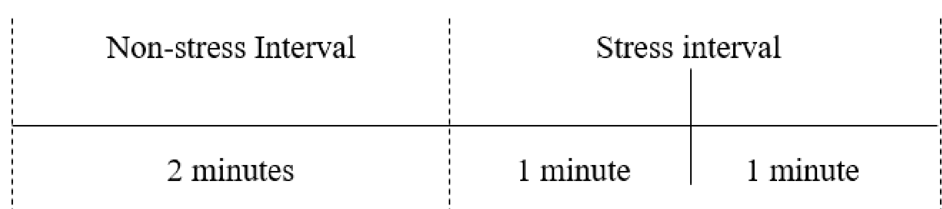


*Figure 3.2.* Graphical representation of stress vs non-stress intervals

There are several reasons for picking the two-minute window. First, the test consisted twenty (20) questions in thirty-five (35) minutes; on average, the participants have slightly less than two minutes to complete each question. Second, based on the researcher's observations, participants mostly don't report stress immediately after seeing the questions they later reported as stressful. They usually engaged in the questions with reasonable amount of time before reporting stress. Third, the two-minute interval gives sufficient time for detecting statistically significant heart rate changes. According to Salahuddin, Cho, Jeong, and Kim (2007), MIBI and RMSSD can demonstrate statistical differences for mental stress by using intervals as short as ten (10) seconds; however, SDNN requires at least sixty (60) seconds. A two-minute window allows sufficient samples to detect statistical significant changes. Finally, long intervals might not be very useful for short-term anxiety monitoring in real classrooms. Two-minute interval is relatively short and can be useful.

The MIBIs were compared using Welch's t-test which is a two-sample test for testing the hypothesis that the two samples have equal means. Welch's t-test is known to be more reliable than Student's t-test when the two samples have unequal variances and sample sizes (Ruxton, 2006). The significance level (error budget) for the t-test is set to be 0.05. The Mann-Whitney U test was used to compare RMSSD because the distribution was not normally distributed. The SDNN was compared using Barlett's test to check equal variance.

The Pearson product-moment correlation coefficient or the Pearson's r was calculated to determine the correlation between STAI and anxiety detection accuracy. Pearson's r ranges from -1 to 1. Between the two variables, -1 indicates a perfectly negative linear relationship and 1 indicates a perfectly positive linear relationship.

## 3.11 Summary

This chapter provided the framework and methodology to be used in this research study which include the device the collects the physiological data, the instrument that measures anxiety, the ethical consideration, the settings, the anxiety detection method, and the data analysis.

# CHAPTER 4. RESULTS

The main goal of this research design was to validate whether current wearable technology can be used to identify the student's anxiety resulting from a potentially distressing learning activity. Heart rate variability and skin conductance sensors are the two relevant sensors in current wearable technology that can potentially be used to identify anxiety. This section includes the results of the data collected from twenty (20) participants to answer the following two questions.

- Can a wearable technology use heart rate variability and skin conductance response to identify a student's anxiety resulting from engagement in a potentially distressing learning activity?
- Is the use of wearable technology for educational purposes, such as intelligent tutoring and classroom intervention, socially acceptable?

## 4.1 Participants' Demographics

Twenty (20) undergraduate students who were in the age group of eighteen (18) to twenty-four (24) years old participated in the study. Fifteen (15) participants were native English speakers. Five (5) participants were international students whose native language was not English. Nine (9) participants were female, and eleven (11) participants were male. All participants reported they were planning to take GRE within one year. As to answering the question "which one of the following sections on GRE do you expect to be more challenging?" Two (2) participants reported they expect the quantitative reasoning section to be more challenging. Eleven (11) participants reported they expect verbal reasoning section to be more challenging. Seven (7) participants reported they expect both sections to be equally challenging. See Table C.1 for detailed information.

The means of state and trait anxiety for female participants were 33.6 and 46.6, respectively. The means of state and trait anxiety for male participants were 30.7 and 39, respectively. The means of state and trait anxiety for all participants combined were 32.05 and 42.45, respectively. See Table 4.1. According to the STAI manual, male students with a score of 30 in state anxiety is equivalent to 30 percentile and a score of 39 in trait anxiety is equivalent to 57 percentiles. Female students with a score of 33 in state anxiety is equivalent to 39 percentile and a score of 46.6 in trait anxiety is equivalent to 76 percentiles (Spielberger,  2015). The STAI results showed that the group of participants in this study had relatively high trait anxiety but low state anxiety. One probable reason for lower than average state anxiety is that the potential participants who had high levels of state anxiety probably would not want to experience extra anxiety and participate in a practice exam. One explanation for higher than average trait anxiety is that some participants expressed very strong interest in the technology itself during the study. This is possibly because they experience high levels of anxiety themselves.

Table 4.1. *State and Trait Anxiety Score*

| | | State Anxiety | | Trait Anxiety | |
|---|---|---|---|---|---|
| Participant | Gender | Raw Score | Percentile | Raw Score | Percentile |
| 1 | Female | 38 | 55 | 61 | 96 |
| 2 | Female | 52 | 85 | 56 | 92 |
| 3 | Male | 33 | 46 | 38 | 54 |
| 4 | Male | 32 | 42 | 40 | 60 |
| 5 | Female | 40 | 63 | 45 | 72 |
| 6 | Female | 44 | 71 | 57 | 93 |
| 7 | Female | 29 | 24 | 40 | 53 |
| 8 | Male | 28 | 22 | 33 | 35 |
| 9 | Male | 29 | 25 | 33 | 35 |
| 10 | Female | 34 | 42 | 40 | 53 |
| 11 | Male | 23 | 6 | 37 | 52 |
| 12 | Female | 20 | 3 | 46 | 76 |
| 13 | Male | 35 | 53 | 52 | 92 |
| 14 | Female | 26 | 15 | 40 | 53 |
| 15 | Male | 31 | 36 | 47 | 82 |
| 16 | Male | 23 | 6 | 31 | 28 |
| 17 | Male | 42 | 75 | 39 | 57 |
| 18 | Female | 20 | 3 | 35 | 36 |
| 19 | Male | 32 | 42 | 36 | 49 |
| 20 | Male | 30 | 30 | 43 | 74 |

## 4.2 Individual Heart Rate Results

This section includes the HR results for individual participants. For each participant, the results include analysis for RMSSD, SDNN, and MIBI; each participant completed both the quantitative and verbal reasoning sections. Therefore, there are six tables of results for pre and post SI for each participant in the Appendix. In the tables, N is the number of IBI samples; Lapses are the elapsed period in seconds from previous SI or the beginning of the test for SI #1. The researcher first analyzed the results for individual participants; the aggregated results are provided in the next section. To see the final analysis, skip this section and proceed to section 4.3 Aggregated Heart Rate Variability Results on page 52.

### 4.2.1 Participant 1

Participant 1 reported thirteen (13) SI in the quantitative reasoning section and three (3) SI in the verbal reasoning section. Participant 1 has previously reported that she expected the quantitative reasoning section to be more challenging. As a result, it was expected that she would report more SI in the quantitative reasoning section. Considering there were twenty (20) questions in each GRE section, this data shows that she found more than half of the questions distressing. Participant 1 has scored 61 in her trait anxiety test, which indicates that she has high trait anxiety. Her state anxiety score was 38. Among the thirteen (13) SI she reported, only the first four (4) are valid for the analysis because the rest of the SI were too close to each other that there was not enough time to collect enough data samples to establish the pre and post SI relationship. Among the four (4) valid SI, only SI #3 showed expected HRV change in RMSSD and IBI. None of them showed expected change in SDNN. Unexpectedly, SI #1 indicated the opposite of expected outcome. The RMSDD prior to the SI is lower than the RMSDD after the SI at significant level. As the HRV data from many other participants also revealed similar patterns, the researcher believes this pattern indicated that many participants have very high stress level at the beginning of the GRE test. The initial high stress affected the HRV analysis for the

SI that were reported near the beginning of the test. See Table C.2 for detailed information. The first SI indicated the opposite outcome for RMSSD, SDNN, and IBI.

For the verbal reasoning section, participant 1 only reported three (3) SI. Two (2) SI showed expected significant change in IBI; See Table C.7. Although the first SI did not show significant changes in any metrics, it did not yield the opposite of the expected outcome because the first SI in verbal reasoning section was reported 802 seconds after the test started, which might have given the participant enough time to calm. SI #3 showed the opposite of expected outcome in SDNN possibly because the pre-SI samples were too small (n=15). However, SI #3 indicated expected outcome for mean IBI. This result is in alignment with previous research that IBI can show significant differences for data as short as ten (10) seconds (Salahuddin et al., 2007).

### 4.2.2 Participant 2

Participant 2 reported a total number of five (5) and six (6) SI for the quantitative reasoning and verbal reasoning sections, respectively. Participant 2 had previously self-identified that she expected both sections to be equally challenging. For the quantitative reasoning section, SI #2, #3, and #4 are too close to each other for separate data analysis; and only SI #1 and #5 has enough samples for the analysis. See Table C.8. SI #1 in quantitative section showed the opposite of expected outcome in IBI, which was probably due to the high initial test stress. Participant 2 began with quantitative section. It can be inferred that she started the test with high levels of stress, as SI #1 showed the opposite outcome even though it was reported 560 seconds from the start of the test. SI #5 showed expected outcome for significant decrease in IBI although the pre and post HRV sample size was small. See Table C.10.

For the verbal reasoning section, SI #3 did not have enough samples. SI #2 showed expected HRV change in RMSSD, SDNN, and IBI. SI #6 showed expected HRV change in RMSSD and SDNN, but the opposite outcome for IBI. SI #4 and #6 showed expected outcome for IBI, but the opposite outcome for SDNN; RMSSD showed no significant differences. See Table C.11, C.12, C.13.

### 4.2.3 Participant 3

Participant 3 reported five (5) SI for both quantitative and verbal reasoning sections. Participant 3 had previously self-identified he expected both sections to be equally challenging. For the quantitative section, only SI #5 indicated expected outcome in IBI; see Table C.16. SDNN showed the opposite outcome for SI #2 to #5 possibly because there were not enough samples for SDNN to be accurate. Previous research study showed that SDNN requires sixty (60) seconds of data to show statistical significance (Salahuddin et al., 2007). Note that there were enough time between each SI, but the samples were still not enough; See table C.15. This happened because the Empatica was not able to catch some of the IBI due to motion artifact; the participant was moving excessively during the period of SI and interfered with the device detecting heart rate.

For the verbal section, SI #4 did not have enough samples because it was too close to the previous SI. SI #1 and #5 indicated the expected outcome in IBI at significant level. RMSSD also decreased but not at significant level. SDNN did not indicate expected outcome for SI #1. See Table C.17, C.18, C.19.

### 4.2.4 Participant 4

Participant 4 reported two (2) and three (3) SI for quantitative reasoning and verbal reasoning sections, respectively. Participant 4 had previously self-identified that he expected both sections to be equally challenging. SI #1 for the quantitative section indicated expected outcome for IBI at significant level; see table C.22. RMSSD decreased but not at significant level. SDNN was not valid because there wasn't enough samples. See table C.21 and C.22. SI #2 did not have enough samples because it was too close to the previous SI.

For the verbal reasoning section, SI #1 indicated the opposite of expected outcome at non-significant level. Participant 3 began the GRE test with the verbal reasoning section, this also indicated the participant started the test with high levels of stress. SI #2 did not have pre SI samples because it was too close to the previous SI. SI #3 indicated expected outcome in RMSSD and SDNN at significant level. See Table C.23 and C.24.

### 4.2.5 Participant 5

Participant 5 reported seventeen (17) and eight (8) SI for the quantitative and verbal reasoning sections, respectively. Participant 5 previously identified that she expected the verbal reasoning section to be more challenging; however, she reported more SI in the quantitative reasoning section. In the quantitative reasoning section, only the first seven (7) SI had samples for the analysis. The rest of the SI were too close to each other that there were no samples available for analysis. SI #5 showed expected outcome in RMSSD and SDNN but the opposite outcome in MIBI. The other SI did not show significant changes likely because they were too close to each other. This indicated the stress was continuous and therefore significant heart rate changes should not be expected. SI #5 was 161 seconds from the previous SI, which might be the reason it had significant decrease in RMSSD and SDNN.

### 4.2.6 Participant 6

Participant 6 reported three (3) and four (4) SI for the quantitative and verbal reasoning sections, respectively. She began the test with quantitative section and previously reported that she expected both sections to be equally challenging; See Table C.1. In the quantitative reasoning section, RMSSD indicated expected outcomes for all SI. SDNN and MIBI indicated expected outcomes for SI #1 and #2. See Table C.32, C.33, and C.34. In the verbal reasoning section, RMSSD and IBI indicated expected outcome for SI #3 and #4. Although the SI #1 and #2 did not show any significant changes in any of the three (3) metrics. See Table C.35, C.36, and C.37. One thing that stands out for Participant 6 is that she had a state anxiety score of 44 which was the highest among the twenty (20) participants. Her trait anxiety score is 57 which was the second highest among the twenty (20) participants. See Table 4.1.

### 4.2.7 Participant 7

Participant 7 reported five (5) and ten (10) SI for the quantitative and verbal reasoning sections, respectively. Participant 7 began the test with the verbal reasoning section and previously reported she expected both sections to be equally challenging. In the quantitative reasoning section, RMSSD indicated expected outcome for SI #3; SDNN indicated expected outcome for SI #4; MIBI did not indicated expected outcome for any SI. Note that there was a sufficient lapse among the SI reported in the quantitative section. However, the samples were relatively small for the length of time. This indicated the participant had excessive movement and thus interfered with the device detecting heart rate. See Table C.38, C.39, and C.40.

In the verbal reasoning section, SDNN indicated expected change for SI #4. MIBI indicated expected change for SI #5 and #6. Other SI did not indicate any significant heart rate changes. SI #3, #8 and #10 did not have enough samples for the analysis. See Table C.41, C.42, and C.43.

### 4.2.8 Participant 8

Participant 8 reported three (3) and one (1) SI for the quantitative and verbal reasoning sections, respectively. Participant 8 began the test with the verbal section and previously reported he expected the verbal section to be more challenging. In the quantitative section, MIBI indicated the opposite of expected outcome for SI #3. The other SI did not indicate significant heart rate changes in any metrics. In the verbal reasoning section, MIBI indicated expected outcome for the SI. See Table C.44, C.45, C.46, C.47, C.48 and C.49.

### 4.2.9 Participant 8

Participant 8 reported three (3) and one (1) SI for the quantitative and verbal reasoning sections, respectively. Participant 8 began the test with the verbal section and previously reported he expected the verbal section to be more challenging. In the quantitative section, MIBI indicated the opposite of expected outcome for SI #3. The other SI did not indicate significant heart rate changes in any metrics. In the verbal reasoning section, MIBI indicated expected outcome for the only one SI. See Table C.44, C.45, C.46, C.47, C.48 and C.49.

#### 4.2.10 Participant 10

Participant 10 reported seven (7) and three (3) SI for the quantitative and verbal reasoning sections, respectively. Participant 10 began the test with the quantitative reasoning section and previously reported she expected the verbal reasoning section to be more challenging. See Table C.1. In the quantitative reasoning section, SI #1 indicated unexpected outcome in RMSSD. SI #3, #4, and #5 showed expected outcome in RMSSD. SI #3 and #5 showed expected outcome in SDNN. SI #4, #6, and #7 showed expected outcome in MIBI. The rest of the SI did not show significant changes in heart rate. See Table C.56, C.57, and C.58.

In the verbal reasoning section, SI #1 indicated expected outcome in RMSSD and SI #2 indicated expected outcome in MIBI. However, SI #2 indicated increase in HRV at significant level for RMSSD and SDNN. This shows, in practice, IBI and HRV are independent metrics and could yield outcomes not dependent on one another. SI #3 did not indicate significant changes in any metrics. See TableC.59, C.60, and C.61.

#### 4.2.11 Participant 11

Participant 11 reported two (2) and four (4) SI for the quantitative and verbal reasoning sections, respectively. Participant 11 had previously self-identified that he expected the verbal section to be more challenging. In the quantitative reasoning section, SI #2 indicated the expected outcome in RMSSD, and SI #1 indicated the expected outcome in SDNN. The Pre-SI sample for SI #2 was small because the participant was making excessive movement and interfered with the wearable device's sensor. See Table C.62, C.63, and C.64. In the verbal reasoning section, SI #1 and #4 indicated the expected outcome in RMSSD. SI #4 indicated the expected outcome in SDNN. SI #2 and #4 indicated expected outcome in MIBI. However, SI 2 indicated increase in HRV. This also shows IBI and HRV are two separate metrics independent of each other and could yield different results. See Table C.65, C.66, and C.67.

### 4.2.12 Participant 12

Participant 12 reported fourteen (14) and two (2) SI for quantitative reasoning and verbal reasoning sections, respectively. Participant 12 had previously self-identified that she expected the verbal section to be more challenging. Participant 12 began the test with the verbal reasoning section. In the quantitative reasoning section, most of the SI the participant reported was too close to each other for data analysis. SI #5 and #6 indicated the opposite of the expected outcome for all three metrics. One possibility for this to occur is that the participant had continuous high stress and reported the stress after she decided to give up the test questions. SI #9 did not show any significant changes in any metrics. See Table C.68, C.69, and C.70.

In the verbal reasoning section, SI #1 indicated the expected change in RMSSD. However, SI #1 also indicated a decrease in heart rate. This also supports that RMSSD and IBI are separate metrics independent of each other and could yield conflicting results. SI #2 shows the opposite of the expected outcome for all three metrics. Like the quantitative reasoning, this could indicate the participant reported the stress after giving up the question and therefore her stress was actually reduced. See Table C.65, C.66, and C.67.

### 4.2.13 Participant 13

Participant 13 reported three (3) and five (5) SI for quantitative reasoning and verbal reasoning sections, respectively. Participant 13 began the test with the quantitative reasoning section and previously reported that he expected the verbal section to be more challenging. In the quantitative reasoning section, SI #3 indicated the expected outcome in MIBI. SI #2 showed the opposite of the expected outcome in SDNN. The rest did not indicate significant changes. Note that SI #1 showed slight decrease in RMSSD, but slight increase in SDNN. This indicate RMSSD and SDNN could yield different outcomes although both measures HRV. See Table C.74, C.75, and C.76.

In the verbal reasoning section, SI #3 and #4 indicated the expected outcome for SDNN. However, the participant's heart rate was decreased during SI #1, #2, #3, and #4. This also shows SI #3 and #4 have conflicting results from SDNN and MIBI. SI #1 had unexpected outcome for SDNN and MIBI. SI #1 also showed an increase in RMSSD; this could mean the participant began the test with high stress, and his stress decreased after reporting the stress and giving up on the stress induced question. See Table C.77, C.78, and C.79.

#### 4.2.14 Participant 14

Participant 14 reported seventeen (17) and eight (8) SI for quantitative reasoning and verbal reasoning sections, respectively. Participant 14 began the test with the quantitative reasoning section and previously reported that she expected the quantitative reasoning section to be more challenging. In the quantitative reasoning section, out of seventeen (17) SI, only seven (7) SI had enough samples for the data analysis, including SI #2, #4, #7, #8, #13, #14, and #15. However, only SI #7 showed the expected outcome in SDNN. See Table C.80, C.81, and C.82.

In the verbal reasoning section, SI #8 indicated the expected outcome in MIBI. However, SI #2 and #5 showed a decrease in heart rate. Other SI did not show significant changes in any metrics. See Table C.83, C.84, and C.85.

#### 4.2.15 Participant 15

Participant 15 reported three (3) and two (2) SI for quantitative reasoning and verbal reasoning sections, respectively. Participant 15 had previously self-identified that he expected both sections to be equally challenging. Participant 15 began the test with the verbal reasoning section. In the quantitative reasoning section, SI #1 indicated the expected change in RMSSD and MIBI. However, SI #2 and #3 showed a decreased in heart rate. The other metrics did not show significant changes. See Table C.86, C.87, and C.88.

In the verbal reasoning section, SI #1 indicated the opposite of the expected outcome in RMSSD, SDNN, and IBI at significant level. As noted in many other participant first SI, this is possibly due to the high initial stress of the test. See Table C.89, C.90, and C.91.

### 4.2.16 Participant 16

Participant 16 reported eight (8) and two (2) SI for quantitative reasoning and verbal reasoning sections, respectively. Participant 16 began the test with the quantitative reasoning section and previously reported that he expected the verbal section to be more challenging. In the quantitative reasoning section, SI #5 and #6 indicated the expected outcome in RMSSD, SDNN, and MIBI. SI #7 showed the opposite of the expected outcome in SDNN and MIBI. The lapse between SI 6 and 7 was over 5 minutes so it was possible that the participant did not report the stress after he has struggled awhile and decided to give up the question. See Table C.92, C.93, and C.94.

In the verbal reasoning section, SI #1 showed the expected outcome in SDNN. SI #1 and #2 showed the expected outcome in MIBI. RMSSD did not show any significant changes. See Table C.95, C.96, and C.97.

### 4.2.17 Participant 17

Participant 17 reported five (5) and three (3) SI for the quantitative and verbal reasoning sections, respectively. Participant 17 began the test with the verbal reasoning section and previously reported that he expected the verbal section to be more challenging. In the quantitative reasoning section, SI #1 showed the expected outcome in MIBI but the unexpected result for SDNN. SI #2, #3, #4, and #5 indicated unexpected decrease in heart rate. SDNN and RMSSD did not show significant changes in HRV. Because SI #4 and #5 were too close to SI #3, they were mostly not relevant. One explanation for SI #3 indicating unexpected heart rate decrease could be the participant did not report the stress until he had given up on the stressful question. See Table C.98, C.99, and C.100.

In the verbal reasoning section, no significant changes were shown in any metrics. See Table C.101, C.102, and C.103.

#### 4.2.18 Participant 18

Participant 18 reported seven (7) and two (2) SI for the quantitative and verbal reasoning sections, respectively. Participant 18 began the test with the quantitative reasoning section and previously reported that she expected both sections to be equally challenging. In the quantitative reasoning section, SI #5 indicated the expected outcome in RMSSD. SI #3 indicated the expected outcome in SDNN. However, SI #1, #2, #6, and #7 indicated unexpected results in at least one of three metrics. See Table C.104, C.105, and C.106.

In the verbal reasoning section, SI #1 indicated the expected outcome for RMSSD, SDNN, and MIBI. SI #2 showed a slight decrease in HRV, but the decrease was not significant. However, SI #2 also showed an unexpected decrease in heart rate. See Table C.107, C.108, and C.109.

#### 4.2.19 Participant 19

Participant 19 reported six (6) SI for both the quantitative and verbal reasoning sections, respectively. Participant 19 began the test with the verbal reasoning section and previously reported that he expected the verbal section to be more challenging. In the quantitative reasoning section, SI #3 indicated the expected outcome in MIBI. SI #5 indicated the opposite of the expected outcome in RMSSD. The rest of the SI did not indicate significant changes. See Table C.110, C.111, and C.112.

The data in the verbal reasoning section for participant 19 is not valid. The device was not able to get enough samples for data analysis because the participant was moving excessively. See Table C.113, C.114, and C.115.

### 4.2.20 Participant 20

Participant 20 reported #5 and #4 SI for quantitative reasoning and verbal reasoning sections, respectively. Participant 20 began the test with the quantitative reasoning section and previously reported that he expected both sections to be equally challenging. In the quantitative reasoning section, no SI indicated the expected changes. SI #2 and #4 indicated significant decrease in heart rate for MIBI. However, SI #4 was too close to the previous SI. See Table C.116, C.117, and C.118.

In the verbal reasoning section, only SI #3 indicated the expected outcome. However, the sample for SI #3 was too small to be valid. The other two SI did not indicate significant changes. See Table C.119, C.120, and C.121.

## 4.3 Aggregated Heart Rate Variability Results

This section includes the aggregated results for the twenty (20) participants. The aggregated results are divided into three subsections; (1) the significant HR changes that indicated anxiety, (2) all significant HR changes, and (3) aggregated results for the three measures. Each subsection includes results for the quantitative and verbal reasoning sections because each GRE section appears to have different results. As discussed in the previous section, not all the SI reported by the participants were available for data analysis. Two reasons made some of the SI invalid. First, when a SI was too close to another SI, their intervals overlapped. The overlapping made the baseline (pre-SI) unavailable. Second, the wearable device was not able to pick up enough heart rate samples because of the motion artifact resulted from the participant's excessive movement. In this study, any SI with less than ten (10) samples in pre or post SI were considered invalid and excluded from the analysis. In most cases, an excluded SI can be considered as a part of another SI because the participants were experiencing continuous stress.

In addition to the expected HR changes that were aligned with the participant's stress, the researcher includes all significant HR changes in this section. As discussed previously, there were many instances in which the HR shows the participant is becoming more relaxed than stressed.

### 4.3.1 Significant HR Changes that indicated anxiety

In this category, the participants reported a total of 137 SI; 77 of the SI were valid. 24 of the 77 SI indicated expected significant heart rate changes in at least one of the three measures. In the verbal reasoning section, the participant reported a total of 84 SI; 61 of the SI were valid. 31 of the 61 SI indicated significant heart rate changes in at least one of the three measures.

Note that more participants initially expected the verbal reasoning section to be more challenging. See Table C.1. However, it turned out that the participants were reporting more SI in the quantitative reasoning sections than in the verbal reasoning section. As can be seen on Table 4.2 and 4.5, the accuracy is much lower in the quantitative reasoning section than in the verbal reasoning. Only 31.17% of SI in the quantitative reasoning section indicated the expected HR changes in one of the three measures. 50% of SI in the verbal reasoning section indicated the expected HR changes in one of the three measures.

The researcher initially hypothesized it might have been a result of excessive stress experienced in the quantitative reasoning section that interfered with the analysis. However, by looking at individual participants, many participants had low accuracy results, but they reported no more than five SI. For example, participant 2, 3, 8, 13, 17, and 20 indicated very low accuracy results for the quantitative reasoning section, 33.33%, 25%, 0%, 33.33%, 33.33%, and 0%, respectively. In addition, several of the same participants indicated much higher accuracy results in the verbal reasoning section, for participant 2, 3, 8, 13, the accuracies were 80%, 50%, 100%, and 50%, respectively.

Therefore, the researcher believes there is an alternative explanation based on the observation that many participants reported SI and immediately moved on to the next exam question. That is more participants were using a give-up strategy to cope with the distressing exam questions in the quantitative reasoning section. When the participants encountered the distressing exam questions, they reported the SI and mentally gave up the question; as a result, their HR changes showed they became more relaxed than they were previously. The results in the following sub-section support this explanation.

Table 4.2. *Aggregated Expected Significant HR Changes for the Quantitative Reasoning Section*

| Participant | Total SI | Valid SI | Significant Changes Detected | Accuracy |
|---|---|---|---|---|
| 1 | 13 | 4 | 1 | 25.00 % |
| 2 | 5 | 3 | 1 | 33.33% |
| 3 | 5 | 4 | 1 | 25.00% |
| 4 | 2 | 1 | 1 | 100.00% |
| 5 | 17 | 7 | 1 | 14.29% |
| 6 | 3 | 3 | 3 | 100.00% |
| 7 | 5 | 4 | 2 | 50.00% |
| 8 | 3 | 3 | 0 | 0.00% |
| 9 | 6 | 2 | 1 | 50.00% |
| 10 | 7 | 7 | 4 | 57.14% |
| 11 | 2 | 1 | 1 | 100.00% |
| 12 | 14 | 3 | 0 | 0.00% |
| 13 | 3 | 3 | 1 | 33.33% |
| 14 | 17 | 7 | 1 | 14.29% |
| 15 | 3 | 2 | 1 | 50.00% |
| 16 | 8 | 6 | 2 | 33.33% |
| 17 | 5 | 3 | 1 | 33.33% |
| 18 | 7 | 7 | 2 | 28.57% |
| 19 | 6 | 3 | 0 | 0.00% |
| 20 | 5 | 4 | 0 | 0.00% |
| Total | 137 | 77 | 24 | 31.17% |

Table 4.3. *Aggregated Expected Significant HR Changes for the Verbal Reasoning Section*

| Participant | Total SI | Valid SI | Significant Changes Detected | Accuracy |
|---|---|---|---|---|
| 1 | 3 | 3 | 2 | 66.67% |
| 2 | 6 | 5 | 4 | 80.00% |
| 3 | 5 | 4 | 2 | 50.00% |
| 4 | 3 | 2 | 1 | 50.00% |
| 5 | 8 | 7 | 4 | 57.14% |
| 6 | 4 | 4 | 2 | 50.00% |
| 7 | 10 | 5 | 3 | 60.00% |
| 8 | 1 | 1 | 1 | 100.00% |
| 9 | 4 | 4 | 2 | 50.00% |
| 10 | 3 | 3 | 2 | 66.67% |
| 11 | 4 | 3 | 2 | 66.67% |
| 12 | 2 | 2 | 1 | 50.00% |
| 13 | 5 | 4 | 2 | 50.00% |
| 14 | 8 | 3 | 0 | 0.00% |
| 15 | 2 | 2 | 0 | 0.00% |
| 16 | 2 | 1 | 1 | 100.00% |
| 17 | 3 | 3 | 0 | 0.00% |
| 18 | 2 | 2 | 1 | 50.00% |
| 19 | 6 | 0 | 0 | 0.00% |
| 20 | 3 | 2 | 0 | 0.00% |
| Total | 84 | 60 | 30 | 50.00% |

#### 4.3.2 All Significant HR Changes

As discussed in the previous subsection, the accuracy was much lower in the quantitative reasoning section than in the verbal reasoning section. In the quantitative reasoning section, many participants had ”unexpected” HR changes which showed they were more relaxed during the time interval of the SI they reported. The researcher’s observation and explanation is that the participants were adopting a give-up and move-on strategy frequently for many of the quantitative questions. The results in this section shows that if all significant HR changes are considered, the accuracies in both GRE sections are much closer. The accuracy for the quantitative reasoning section is also much higher. As can be seen on Table 4.4 and 4.3, the accuracies are 66.23% and 70% for the quantitative and verbal reasoning sections, respectively.

Table 4.4. *Aggregated Significant HR Changes for the Quantitative Reasoning Section*

| Participant | Total SI | Valid SI | Significant Changes Detected | Accuracy |
|---|---|---|---|---|
| 1 | 13 | 4 | 3 | 75.00% |
| 2 | 5 | 3 | 2 | 66.67% |
| 3 | 5 | 4 | 4 | 100.00% |
| 4 | 2 | 1 | 1 | 100.00% |
| 5 | 17 | 7 | 3 | 42.86% |
| 6 | 3 | 3 | 3 | 100.00% |
| 7 | 5 | 4 | 3 | 75.00% |
| 8 | 3 | 3 | 1 | 33.33% |
| 9 | 6 | 2 | 2 | 100.00% |
| 10 | 7 | 7 | 5 | 71.43% |
| 11 | 2 | 1 | 1 | 100.00% |
| 12 | 14 | 3 | 2 | 66.67% |
| 13 | 3 | 3 | 2 | 66.67% |
| 14 | 17 | 7 | 4 | 57.14% |
| 15 | 3 | 2 | 2 | 100.00% |
| 16 | 8 | 6 | 3 | 50.00% |
| 17 | 5 | 3 | 3 | 100.00% |
| 18 | 7 | 7 | 5 | 71.43% |
| 19 | 7 | 3 | 1 | 33.33% |
| 20 | 5 | 4 | 1 | 25.00% |
| Total | 137 | 77 | 51 | 66.23% |

Table 4.5. *Aggregated Significant HR Changes for the Verbal Reasoning Section*

| Participant | Total SI | Valid SI | Significant Changes Detected | Accuracy |
|---|---|---|---|---|
| 1 | 3 | 3 | 2 | 66.67% |
| 2 | 6 | 5 | 4 | 80.00% |
| 3 | 5 | 4 | 3 | 75.00% |
| 4 | 3 | 2 | 1 | 50.00% |
| 5 | 8 | 7 | 7 | 100.00% |
| 6 | 4 | 4 | 2 | 50.00% |
| 7 | 10 | 5 | 3 | 60.00% |
| 8 | 1 | 1 | 1 | 100.00% |
| 9 | 4 | 4 | 2 | 50.00% |
| 10 | 3 | 3 | 2 | 66.67% |
| 11 | 4 | 3 | 2 | 66.67% |
| 12 | 2 | 2 | 2 | 100.00% |
| 13 | 5 | 4 | 4 | 100.00% |
| 14 | 8 | 3 | 2 | 66.67% |
| 15 | 2 | 2 | 1 | 50.00% |
| 16 | 2 | 1 | 1 | 100.00% |
| 17 | 3 | 3 | 0 | 0.00% |
| 18 | 2 | 2 | 2 | 100.00% |
| 19 | 6 | 0 | 0 | 0.00% |
| 20 | 3 | 2 | 1 | 50.00% |
| Total | 84 | 60 | 42 | 70.00% |

### 4.3.3 Aggregated Results for RMSSD, SDNN, and MIBI

This section includes the aggregated results for the three measures used in the study. The results can be seen in Table 4.6. There were seventy-seven (77) and sixty (60) valid SI for the quantitative and verbal reasoning sections, respectively. For the quantitative reasoning section, more than half of the SI did not show any changes in RMSDD or SDNN. Unexpectedly, there were more increased MIBI than decreased MIBI in the quantitative reasoning section. Increased MIBI shows the participants heart rate were slowed down during the time interval the SI occurred. This is highly counter-intuitive because the increased stress should have caused the students heart rate to increase.

The number of decreases in RMSDD is only slightly higher than the number of increases in RMSDD. The number of decreases in SDNN is the same as the number of increases in SDNN. This result was also unexpected because it meant that the participant's HRV increased under stress, which contradicted with previous studies.

The results for the verbal reasoning section also showed similar patterns. Some SI showed the participants had increase in HRV and some SI showed the participants had decrease in HRV. As discussed in the previous section, this contradiction is likely due to the participant giving up on the question and moving on after reporting the SI. As a result, their level of stress decreased. Furthermore, for many participants, the first SI they reported indicated increase in the measures. This was likely due to the high levels of anxiety the participant had at the onset of the exam. The participants' levels of anxiety gradually decreased and by the time they reported the first SI; their levels of anxiety is actually lower than the onset.

Table 4.6. *Aggregated Results for RMSSD, SDNN, and MIBI*

| | Quantitative - 77 Valid SI | | | Verbal - 60 Valid SI | | |
|---|---|---|---|---|---|---|
| Metric | Decreased | Increased | No Change | Decrease | Increased | No Change |
| RMSSD | 14 | 9 | 54 | 13 | 8 | 39 |
| SDNN | 12 | 12 | 51 | 10 | 11 | 38 |
| MIBI | 14 | 24 | 33 | 18 | 15 | 28 |

## 4.4 Correlation Between STAI and HR Changes

The purpose of administering STAI to the participant is to know whether the participant was prone to have test anxiety. The researcher expected that participants with higher score of anxiety will report more SI. However, the results indicated there is only a weak correlation between the STAI score and the number of SI reported. See Table 4.7. The results indicated that level of anxiety prior to the test or proneness to experience anxiety was not the major factor for reporting SI.

The correlation between the number of SI reported in the quantitative reasoning section and in the verbal reasoning section is .309, which shows the participants who reported more SI in one section is also likely to report more SI in another section. Because the correlation between STAI and number of SI reported was weak, and there is a medium correlation between the numbers of SI reported in the two sections, the results may suggest that the participants' anxiety mainly came from the GRE itself instead of their levels of anxiety before the test or their proneness to experience anxiety in general. Additional factors that could affect the test anxiety include the participants' levels of preparedness for GRE or the participants' quantitative and verbal reasoning abilities, which were not measured in this study.

The anxiety detection accuracy was also only weakly correlated to the STAI scores in the quantitative reasoning section; and it is almost not correlated with the accuracy in the verbal reasoning section. See Table 4.8. This result indicated that heart rate changes do not work better or worse for participants who have higher or lower levels of state and trait anxiety.

## 4.5 Conclusion for Research Question#1

About Only 31.17% and 50% of SI indicated the expected HR changes in at least one of the three measures. In addition, about 66% and 70% of SI indicated significant HR changes in at least one of the three measures used in the study. The results indicated that the Empatica and the proposed three measures were able to detect short-term significant

HR changes associated with learning. However, it is not clear why many participants became "more relaxed" during the time they reported SI. An observation that could offer an explanation is that the participants were using a give-up strategy to cope with the distressing exam questions. Implications are discussed in the following chapter.

Table 4.7. *Correlations Between STAI and Number of SI Reported*

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1. State Anxiety | 1 | .638* | -.110 | 0.264 |
| 2. Trait Anxiety | | 1 | .119 | .116 |
| 3. Number of SI in Quantitative Section | | | 1 | .309 |
| 4. Number of SI in Verbal Section | | | | 1 |

*Correlation is significant at the 0.01 level (2-tailed)

Table 4.8. *Correlations Between STAI and Significant HR Changes*

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1. State Anxiety | 1 | .638* | .135 | -.285 |
| 2. Trait Anxiety | | 1 | .132 | -.055 |
| 3. Quantitative Reasoning Accuracy | | | 1 | -.247 |
| 4. Verbal Reasoning Accuracy | | | | 1 |

*Correlation is significant at the 0.01 level (2-tailed)

## 4.6 Social Validity Results

This section includes the results collected from the acceptability questionnaire administered after the practice GRE exam. The questionnaire included nine (9) questions related to the social validity of adopting the wearable technology in educational environments on a Likert scale of 1 to 5. See Table 4.9 for the questions and their descriptive statistics.

### 4.6.1 Question 1

The mean score for the first question ”I felt the device was comfortable to wear” was 4.0 out of total score 5. The range was from 1 to 5. Participant 6, 10, 15, and 19 felt the device was not comfortable to wear. See Table 4.11. For these participants, the researcher noticed their wrists were too small or big for the wearable device; it was hard for the researcher to properly put on the device for these participants. For female participants, their wrists were too small for the device. As a result, to make the sensor properly working, the researcher had to adjust the wrist band to a level that the participants felt the device was too tight and uncomfortable. The same also applied to the male participants who had large wrists. Although the wrist band was adjustable, it did not work very well with large wrists. The researcher had to make the wrist band very tight to properly secure the sensor’s position. Question 1 was significantly correlated with question 2 and 3. This indicates the participant’s perception of the device’s comfort was positively correlated with their perception of the device’s safety. It also shows the participant’s perception of the device’s comfort is correlated to whether they felt the device was distracting.

### 4.6.2 Question 2

The second question was ”I felt the device was safe to wear”. The mean score was 4.7 and the range was from 1 to 5. Participant 19 felt the device was not safe to wear and gave a score of 1 to the second question. Besides participant 19, all other participants felt the device was safe to wear.

#### 4.6.3 Question 3

The third question was ”I felt the device did not prevent me from focusing on the practice exam”. The mean score was 4.05 and the range was 1 to 5. Three participants felt the device was distracting to the exam, including participant 5, 6, and 19. Participant 6 and 19 also felt the device was not comfortable to wear. This may suggest the device's comfort plays a role in how distracting it is to the participant. Furthermore, there was a strong correlation between the participant's familiarity with wearable device and their answers to question 3. The Pearson's correlation score was .57, and the $p$ value was less than .01. This indicates participants who were more familiar with wearable devices also reported they felt the devices less distracting.

#### 4.6.4 Question 4

The fourth question was ”I felt comfortable knowing the device was monitoring my physiological response during the practice exam”. The mean was 4.2 and the range was from 2 to 5. The mean score for this question was lower than the second question which was about whether the participant felt the device was safe to wear. Although the participant knew the device was safe, they were not particularly comfortable with their physiological signals being monitored. Four participants chose neither agree nor disagree on this question. Two participants disagreed they felt comfortable the device was monitoring their physiological responses.

There was also a negative correlation between this question and the participant's levels of state and trait anxiety. The Pearson's r for STAI and the question is -.46, and the $p$ value was 0.03. This possibly suggests that people with higher levels of anxiety are less likely to feel comfortable having their physiological signals being monitored. This is a critical issue to address in future research studies because such technology is most useful for those who experience higher levels of anxiety. If the target population is not comfortable with having their physiological signals being monitored, it might exacerbate their existing anxiety.

#### 4.6.5 Question 5

The fifth question was ”I think wearing a device like Empatica in a classroom would not attract special attentions from my peers”. The mean was 4.1 and the range was from 1 to 5. Three participants chose neither agree nor disagree for this question, and two participants disagreed it would not attract special attentions.

There was a negative correlation between the anxiety score and the answers to question 5. The Pearson’s correlation score for trait anxiety and question 5 was -.25. The correlation score for state anxiety and question 5 was -.29. However, the correlation was not significant at .05 level.

Furthermore, there was a positive correlation between familiarity with wearable devices and question 5. The Pearson’s correlation score was .39, and the *p* value was .08. Although the correlation was strongly significant, it appeared that participants who were less familiar with the wearable devices thought they device would attract special attentions from the peers.

Finally, question 5 was highly correlated with the previous four questions. Participants who agreed with the wearable device in general also felt the device would not attract special attention from peers.

#### 4.6.6 Question 6

The sixth question was ”Knowing the device could possibly help improve my learning outcome, I feel more comfortable letting it monitor my physiological data”. The mean was 4.45 and the range was from 2 to 5. The mean score was slightly higher than the mean of question 4, which was also about how comfortable the participant felt their physiological responses being monitored. Six participants gave higher score on question 6 than they did on question 4. Two participants did not think it would make a difference. One participant disagreed. The results suggested that with a clear purpose in place, the students could feel more comfortable with their physiological signals being monitored. The results of this question were not strongly correlated with the STAI scores or familiarity with wearable devices.

### 4.6.7 Question 7

The seventh question was ”I think teachers or computer applications can better enhance my learning if they are aware of my mental stress or anxiety”. The mean was 4.1 and the range was from 1 to 5. Three participants did not agree with the statement, and one participant chose neither agree nor disagree. Interestingly, this question was highly correlated with question 4. The Pearson’s correlation score was .57, and the *p* value was less than .01. The question was also highly correlated with question 6. The Pearson’s correlation score was .83, and the *p* value was smaller than .01. However, this question was not highly correlated with the participant’s familiarity with wearable devices or STAI scores. The results indicate that the answers to this question was highly correlated to how comfortable they participants were with their physiological signals being monitored and whether they believe they device could help them improve their learning.

### 4.6.8 Question 8

The eighth question was ”I want to be immediately notified if the device detects anxiety while I am learning or studying”. The mean was 3.25, and the range was from 1 to 5. Five participants disagreed with the statement, and five participants chose neither agree nor disagree with the statement; ten participants agreed with the statement.

There appeared to be some gender differences in the answers to this question. However, the test statistics for Mann-Whitney Two tailed U Test was 25.5 which yielded a *p* value slightly higher than higher than .05. Although the gender difference is not significant at .05 level, future research studies could include more participants and examine whether gender difference exist and why female participants are more open to be notified of their anxiety immediately than male participants.

### 4.6.9 Question 9

The ninth question was ”Being able to know exactly what raised my levels of anxiety on the exam could help me improve my learning outcome”. The mean was 4.15, and the range was from 1 to 5. Two participants disagreed with the statement; Two participants chose neither agree nor disagree; Sixteen participants agreed with the statement. Analyzing question 9 with question 8, the results indicated that many participants were interested in knowing what raised their levels of anxiety during the exam; however, many of them did not want to be notified of their anxiety immediately.

## 4.7 Conclusion for Research Question#2

The results indicated that all of the questions had very big range on the answers. This shows the social validity of the device can vary greatly depending on users. In addition, the results indicated that familiarity with the wearable device is highly correlated with whether the participant felt the device was distracting or not. Participants with higher levels of anxiety did not feel comfortable with their physiological signals monitored. Finally, only half of the participants indicated that they wanted to be immediately notified for their learning related anxiety. Implications are discussed in the following chapter.

Table 4.9. *Social Validity Results Summary*

| Number | Question | Mean | Range |
|---|---|---|---|
| 1 | I felt the device was comfortable to wear. | 4.0 | (1,5) |
| 2 | I felt the device was safe to wear. | 4.7 | (1,5) |
| 3 | I felt the device did not prevent me from focusing on the practice exam. | 4.05 | (1,5) |
| 4 | I felt comfortable knowing the device was monitoring my physiological response during the practice exam. | 4.2 | (2,5) |
| 5 | I think wearing a device like Empatica in a classroom would not attract special attentions from my peers. | 4.1 | (1,5) |
| 6 | Knowing the device could possibly help improve my learning outcome, I feel more comfortable letting it monitor my physiological data. | 4.45 | (2,5) |
| 7 | I think teachers or computer applications can better enhance my learning if they are aware of my mental stress or anxiety | 4.1 | (1,5) |
| 8 | I want to be immediately notified if the device detects anxiety while I am learning or studying. | 3.25 | (1,5) |
| 9 | Being able to know exactly what raised my levels of anxiety on the exam could help me improve my learning outcome. | 4.15 | (1,5) |

Table 4.10. *Social Validity Results by Gender*

| | Male | | Female | |
|---|---|---|---|---|
| Question Number | Mean | Range | Mean | Range |
| 1 | 3.88 | (1, 5) | 3.87 | (2,5) |
| 2 | 4.65 | (1, 5) | 4.65 | (4,5) |
| 3 | 4.15 | (1, 5) | 3.67 | (2, 5) |
| 4 | 4.24 | (2, 5) | 4.35 | (3, 5) |
| 5 | 4.10 | (1, 5) | 3.87 | (2, 5) |
| 6 | 4.42 | (2, 5) | 4.50 | (3, 5) |
| 7 | 4.03 | (1, 5) | 4.47 | (4, 5) |
| 8 | 3.20 | (1, 5) | 3.62 | (2, 5) |
| 9 | 4.08 | (1, 5) | 4.41 | (3, 5) |

Table 4.11. *Social Validity Individual Results*

| Participant | Familiarity | Gender | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 4 | Female | 4 | 5 | 4 | 4 | 4 | 5 | 5 | 4 | 5 |
| 2 | 4 | Female | 5 | 5 | 4 | 3 | 5 | 4 | 4 | 3 | 4 |
| 3 | 5 | Male | 5 | 4 | 5 | 3 | 5 | 4 | 3 | 2 | 3 |
| 4 | 4 | Male | 4 | 5 | 5 | 5 | 5 | 3 | 2 | 1 | 4 |
| 5 | 4 | Female | 5 | 5 | 2 | 5 | 3 | 5 | 5 | 4 | 5 |
| 6 | 3 | Female | 2 | 5 | 2 | 3 | 2 | 4 | 4 | 5 | 3 |
| 7 | 5 | Female | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 |
| 8 | 5 | Male | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 3 | 5 |
| 9 | 5 | Male | 4 | 5 | 4 | 5 | 5 | 5 | 4 | 3 | 5 |
| 10 | 4 | Female | 2 | 4 | 4 | 4 | 4 | 5 | 5 | 4 | 4 |
| 11 | 5 | Male | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 2 | 1 |
| 12 | 5 | Female | 5 | 5 | 5 | 5 | 5 | 3 | 4 | 2 | 5 |
| 13 | 4 | Male | 5 | 5 | 5 | 2 | 4 | 4 | 2 | 3 | 4 |
| 14 | 5 | Female | 4 | 5 | 4 | 5 | 5 | 5 | 5 | 4 | 5 |
| 15 | 5 | Male | 1 | 5 | 4 | 3 | 3 | 5 | 5 | 4 | 4 |
| 16 | 5 | Male | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 |
| 17 | 5 | Male | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 3 | 5 |
| 18 | 2 | Female | 3 | 5 | 3 | 5 | 4 | 5 | 5 | 4 | 5 |
| 19 | 4 | Male | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 1 |
| 20 | 5 | Male | 5 | 5 | 5 | 5 | 3 | 5 | 5 | 4 | 5 |

Table 4.12. *Social validity Correlations*

| | FWW | State | Trait | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FWW | - | -.21 | -.30 | .41 | .10 | .57** | .26 | .40 | .17 | .12 | -.17 | .09 |
| State | - | - | .64** | -.05 | -.02 | -.24 | -.46* | -.30 | -.08 | -.07 | .10 | -.07 |
| Trait | - | - | - | -.08 | .22 | -.11 | -.46* | -.26 | -.11 | .03 | .22 | .02 |
| Q1 | - | - | - | - | .52* | .62** | .47* | .67** | .25 | .15 | -.06 | .38 |
| Q2 | - | - | - | - | - | .54* | .53* | .57** | .62** | .59** | .47* | .62** |
| Q3 | - | - | - | - | - | - | .35 | .75** | .28 | .14 | -.16 | .31 |
| Q4 | - | - | - | - | - | - | - | .52* | .49* | .57** | .16 | .54* |
| Q5 | - | - | - | - | - | - | - | - | .31 | .22 | -.10 | .38 |
| Q6 | - | - | - | - | - | - | - | - | - | .84** | .70** | .50* |
| Q7 | - | - | - | - | - | - | - | - | - | - | .77** | .61** |
| Q8 | - | - | - | - | - | - | - | - | - | - | - | .51* |
| Q9 | - | - | - | - | - | - | - | - | - | - | - | - |

FWW = familiarity with wearable devices

*Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

# CHAPTER 5. SUMMARY

As discussed in Chapter 2, numerous previous research studies has shown that HRV decreases and HR increases when a person is under stress or has anxiety. This research study was built upon previous studies and attempted to test whether HRV could be used for anxiety detection in educational settings using a wearable device. This chapter discusses the results of the study and its implications. The chapter is divided into the following sections; (1) Anxiety Detection Using Physiological Signals, (2) Social Validity, (3) Contribution, (4) Limitations, and (5) Future Research Directions.

## 5.1 Anxiety Detecting Wearable Technology for Educational Purposes

The researcher originally planned to study anxiety detection using both HRV and SC data. However, after collecting the data from participants, the researcher realized the SC data collected from the Empatica were not reliable. Similar issues have been reported by other researchers because of loosed electrodes (Empatica Inc., 2017). Thus, SC was excluded from the study. So the first research question become "Can a wearable technology use heart rate variability to identify a student's anxiety resulting from engagement in a potentially distressing learning activity?" Based on the results of this study, the answer to this question is mostly.

As discussed in the previous chapter, about 66% and 70% of SI indicated significant HR changes in at least one of the three measures used in the study. However, the researcher did not actually anticipate increase in any of the three measures during the time interval of SI. The researcher did not expect the participant's physiological signals to become "relaxed" when the exam question are distressing. The results showed that in many cases, the stressful moments were also the give-up and move-on moments for the participants taking the exam. When the participants reported the stress, they also mentally gave up the questions. As a result, their levels of stress decreased after the reporting.

This study was conducted in a practice, timed exam. The participants were not actually getting scored so they would not actually face negative consequences if they did not try their best. This might have lead them to give up distressing questions more quickly. Furthermore, even if the participant had the intention to try their best, in most exams scenarios, it is also common to give up on the difficult questions and move on to focus on the ones that could be tackled more easily. In the real-life classrooms settings, students might not necessarily adopt this give-up and move-on strategy.

Although it is uncertain how frequently students mentally give up on distressing learning activities, the results of this study suggest that physiological signals alone cannot always detect the anxiety associated with learning. The original purpose of the wearable technology is to enable teachers or intelligent tutors to provide timely intervention to students whose learning were interfered by the anxiety. However, the result of this study suggest the wearable technology cannot be useful if the students are mentally giving up the learning tasks when they feel stressed.

In terms of the technical perspectives, the results of this study indicated that the Empatica and the proposed three measures were able to detect short-term significant HR changes associated with learning. The results of this study supported previous research studies and suggested that HR changes can be used to identify short-term anxiety. The results of this study also showed some limitations of the physical wearable device; for instance, the wearable device was not collecting heart rate data properly when the participants were moving their arms excessively. To minimize sensor light leaking from the wearable device, the device must be snuggly attached to the users skin. Some participant felt the device was too tight when it was properly attached to their skin. This indicated the device can not necessarily be worn comfortably if the primary object is to maximize sensor accuracy. This technical limitation could adversely affect the acceptance of the technology.

Finally, the researcher originally expected the following outcomes.

- High levels of state and trait anxiety leads to more prominent changes in IBI, RMSDD, and SDNN.
- Participants with high levels of state and trait anxiety would report more SI during the exam.
- Mean IBI decreases during the time interval of SI.
- RMSSD decreases during the time interval of SI.
- SDNN decreases during the time interval of SI.

The first expected outcome was not supported by the results of this study. There was no correlation between the accuracy and the scores of STAI. This means HR changes do not work better or worse with participants of different levels of anxiety. The second expected outcome was also not supported by the results. Participant with higher levels of anxiety did not necessarily report more SI. Factors not studied in this study such as the participants' levels of preparedness for the GRE or quantitative and verbal reasoning abilities were likely the contributors to reporting the SI. Finally, the three measures did not necessarily always decrease and indicate signs of anxiety during the time interval of SI because of the give-up and move-on strategy discussed previously.

## 5.2 Social Validity

One of the research questions of this study was “Is the use of wearable technology for educational purposes, such as intelligent tutoring and classroom intervention, socially acceptable?”

The results of this study indicated a few things. First, all the questions except question 8 had a mean that indicated most people felt the technology was acceptable for educational purposes. Meanwhile, almost of the questions had very big range on the answers. This shows the social validity of the device can vary greatly depending on the user. This suggests that future studies should examine the factors that influence the acceptance of such technologies. The following discusses the key findings on the social validity in this study.

The acceptability questionnaire revealed that familiarity with the wearable device is highly correlated with whether the participant felt the device was distracting or not. However, familiarity with wearable device was not correlated with any other questions. This may suggest the wearable device will likely not be distracting as the user become more familiar with it.

Furthermore, the results suggest that people with high levels of anxiety are less likely to feel comfortable with their physiological signals being monitored. The results indicated that the participants' levels of anxiety were negatively correlated with whether they felt comfortable having their physiological signals monitored. This was probably the single most important finding in this study because the target population of this technology are the people who have or are prone to experience high levels of anxiety.

Further research studies are needed to evaluate what factors could make people who have higher levels of anxiety feel more comfortable with the idea of having their physiological signals being monitored. Moreover, most wearable devices on the market are used for purposes related to fitness. It is not clear whether people who oppose to having their physiological signals being monitored for educational purposes would also oppose the same for purposes related to fitness. Future research studies should examine whether the purpose affects the acceptance of such technology.

Another key finding of the acceptability questionnaire was that only half of the participants indicated they wanted to be immediately notified of their learning related anxiety. Additionally, half of the participants did not want to "just know" they have anxiety; they expected something that would help improve their learning. This supports the idea that the proposed technology is more useful if it is integrated with potential interventions or adaptive learning. Some of the mindfulness wearable technologies currently in the market such as Spire™ (Spire, n.d.), which notifies the user to take mindfulness actions when it detects anxiety may not be the most useful solution in educational settings. Interventions or adaptation are needed from the teacher's side in educational environments.

Because question 8 “I want to be immediately notified if the device detects anxiety while I am learning or studying” was positively correlated with question 6,7, and 9. It may suggest that learning outcome could be the main factor determining whether the participants wanted to be immediately notified of their learning related anxiety. The results indicated that people who felt comfortable having their physiological signals monitored also felt the device could help improve their learning. This suggests that the participants want to know about their anxiety if it improves their learning outcome. This implies that one way to improve the social acceptance of the technology is to explain or demonstrate how such technology can be used to improve the user’s learning outcomes. Finally, one approach to make the device more acceptable is to improve its comfort. The ergonomics of the device can be improved if the wrist band is tailored made to accommodate users of different wrist sizes.

### 5.2.1 Contribution

Previous research studies have shown that HRV and HR could potentially be indicators of mental stress or anxiety (Berntson et al., 1997; Dishman et al., 2000; Hjortskov et al., 2004; Jönsson, 2007; Nickel & Nachreiner, 2003; Taelman, Vandeput, Spaepen, & Van Huffel, 2008). However, to the knowledge of the researcher, very few or no research studies have examined whether wearable technology equipped with heart rate sensor could be used in educational environment to detect anxiety or stress associated with learning. Most assistive technologies for students with special needs focus on helping students complete specific tasks. They do not address the emotional needs. This research study filled the gap by validating the feasibility of using an unobtrusive wearable devices with PPG sensor to monitor and detect HR changes that indicate mental stress. Furthermore, this research study also provided insights on the social validity of such technology, including whether such technology is perceived as safe or socially acceptable by students with different levels of anxiety.

### 5.2.2 Limitations

This research study is limited to the wearable devices it used. SC could be useful if they electrodes on the device was functioning properly. In addition, the results of this study only included participants ranging from eighteen (18) to twenty-four (24) years old. Students of other ages might have indicated different results for social validity. This research study is also limited to the context of laboratory. Real-life practice exams or actual GRE might have yielded different results.

### 5.2.3 Future Research Directions

Future research studies should focus on studying HR changes in educational settings that are occasionally stressful (real classrooms) instead of highly stressful (standardized tests). Moreover, future researchers should study emotion detection such as anxiety detection in pure authentic learning environments. As discussed earlier, experimental studies do not offer strong enough incentives for the participants to keep on going like they would in a real world scenario. Moreover, future research studies should examine how to help people who have higher levels of anxiety to be more comfortable with the idea of having their physiological signals monitored because people who experience higher levels of anxiety can benefit the most from the proposed technology. One of the possible motivation for the acceptance of the technology is the technology's potential to improve learning outcome. Future research studies should also explore how and whether the technology could help improve the user's learning outcomes. Finally, future research studies can also focus on improving the ergonomics of the wearable device so it is more comfortable to wear. One approach to to make the wrist band tailored made to accommodate users of different wrist sizes as suggested by the results of this study.

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APPENDICES

# CHAPTER A. ACCEPTABILITY OF AN ANXIETY-DETECTING WEARABLE DEVICE FOR LEARNING PURPOSES

Acceptability of an Anxiety-Detecting Wearable Device for Learning Purposes

I felt the device was comfortable to wear.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I felt the device was safe to wear

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I felt the device did not prevent me from focusing on the practice exam.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I felt comfortable knowing the device was monitoring my physiological response during the practice exam.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I think wearing a device like Empatica in a classroom would not attract special attentions from my peers.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Knowing the device could possibly help improve my learning outcome, I feel more comfortable letting it monitor my physiological data.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I think teachers or computer applications can better enhance my learning if they are aware of my mental stress or anxiety

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

I want to be immediately notified if the device detects anxiety while I am learning or studying.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Being able to know exactly what raised my levels of anxiety on the exam could help me improve my learning outcome.

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Please write down any undesirable side effects of wearing the device. Indicate "none" if you did not experience any.

Please feel free to write down any additional comments you may have.

# CHAPTER B. DEMOGRAPHIC QUESTIONNAIRE

Are you over 18 years old?

- ❍ Yes
- ❍ No

Are you planning to take an official GRE within 1 year?

- ❍ Yes
- ❍ No
- ❍ Maybe

Have you ever taken any official or practice Graduate Record Exam (GRE) before?

- ❍ Yes
- ❍ No

Which one of the following sections on GRE do you expect to be more challenging?

- ❍ Verbal Reasoning
- ❍ Quantitative Reasoning
- ❍ Both sections are equally challenging

Are you male or female?

- ❍ Male
- ❍ Female

Which category below includes your age?

- ❍ 18 - 24
- ❍ 25 - 34
- ❍ 35 - 44
- ❍ 45 - 54
- ❍ 55 - 64
- ❍ 65 or older
- ❍ I prefer not to answer

Are you familiar with fitness wearable device (such as Fitbit or AppleWatch)?

- ❍ Definitely not
- ❍ Probably not
- ❍ Might or might not
- ❍ Probably yes
- ❍ Definitely yes

Can you please provide us with your name? Your name will be used solely for contacting purposes.  It will not be used in the study or any other way.

Can you please provide us with your email? Your email will not be used in the study and will be used solely for contacting purposes.

Please all time slots in which you would be available and willing to participate in our study. We will be in contact with you as soon as possible. If at any time, you would like to withdraw from our study, please notify us.

- ❑ Monday Morning
- ❑ Monday Afternoon
- ❑ Tuesday Morning
- ❑ Tuesday Afternoon
- ❑ Wednesday Morning
- ❑ Wednesday Afternoon
- ❑ Thursday Morning
- ❑ Thursday Afternoon
- ❑ Friday Morning
- ❑ Friday Afternoon
- ❑ Saturday Morning
- ❑ Saturday Afternoon

# CHAPTER C. DATA COLLECTION RESULTS

Table C.1. *Demographics*

| P | English 1st Language | Gender | Age | Start Section | Challenging Section |
|---|---|---|---|---|---|
| 1 | Yes | Female | 18 - 24 | Verbal | Quantitative |
| 2 | Yes | Female | 18 - 24 | Quantitative | Equally Challenging |
| 3 | No | Male | 18 - 24 | Verbal | Equally Challenging |
| 4 | Yes | Male | 18 - 24 | Verbal | Equally Challenging |
| 5 | Yes | Female | 18 - 24 | Verbal | Verbal |
| 6 | Yes | Female | 18 - 24 | Quantitative | Equally Challenging |
| 7 | No | Female | 18 - 24 | Verbal | Verbal |
| 8 | Yes | Male | 18 - 24 | Verbal | Verbal |
| 9 | Yes | Male | 18 - 24 | Quantitative | Verbal |
| 10 | Yes | Female | 18 - 24 | Quantitative | Verbal |
| 11 | Yes | Male | 18 - 24 | Quantitative | Verbal |
| 12 | Yes | Female | 18 - 24 | Verbal | Verbal |
| 13 | No | Male | 18 - 24 | Quantitative | Verbal |
| 14 | Yes | Female | 18 - 24 | Quantitative | Quantitative |
| 15 | Yes | Male | 18 - 24 | Verbal | Equally Challenging |
| 16 | Yes | Male | 18 - 24 | Quantitative | Verbal |
| 17 | Yes | Male | 18 - 24 | Verbal | Verbal |
| 18 | No | Female | 18 - 24 | Quantitative | Equally Challenging |
| 19 | Yes | Male | 18 - 24 | Verbal | Verbal |
| 20 | No | Male | 18 - 24 | Quantitative | Equally Challenging |

Table C.2. *Pre and Post Stressful Incident RMSSD for Participant #1 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 177 | 129 | 286 | 0.043 | 0.0566 | <0.001 |
| 2 | 45 | 140 | 93 | 0.0383 | 0.0555 | 0.0868 |
| 3 | 44 | 165 | 158 | 0.0673 | 0.0473 | 0.0292* |
| 4 | 44 | 150 | 68 | 0.0673 | 0.0536 | 0.2045 |
| 5** | 0 | 148 | 93 | N/A | 0.0516 | N/A |
| 6** | 0 | 145 | 40 | N/A | 0.055 | N/A |
| 7** | 1 | 145 | 123 | 0.0938 | 0.0592 | 0.1079 |
| 8** | 1 | 145 | 107 | 0.0938 | 0.0525 | 0.0782 |
| 9** | 0 | 125 | 86 | N/A | 0.0644 | N/A |
| 10** | 0 | 143 | 86 | N/A | 0.0546 | N/A |
| 11** | 0 | 152 | 40 | N/A | 0.0487 | N/A |
| 12** | 0 | 128 | 96 | N/A | 0.0467 | N/A |
| 13** | 0 | 131 | 43 | N/A | 0.0487 | N/A |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.3. *Pre and Post Stressful Incident SDNN for Participant #1 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 177 | 129 | 286 | 0.054 | 0.0777 | <0.001 |
| 2 | 45 | 140 | 93 | 0.0688 | 0.0703 | 0.8558 |
| 3 | 44 | 165 | 158 | 0.0684 | 0.0754 | 0.4304 |
| 4 | 44 | 150 | 68 | 0.0684 | 0.0762 | 0.3891 |
| 5** | 0 | 148 | 93 | N/A | 0.0802 | N/A |
| 6** | 0 | 145 | 40 | N/A | 0.0734 | N/A |
| 7** | 1 | 145 | 123 | N/A | 0.062 | N/A |
| 8** | 1 | 145 | 107 | N/A | 0.0677 | N/A |
| 9** | 0 | 125 | 86 | N/A | 0.0787 | N/A |
| 10** | 0 | 143 | 86 | N/A | 0.068 | N/A |
| 11** | 0 | 152 | 40 | N/A | 0.0698 | N/A |
| 12** | 0 | 128 | 96 | N/A | 0.0731 | N/A |
| 13** | 0 | 131 | 43 | N/A | 0.0731 | N/A |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.4. *Pre and Post Stressful Incident MIBI for Participant #1 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 177 | 129 | 286 | 0.6194 | 0.6695 | <0.001 |
| 2 | 45 | 140 | 93 | 0.599 | 0.641 | <0.001 |
| 3 | 44 | 165 | 158 | 0.6559 | 0.6289 | 0.0257* |
| 4 | 44 | 150 | 68 | 0.6559 | 0.6578 | 0.8738 |
| 5** | 0 | 148 | 93 | N/A | 0.648 | N/A |
| 6** | 0 | 145 | 40 | N/A | 0.6552 | N/A |
| 7** | 1 | 145 | 123 | 0.7657 | 0.64 | N/A |
| 8** | 1 | 145 | 107 | 0.7657 | 0.651 | N/A |
| 9** | 0 | 125 | 86 | N/A | 0.6544 | N/A |
| 10** | 0 | 143 | 86 | N/A | 0.6448 | N/A |
| 11** | 0 | 152 | 40 | N/A | 0.657 | N/A |
| 12** | 0 | 128 | 96 | N/A | 0.6554 | N/A |
| 13** | 0 | 131 | 43 | N/A | 0.6421 | N/A |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.5. *Pre and Post Stressful Incident RMSSD for Participant #1 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 143 | 130 | 802 | 0.0764 | 0.0551 | 0.2237 |
| 2 | 154 | 159 | 240 | 0.0505 | 0.0486 | 0.2328 |
| 3 | 15 | 120 | 130 | 0.0421 | 0.0466 | 0.2531 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.6. *Pre and Post Stressful Incident SDNN for Participant #1 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 143 | 130 | 802 | 0.0785 | 0.0686 | 0.1183 |
| 2 | 154 | 159 | 240 | 0.0718 | 0.0759 | 0.4857 |
| 3 | 15 | 120 | 130 | 0.0338 | 0.0566 | 0.0256 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.7. *Pre and Post Stressful Incident MIBI for Participant #1 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 143 | 130 | 802 | 0.6373 | 0.6425 | 0.5604 |
| 2 | 154 | 159 | 240 | 0.6583 | 0.6277 | <0.001* |
| 3 | 15 | 120 | 130 | 0.65 | 0.6198 | <0.001* |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.8. *Pre and Post Stressful Incident RMSSD for Participant #2 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 126 | 88 | 560 | 0.0758 | 0.0813 | 0.2869 |
| 2 | 19 | 44 | 384 | 0.0846 | 0.0936 | 0.2944 |
| 3** | 2 | 50 | 91 | 0.0349 | 0.1134 | 0.1702 |
| 4** | 0 | 56 | 87 | N/A | 0.0932 | N/A |
| 5 | 56 | 28 | 180 | 0.0893 | 0.0862 | 0.4659 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.9. *Pre and Post Stressful Incident SDNN for Participant #2 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 126 | 88 | 560 | 0.0598 | 0.0577 | 0.7142 |
| 2 | 19 | 44 | 384 | 0.068 | 0.0748 | 0.6388 |
| 3** | 2 | 50 | 91 | 0.0331 | 0.0841 | 0.384 |
| 4** | 0 | 56 | 87 | N/A | 0.0602 | N/A |
| 5 | 56 | 28 | 180 | 0.0557 | 0.048 | 0.3844 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.10. *Pre and Post Stressful Incident MIBI for Participant #2 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 126 | 88 | 560 | 0.701 | 0.7248 | <0.001 |
| 2 | 19 | 44 | 384 | 0.7114 | 0.7376 | 0.1812 |
| 3** | 2 | 50 | 91 | 0.711 | 0.7435 | 0.369 |
| 4** | 0 | 56 | 87 | N/A | 0.7076 | N/A |
| 5 | 56 | 28 | 180 | 0.7258 | 0.7015 | 0.0427* |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.11. *Pre and Post Stressful Incident RMSSD for Participant #2 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 81 | 75 | 180 | 0.0785 | 0.084 | 0.4344 |
| 2 | 28 | 92 | 85 | 0.1136 | 0.0783 | 0.0114* |
| 3** | 0 | 92 | 86 | N/A | 0.0961 | N/A |
| 4 | 152 | 140 | 328 | 0.0367 | 0.0377 | 0.089 |
| 5 | 84 | 109 | 52 | 0.0381 | 0.0701 | 0.0691 |
| 6 | 96 | 147 | 232 | 0.0918 | 0.0506 | 0.0287* |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.12. *Pre and Post Stressful Incident SDNN for Participant #2 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 81 | 75 | 180 | 0.0693 | 0.0611 | 0.275 |
| 2 | 28 | 92 | 85 | 0.0756 | 0.0558 | 0.0404* |
| 3** | 0 | 92 | 86 | N/A | 0.0722 | N/A |
| 4 | 152 | 140 | 328 | 0.0319 | 0.0508 | <0.001 |
| 5 | 84 | 109 | 52 | 0.0321 | 0.0718 | <0.001 |
| 6 | 96 | 147 | 232 | 0.0741 | 0.0551 | <0.001* |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.13. *Pre and Post Stressful Incident MIBI for Participant #2 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 81 | 75 | 180 | 0.7523 | 0.7438 | 0.4134 |
| 2 | 28 | 92 | 85 | 0.7824 | 0.7461 | 0.0242* |
| 3** | 0 | 92 | 86 | N/A | 0.7327 | N/A |
| 4 | 152 | 140 | 328 | 0.7489 | 0.7003 | <0.001* |
| 5 | 84 | 109 | 52 | 0.7381 | 0.7056 | <0.001* |
| 6 | 96 | 147 | 232 | 0.7248 | 0.7607 | <0.001 |

*post-MIBI decreased from pre-MIBI and *p* value $<.05$
**SI not valid for data analysis

Table C.14. *Pre and Post Stressful Incident RMSSD for Participant #3 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 50 | 48 | N/A | 0.0642 | N/A |
| 2 | 90 | 49 | 409 | 0.0533 | 0.0827 | 0.0229 |
| 3 | 71 | 35 | 265 | 0.0846 | 0.0589 | 0.1585 |
| 4 | 45 | 47 | 328 | 0.0603 | 0.0949 | 0.0818 |
| 5 | 69 | 39 | 240 | 0.0574 | 0.0838 | 0.1186 |

*post-RMSSD decreased from pre-RMSSD and *p* value $<.05$
**SI not valid for data analysis

Table C.15. *Pre and Post Stressful Incident SDNN for Participant #3 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 50 | 48 | N/A | 0.0668 | N/A |
| 2 | 90 | 49 | 409 | 0.0606 | 0.0836 | <0.001 |
| 3 | 71 | 35 | 265 | 0.0671 | 0.0496 | 0.0509 |
| 4 | 45 | 47 | 328 | 0.0686 | 0.1011 | 0.011 |
| 5 | 69 | 39 | 240 | 0.0705 | 0.1092 | <0.001 |

*post-SDNN decreased from pre-SDNN and *p* value $<.05$
**SI not valid for data analysis

Table C.16. *Pre and Post Stressful Incident MIBI for Participant #3 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 50 | 48 | N/A | 0.9479 | N/A |
| 2 | 90 | 49 | 409 | 0.8792 | 0.9034 | 0.0779 |
| 3 | 71 | 35 | 265 | 0.8656 | 0.9148 | <0.001 |
| 4 | 45 | 47 | 328 | 0.8747 | 0.8624 | 0.4956 |
| 5 | 69 | 39 | 240 | 0.9541 | 0.8959 | <0.001* |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.17. *Pre and Post Stressful Incident RMSSD for Participant #3 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 87 | 117 | 445 | 0.0419 | 0.0318 | 0.1408 |
| 2 | 116 | 91 | 442 | 0.0391 | 0.0444 | 0.3691 |
| 3 | 41 | 73 | 372 | 0.0712 | 0.0526 | 0.1049 |
| 4** | 0 | 22 | 122 | N/A | 0.0576 | N/A |
| 5 | 37 | 14 | 212 | 0.0649 | 0.0463 | 0.2389 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.18. *Pre and Post Stressful Incident SDNN for Participant #3 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 87 | 117 | 445 | 0.054 | 0.0613 | 0.21 |
| 2 | 116 | 91 | 442 | 0.0547 | 0.0487 | 0.2423 |
| 3 | 41 | 73 | 372 | 0.0619 | 0.0705 | 0.3615 |
| 4** | 0 | 22 | 122 | N/A | 0.0572 | N/A |
| 5 | 37 | 14 | 212 | 0.0686 | 0.0503 | 0.2053 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.19. *Pre and Post Stressful Incident MIBI for Participant #3 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 87 | 117 | 445 | 0.8348 | 0.8164 | 0.0243* |
| 2 | 116 | 91 | 442 | 0.8477 | 0.8376 | 0.1629 |
| 3 | 41 | 73 | 372 | 0.8083 | 0.8652 | <0.001 |
| 4** | 0 | 22 | 122 | N/A | 0.8346 | N/A |
| 5 | 37 | 14 | 212 | 0.8915 | 0.8549 | 0.0453* |

*post-MIBI decreased from pre-MIBI and $p$ value $<.05$
**SI not valid for data analysis

Table C.20. *Pre and Post Stressful Incident RMSSD for Participant #4 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 13 | 57 | 677 | 0.0505 | 0.0377 | 0.1057 |
| 2** | 1 | 28 | 112 | 0.0625 | 0.0672 | 0.218 |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.21. *Pre and Post Stressful Incident SDNN for Participant #4 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 13 | 57 | 677 | 0.048 | 0.0465 | 0.8853 |
| 2** | 1 | 28 | 112 | N/A | 0.0739 | N/A |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.22. *Pre and Post Stressful Incident MIBI for Participant #4 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 13 | 57 | 677 | 0.7885 | 0.7446 | <0.001* |
| 2** | 1 | 28 | 112 | 0.75 | 0.7205 | N/A |

*post-MIBI decreased from pre-MIBI and $p$ value <.05
**SI not valid for data analysis

Table C.23. *Pre and Post Stressful Incident RMSSD for Participant #4 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 32 | 27 | 388 | 0.048 | 0.0571 | 0.2753 |
| 2** | 0 | 33 | 141 | N/A | 0.0325 | N/A |
| 3 | 39 | 53 | 302 | 0.0742 | 0.0435 | 0.0252* |

*post-RMSSD decreased from pre-RMSSD and $p$ value <.05
**SI not valid for data analysis

Table C.24. *Pre and Post Stressful Incident SDNN for Participant #4 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 32 | 27 | 388 | 0.0377 | 0.0407 | 0.6797 |
| 2** | 0 | 33 | 141 | N/A | 0.0363 | N/A |
| 3 | 39 | 53 | 302 | 0.0629 | 0.042 | <0.001* |

*post-SDNN decreased from pre-SDNN and $p$ value <.05
**SI not valid for data analysis

Table C.25. *Pre and Post Stressful Incident MIBI for Participant #4 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI $p$ value |
|---|---|---|---|---|---|---|
| 1 | 32 | 27 | 388 | 0.7891 | 0.772 | 0.1026 |
| 2 | 0 | 33 | 141 | N/A | 0.7841 | N/A |
| 3 | 39 | 53 | 302 | 0.7657 | 0.781 | 0.1914 |

*post-MIBI decreased from pre-MIBI and $p$ value <.05
**SI not valid for data analysis

Table C.26. *Pre and Post Stressful Incident RMSSD for Participant #5 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD $p$ value |
|---|---|---|---|---|---|---|
| 1 | 95 | 78 | 489 | 0.0584 | 0.0484 | 0.4408 |
| 2 | 79 | 73 | 18 | 0.0619 | 0.0547 | 0.3905 |
| 3 | 73 | 64 | 18 | 0.0628 | 0.0597 | 0.2499 |
| 4 | 18 | 85 | 72 | 0.078 | 0.0611 | 0.4307 |
| 5 | 39 | 137 | 161 | 0.0682 | 0.0357 | <0.001* |
| 6 | 39 | 129 | 37 | 0.0682 | 0.0454 | 0.0765 |
| 7 | 22 | 92 | 58 | 0.038 | 0.0543 | 0.3031 |
| 8** | 0 | 57 | 69 | N/A | 0.0653 | N/A |
| 9** | 0 | 60 | 37 | N/A | 0.0751 | N/A |
| 10** | 0 | 66 | 19 | N/A | 0.0744 | N/A |
| 11** | 0 | 56 | 19 | N/A | 0.0724 | N/A |
| 12** | 0 | 63 | 33 | N/A | 0.0851 | N/A |
| 13** | 0 | 89 | 109 | N/A | 0.0527 | N/A |
| 14** | 0 | 98 | 29 | N/A | 0.0497 | N/A |
| 15** | 0 | 76 | 81 | N/A | 0.0549 | N/A |
| 16** | 0 | 51 | 83 | N/A | 0.0697 | N/A |
| 17** | 0 | 108 | 105 | N/A | 0.0675 | N/A |

*post-RMSSD decreased from pre-RMSSD and $p$ value <.05
**SI not valid for data analysis

Table C.27. *Pre and Post Stressful Incident SDNN for Participant #5 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-$p$ value |
|---|---|---|---|---|---|---|
| 1 | 95 | 78 | 489 | 0.0462 | 0.0401 | 0.1961 |
| 2 | 79 | 73 | 18 | 0.0494 | 0.0425 | 0.1978 |
| 3 | 73 | 64 | 18 | 0.0493 | 0.0475 | 0.7557 |
| 4 | 18 | 85 | 72 | 0.0502 | 0.0461 | 0.6474 |
| 5 | 39 | 137 | 161 | 0.0507 | 0.0364 | $<0.001^{*}$ |
| 6 | 39 | 129 | 37 | 0.0507 | 0.0539 | 0.6398 |
| 7 | 22 | 92 | 58 | 0.036 | 0.0627 | $<0.001$ |
| 8** | 0 | 57 | 69 | N/A | 0.0573 | N/A |
| 9** | 0 | 60 | 37 | N/A | 0.0565 | N/A |
| 10** | 0 | 66 | 19 | N/A | 0.0544 | N/A |
| 11** | 0 | 56 | 19 | N/A | 0.0517 | N/A |
| 12** | 0 | 63 | 33 | N/A | 0.0572 | N/A |
| 13** | 0 | 89 | 109 | N/A | 0.0473 | N/A |
| 14** | 0 | 98 | 29 | N/A | 0.0457 | N/A |
| 15** | 0 | 76 | 81 | N/A | 0.0499 | N/A |
| 16** | 0 | 51 | 83 | N/A | 0.0589 | N/A |
| 17** | 0 | 108 | 105 | N/A | 0.0498 | N/A |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.28. *Pre and Post Stressful Incident MIBI for Participant #5 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 95 | 78 | 489 | 0.6959 | 0.7058 | 0.1356 |
| 2 | 79 | 73 | 18 | 0.698 | 0.7049 | 0.3596 |
| 3 | 73 | 64 | 18 | 0.701 | 0.7012 | 0.982 |
| 4 | 18 | 85 | 72 | 0.6841 | 0.7043 | 0.1288 |
| 5 | 39 | 137 | 161 | 0.7112 | 0.729 | 0.045 |
| 6 | 39 | 129 | 37 | 0.7112 | 0.7353 | 0.0127 |
| 7 | 22 | 92 | 58 | 0.7273 | 0.74 | 0.2129 |
| 8** | 0 | 57 | 69 | N/A | 0.7308 | N/A |
| 9** | 0 | 60 | 37 | N/A | 0.7076 | N/A |
| 10** | 0 | 66 | 19 | N/A | 0.7086 | N/A |
| 11** | 0 | 56 | 19 | N/A | 0.709 | N/A |
| 12** | 0 | 63 | 33 | N/A | 0.7158 | N/A |
| 13** | 0 | 89 | 109 | N/A | 0.7102 | N/A |
| 14** | 0 | 98 | 29 | N/A | 0.71 | N/A |
| 15** | 0 | 76 | 81 | N/A | 0.7052 | N/A |
| 16** | 0 | 51 | 83 | N/A | 0.7041 | N/A |
| 17** | 0 | 108 | 105 | N/A | 0.6668 | N/A |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.29. *Pre and Post Stressful Incident RMSSD for Participant #5 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 20 | 101 | 120 | 0.0292 | 0.0522 | 0.0172 |
| 2 | 62 | 75 | 334 | 0.0832 | 0.0532 | <0.001* |
| 3 | 31 | 66 | 24 | 0.0789 | 0.051 | <0.001* |
| 4 | 30 | 52 | 22 | 0.0711 | 0.0278 | <0.001* |
| 5 | 27 | 52 | 12 | 0.0714 | 0.0278 | <0.001* |
| 6** | 6 | 46 | 30 | 0.1048 | 0.0266 | <0.001* |
| 7 | 18 | 100 | 160 | 0.0271 | 0.0552 | 0.0343 |
| 8 | 18 | 88 | 51 | 0.0271 | 0.0579 | 0.0155 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.30. *Pre and Post Stressful Incident SDNN for Participant #5 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 20 | 101 | 120 | 0.0227 | 0.0396 | <0.001 |
| 2 | 62 | 75 | 334 | 0.0561 | 0.0463 | 0.1165 |
| 3 | 31 | 66 | 24 | 0.0555 | 0.0436 | 0.116 |
| 4 | 30 | 52 | 22 | 0.0476 | 0.0289 | <0.001* |
| 5 | 27 | 52 | 12 | 0.0428 | 0.0289 | 0.0176* |
| 6** | 6 | 46 | 30 | 0.0644 | 0.0365 | 0.0557 |
| 7 | 18 | 100 | 160 | 0.0253 | 0.0562 | <0.001 |
| 8 | 18 | 88 | 51 | 0.0253 | 0.0538 | <0.001 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.31. *Pre and Post Stressful Incident MIBI for Participant #5 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 20 | 101 | 120 | 0.661 | 0.6963 | <0.001 |
| 2 | 62 | 75 | 334 | 0.685 | 0.6838 | 0.8904 |
| 3 | 31 | 66 | 24 | 0.6981 | 0.6901 | 0.4845 |
| 4 | 30 | 52 | 22 | 0.6927 | 0.6869 | 0.5467 |
| 5 | 27 | 52 | 12 | 0.6852 | 0.6869 | 0.8526 |
| 6** | 6 | 46 | 30 | 0.6745 | 0.6688 | 0.8405 |
| 7 | 18 | 100 | 160 | 0.6068 | 0.6986 | <0.001 |
| 8 | 18 | 88 | 51 | 0.6068 | 0.7067 | <0.001 |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.32. *Pre and Post Stressful Incident RMSSD for Participant #6 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 35 | 113 | 115 | 0.0814 | 0.0479 | <0.001* |
| 2 | 35 | 91 | 87 | 0.0814 | 0.0471 | <0.001* |
| 3 | 38 | 96 | 345 | 0.0631 | 0.0462 | 0.0357* |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.33. *Pre and Post Stressful Incident SDNN for Participant #6 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 35 | 113 | 115 | 0.0564 | 0.0362 | <0.001* |
| 2 | 35 | 91 | 87 | 0.0564 | 0.0377 | <0.001* |
| 3 | 38 | 96 | 345 | 0.0475 | 0.0383 | 0.1075 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.34. *Pre and Post Stressful Incident MIBI for Participant #6 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 35 | 113 | 115 | 0.6915 | 0.6586 | <0.001* |
| 2 | 35 | 91 | 87 | 0.6915 | 0.6693 | 0.0365* |
| 3 | 38 | 96 | 345 | 0.6797 | 0.6931 | 0.1277 |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.35. *Pre and Post Stressful Incident RMSSD for Participant #6 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 174 | 127 | 245 | 0.0254 | 0.0316 | 0.3537 |
| 2 | 136 | 130 | 26 | 0.0263 | 0.0385 | 0.2186 |
| 3 | 46 | 163 | 151 | 0.0341 | 0.0277 | <0.001* |
| 4 | 46 | 150 | 9 | 0.0341 | 0.0278 | <0.001* |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.36. *Pre and Post Stressful Incident SDNN for Participant #6 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 174 | 127 | 245 | 0.0329 | 0.0369 | 0.1734 |
| 2 | 136 | 130 | 26 | 0.0346 | 0.0383 | 0.2436 |
| 3 | 46 | 163 | 151 | 0.0283 | 0.0304 | 0.5555 |
| 4 | 46 | 150 | 9 | 0.0283 | 0.0312 | 0.431 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.37. *Pre and Post Stressful Incident MIBI for Participant #6 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 174 | 127 | 245 | 0.6661 | 0.672 | 0.1487 |
| 2 | 136 | 130 | 26 | 0.6651 | 0.6715 | 0.1538 |
| 3 | 46 | 163 | 151 | 0.6797 | 0.648 | <0.001* |
| 4 | 46 | 150 | 9 | 0.6797 | 0.6473 | <0.001* |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.38. *Pre and Post Stressful Incident RMSSD for Participant #7 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 96 | 76 | 371 | 0.0589 | 0.0661 | 0.1564 |
| 2 | 35 | 50 | 653 | 0.0886 | 0.0858 | 0.1294 |
| 3 | 16 | 66 | 147 | 0.0994 | 0.0836 | 0.0205* |
| 4 | 86 | 93 | 237 | 0.0631 | 0.063 | 0.0574 |
| 5** | 0 | 88 | 116 | N/A | 0.0622 | N/A |

*post-RMSSD decreased from pre-RMSSD and *p* value $<.05$
**SI not valid for data analysis

Table C.39. *Pre and Post Stressful Incident SDNN for Participant #7 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 96 | 76 | 371 | 0.0745 | 0.0745 | 0.9986 |
| 2 | 35 | 50 | 653 | 0.0883 | 0.0887 | 0.9794 |
| 3 | 16 | 66 | 147 | 0.0612 | 0.0902 | 0.0811 |
| 4 | 86 | 93 | 237 | 0.1033 | 0.0584 | <0.001* |
| 5** | 0 | 88 | 116 | N/A | 0.0629 | N/A |

*post-SDNN decreased from pre-SDNN and *p* value $<.05$
**SI not valid for data analysis

Table C.40. *Pre and Post Stressful Incident MIBI for Participant #7 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 96 | 76 | 371 | 0.7121 | 0.7377 | 0.0266 |
| 2 | 35 | 50 | 653 | 0.7282 | 0.731 | 0.8857 |
| 3 | 16 | 66 | 147 | 0.7168 | 0.7354 | 0.334 |
| 4 | 86 | 93 | 237 | 0.6937 | 0.7272 | <0.001 |
| 5** | 0 | 88 | 116 | N/A | 0.6856 | N/A |

*post-MIBI decreased from pre-MIBI and *p* value $<.05$
**SI not valid for data analysis

Table C.41. *Pre and Post Stressful Incident RMSSD for Participant #7 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 19 | 35 | 174 | 0.0875 | 0.0816 | 0.2958 |
| 2 | 19 | 26 | 21 | 0.0875 | 0.0817 | 0.3603 |
| 3** | 0 | 63 | 101 | N/A | 0.0501 | N/A |
| 4 | 59 | 72 | 343 | 0.0658 | 0.0446 | 0.1614 |
| 5 | 14 | 48 | 154 | 0.0779 | 0.0793 | 0.4731 |
| 6 | 14 | 24 | 55 | 0.0779 | 0.0852 | 0.4939 |
| 7** | 5 | 59 | 40 | 0.0983 | 0.0573 | 0.3671 |
| 8** | 0 | 54 | 85 | N/A | 0.0472 | N/A |
| 9** | 4 | 87 | 152 | 0.0677 | 0.0519 | 0.1138 |
| 10** | 1 | 52 | 125 | 0.0781 | 0.0589 | 0.1249 |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.42. *Pre and Post Stressful Incident SDNN for Participant #7 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 19 | 35 | 174 | 0.0618 | 0.0554 | 0.5959 |
| 2 | 19 | 26 | 21 | 0.0618 | 0.0549 | 0.5954 |
| 3** | 0 | 63 | 101 | N/A | 0.0608 | N/A |
| 4 | 59 | 72 | 343 | 0.0585 | 0.0428 | 0.0125* |
| 5 | 14 | 48 | 154 | 0.0589 | 0.0707 | 0.4337 |
| 6 | 14 | 24 | 55 | 0.0589 | 0.0856 | 0.1517 |
| 7** | 5 | 59 | 40 | 0.0849 | 0.0716 | 0.6396 |
| 8** | 0 | 54 | 85 | N/A | 0.054 | N/A |
| 9** | 4 | 87 | 152 | 0.0727 | 0.0699 | 0.9276 |
| 10** | 1 | 52 | 125 | N/A | 0.0799 | N/A |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.43. *Pre and Post Stressful Incident MIBI for Participant #7 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI $p$ value |
|---|---|---|---|---|---|---|
| 1 | 19 | 35 | 174 | 0.6908 | 0.7107 | 0.2488 |
| 2 | 19 | 26 | 21 | 0.6908 | 0.7146 | 0.1904 |
| 3** | 0 | 63 | 101 | N/A | 0.7158 | N/A |
| 4 | 59 | 72 | 343 | 0.7265 | 0.7101 | 0.0761 |
| 5 | 14 | 48 | 154 | 0.7824 | 0.6892 | <0.001* |
| 6 | 14 | 24 | 55 | 0.7824 | 0.7019 | <0.001* |
| 7** | 5 | 59 | 40 | 0.7969 | 0.7185 | 0.1075 |
| 8** | 0 | 54 | 85 | N/A | 0.7049 | N/A |
| 9** | 4 | 87 | 152 | 0.7578 | 0.7129 | 0.3061 |
| 10** | 1 | 52 | 125 | 0.7188 | 0.7164 | N/A |

*post-MIBI decreased from pre-MIBI and $p$ value $<.05$
**SI not valid for data analysis

Table C.44. *Pre and Post Stressful Incident RMSSD for Participant #8 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD $p$ value |
|---|---|---|---|---|---|---|
| 1 | 45 | 39 | 1430 | 0.0884 | 0.1032 | 0.1694 |
| 2 | 17 | 12 | 205 | 0.098 | 0.0876 | 0.4207 |
| 3 | 20 | 19 | 371 | 0.0601 | 0.0701 | 0.4719 |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.45. *Pre and Post Stressful Incident SDNN for Participant #8 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-$p$ value |
|---|---|---|---|---|---|---|
| 1 | 45 | 39 | 1430 | 0.0672 | 0.0817 | 0.2169 |
| 2 | 17 | 12 | 205 | 0.0875 | 0.0638 | 0.2768 |
| 3 | 20 | 19 | 371 | 0.0494 | 0.0714 | 0.1208 |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.46. *Pre and Post Stressful Incident MIBI for Participant #8 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 45 | 39 | 1430 | 0.8948 | 0.9143 | 0.2411 |
| 2 | 17 | 12 | 205 | 0.8962 | 0.8412 | 0.0609 |
| 3 | 20 | 19 | 371 | 0.7985 | 0.8578 | <0.001 |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.47. *Pre and Post Stressful Incident RMSSD for Participant #8 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 48 | 69 | 247 | 0.1034 | 0.0897 | 0.2773 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.48. *Pre and Post Stressful Incident SDNN for Participant #8 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 48 | 69 | 247 | 0.0815 | 0.0681 | 0.1769 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.49. *Pre and Post Stressful Incident MIBI for Participant #8 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 48 | 69 | 247 | 0.8451 | 0.8148 | 0.0375* |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.50. *Pre and Post Stressful Incident RMSSD for Participant #9 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 13 | 33 | 489 | 0.054 | 0.1072 | 0.0251 |
| 2** | 4 | 55 | 161 | 0.0469 | 0.0661 | 0.2031 |
| 3** | 4 | 54 | 100 | 0.0469 | 0.0884 | 0.1214 |
| 4** | 0 | 73 | 109 | N/A | 0.1012 | N/A |
| 5** | 5 | 39 | 138 | 0.0719 | 0.0688 | 0.2583 |
| 6 | 17 | 39 | 193 | 0.1479 | 0.1123 | <0.001* |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.51. *Pre and Post Stressful Incident SDNN for Participant #9 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 13 | 33 | 489 | 0.0659 | 0.0925 | 0.1873 |
| 2** | 4 | 55 | 161 | 0.0413 | 0.0913 | 0.1489 |
| 3** | 4 | 54 | 100 | 0.0413 | 0.1158 | 0.076 |
| 4** | 0 | 73 | 109 | N/A | 0.0966 | N/A |
| 5** | 5 | 39 | 138 | 0.0373 | 0.091 | 0.0658 |
| 6 | 17 | 39 | 193 | 0.1365 | 0.0826 | 0.0133* |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.52. *Pre and Post Stressful Incident MIBI for Participant #9 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 13 | 33 | 489 | 0.7116 | 0.7581 | 0.0654 |
| 2** | 4 | 55 | 161 | 0.7266 | 0.7841 | 0.058 |
| 3** | 4 | 54 | 100 | 0.7266 | 0.8328 | <0.001 |
| 4** | 0 | 73 | 109 | N/A | 0.832 | N/A |
| 5** | 5 | 39 | 138 | 0.8469 | 0.8153 | 0.1802 |
| 6 | 17 | 39 | 193 | 0.6912 | 0.7364 | 0.2185 |

*post-MIBI decreased from pre-MIBI and $p$ value $<.05$
**SI not valid for data analysis

Table C.53. *Pre and Post Stressful Incident RMSSD for Participant #9 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 105 | 14 | 263 | 0.1061 | 0.088 | 0.4687 |
| 2 | 52 | 45 | 252 | 0.09 | 0.0962 | 0.3452 |
| 3 | 15 | 33 | 139 | 0.1013 | 0.0983 | 0.1804 |
| 4 | 19 | 10 | 215 | 0.1009 | 0.1002 | 0.4361 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.54. *Pre and Post Stressful Incident SDNN for Participant #9 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 105 | 14 | 263 | 0.1073 | 0.072 | 0.0877 |
| 2 | 52 | 45 | 252 | 0.0829 | 0.103 | 0.1378 |
| 3 | 15 | 33 | 139 | 0.0798 | 0.1148 | 0.1342 |
| 4 | 19 | 10 | 215 | 0.1026 | 0.0925 | 0.7298 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.55. *Pre and Post Stressful Incident MIBI for Participant #9 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 105 | 14 | 263 | 0.8488 | 0.7846 | <0.001* |
| 2 | 52 | 45 | 252 | 0.9015 | 0.8646 | 0.0579 |
| 3 | 15 | 33 | 139 | 0.9167 | 0.8201 | <0.001* |
| 4 | 19 | 10 | 215 | 0.8709 | 0.8625 | 0.8255 |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.56. *Pre and Post Stressful Incident RMSSD for Participant #10 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 64 | 91 | 794 | 0.0616 | 0.0866 | <0.001 |
| 2 | 56 | 80 | 183 | 0.0592 | 0.0623 | 0.4585 |
| 3 | 49 | 95 | 204 | 0.0877 | 0.0526 | <0.001* |
| 4 | 102 | 67 | 324 | 0.0649 | 0.048 | <0.001* |
| 5 | 44 | 67 | 69 | 0.0697 | 0.0407 | <0.001* |
| 6 | 36 | 67 | 165 | 0.0477 | 0.0511 | 0.4066 |
| 7 | 12 | 73 | 103 | 0.0541 | 0.0657 | 0.4371 |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.57. *Pre and Post Stressful Incident SDNN for Participant #10 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 64 | 91 | 794 | 0.0555 | 0.0621 | 0.3439 |
| 2 | 56 | 80 | 183 | 0.0503 | 0.0569 | 0.3282 |
| 3 | 49 | 95 | 204 | 0.0586 | 0.0381 | <0.001* |
| 4 | 102 | 67 | 324 | 0.0577 | 0.0599 | 0.7411 |
| 5 | 44 | 67 | 69 | 0.0587 | 0.0331 | <0.001* |
| 6 | 36 | 67 | 165 | 0.0343 | 0.0408 | 0.2484 |
| 7 | 12 | 73 | 103 | 0.0413 | 0.056 | 0.226 |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.58. *Pre and Post Stressful Incident MIBI for Participant #10 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 64 | 91 | 794 | 0.7635 | 0.7706 | 0.4519 |
| 2 | 56 | 80 | 183 | 0.7601 | 0.7463 | 0.1399 |
| 3 | 49 | 95 | 204 | 0.7832 | 0.7634 | 0.0353* |
| 4 | 102 | 67 | 324 | 0.7404 | 0.7722 | <0.001 |
| 5 | 44 | 67 | 69 | 0.7504 | 0.7678 | 0.0792 |
| 6 | 36 | 67 | 165 | 0.7947 | 0.7589 | <0.001* |
| 7 | 12 | 73 | 103 | 0.8047 | 0.743 | <0.001* |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.59. *Pre and Post Stressful Incident RMSSD for Participant #10 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 24 | 14 | 508 | 0.0964 | 0.0582 | 0.0108* |
| 2 | 91 | 53 | 255 | 0.0571 | 0.0792 | 0.0127 |
| 3 | 46 | 25 | 217 | 0.0608 | 0.092 | 0.4663 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.60. *Pre and Post Stressful Incident SDNN for Participant #10 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 24 | 14 | 508 | 0.0859 | 0.0791 | 0.742 |
| 2 | 91 | 53 | 255 | 0.053 | 0.0849 | <0.001 |
| 3 | 46 | 25 | 217 | 0.0491 | 0.0558 | 0.4755 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.61. *Pre and Post Stressful Incident MIBI for Participant #10 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 24 | 14 | 508 | 0.7702 | 0.7668 | 0.9011 |
| 2 | 91 | 53 | 255 | 0.7883 | 0.745 | <0.001* |
| 3 | 46 | 25 | 217 | 0.7809 | 0.7907 | 0.4691 |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.62. *Pre and Post Stressful Incident RMSSD for Participant #11 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 68 | 55 | 357 | 0.1411 | 0.0666 | 0.1005 |
| 2** | 5 | 26 | 1033 | 0.1098 | 0.038 | <0.001* |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.63. *Pre and Post Stressful Incident SDNN for Participant #11 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 68 | 55 | 357 | 0.1116 | 0.0637 | <0.001* |
| 2** | 5 | 26 | 1033 | 0.0615 | 0.0428 | 0.3187 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.64. *Pre and Post Stressful Incident MIBI for Participant #11 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 68 | 55 | 357 | 0.7512 | 0.7208 | 0.0603 |
| 2** | 5 | 26 | 1033 | 0.7188 | 0.6539 | 0.0762 |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.65. *Pre and Post Stressful Incident RMSSD for Participant #11 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 24 | 14 | 508 | 0.0964 | 0.0582 | 0.0108* |
| 2 | 91 | 53 | 255 | 0.0571 | 0.0792 | 0.0127 |
| 3 | 46 | 25 | 217 | 0.0608 | 0.092 | 0.4663 |
| 4** | 60 | 2 | 477 | 0.0563 | 0.011 | 0.0359* |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.66. *Pre and Post Stressful Incident SDNN for Participant #11 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 24 | 14 | 508 | 0.0859 | 0.0791 | 0.742 |
| 2 | 91 | 53 | 255 | 0.053 | 0.0849 | <0.001 |
| 3 | 46 | 25 | 217 | 0.0491 | 0.0558 | 0.4755 |
| 4** | 60 | 2 | 477 | 0.0554 | 0.0 | <0.001* |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.67. *Pre and Post Stressful Incident MIBI for Participant #11 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 24 | 14 | 508 | 0.7702 | 0.7668 | 0.9011 |
| 2 | 91 | 53 | 255 | 0.7883 | 0.745 | <0.001* |
| 3 | 46 | 25 | 217 | 0.7809 | 0.7907 | 0.4691 |
| 4** | 60 | 2 | 477 | 0.7805 | 0.7657 | 0.0425* |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.68. *Pre and Post Stressful Incident RMSSD for Participant #12 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 53 | 45 | N/A | 0.0386 | N/A |
| 2** | 0 | 61 | 100 | N/A | 0.0441 | N/A |
| 3** | 0 | 89 | 56 | N/A | 0.0377 | N/A |
| 4** | 0 | 99 | 40 | N/A | 0.0456 | N/A |
| 5 | 14 | 50 | 139 | 0.024 | 0.0539 | <0.001 |
| 6 | 14 | 47 | 92 | 0.024 | 0.0598 | <0.001 |
| 7** | 0 | 39 | 44 | N/A | 0.0725 | N/A |
| 8** | 0 | 43 | 2 | N/A | 0.0711 | N/A |
| 9 | 15 | 115 | 160 | 0.0361 | 0.0422 | 0.4518 |
| 10** | 0 | 134 | 92 | N/A | 0.0589 | N/A |
| 11** | 0 | 141 | 102 | N/A | 0.043 | N/A |
| 12** | 0 | 159 | 44 | N/A | 0.0349 | N/A |
| 13** | 0 | 88 | 74 | N/A | 0.0351 | N/A |
| 14** | 0 | 51 | 24 | N/A | 0.0357 | N/A |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.69. *Pre and Post Stressful Incident SDNN for Participant #12 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 53 | 45 | N/A | 0.0304 | N/A |
| 2** | 0 | 61 | 100 | N/A | 0.0351 | N/A |
| 3** | 0 | 89 | 56 | N/A | 0.0346 | N/A |
| 4** | 0 | 99 | 40 | N/A | 0.0454 | N/A |
| 5 | 14 | 50 | 139 | 0.0148 | 0.0406 | <0.001 |
| 6 | 14 | 47 | 92 | 0.0148 | 0.0442 | <0.001 |
| 7** | 0 | 39 | 44 | N/A | 0.0592 | N/A |
| 8** | 0 | 43 | 2 | N/A | 0.0575 | N/A |
| 9 | 15 | 115 | 160 | 0.0289 | 0.0428 | 0.0784 |
| 10** | 0 | 134 | 92 | N/A | 0.0437 | N/A |
| 11** | 0 | 141 | 102 | N/A | 0.0366 | N/A |
| 12** | 0 | 159 | 44 | N/A | 0.0347 | N/A |
| 13** | 0 | 88 | 74 | N/A | 0.0362 | N/A |
| 14** | 0 | 51 | 24 | N/A | 0.0377 | N/A |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.70. *Pre and Post Stressful Incident MIBI for Participant #12 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 53 | 45 | N/A | 0.6218 | N/A |
| 2** | 0 | 61 | 100 | N/A | 0.6156 | N/A |
| 3** | 0 | 89 | 56 | N/A | 0.5985 | N/A |
| 4** | 0 | 99 | 40 | N/A | 0.6061 | N/A |
| 5 | 14 | 50 | 139 | 0.5648 | 0.5982 | <0.001 |
| 6 | 14 | 47 | 92 | 0.5648 | 0.6014 | <0.001 |
| 7** | 0 | 39 | 44 | N/A | 0.6142 | N/A |
| 8** | 0 | 43 | 2 | N/A | 0.6138 | N/A |
| 9 | 15 | 115 | 160 | 0.6386 | 0.636 | 0.7668 |
| 10** | 0 | 134 | 92 | N/A | 0.6356 | N/A |
| 11** | 0 | 141 | 102 | N/A | 0.6507 | N/A |
| 12** | 0 | 159 | 44 | N/A | 0.6475 | N/A |
| 13** | 0 | 88 | 74 | N/A | 0.6385 | N/A |
| 14** | 0 | 51 | 24 | N/A | 0.6296 | N/A |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.71. *Pre and Post Stressful Incident RMSSD for Participant #12 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 109 | 112 | 346 | 0.0514 | 0.0416 | <0.001* |
| 2 | 103 | 35 | 227 | 0.0401 | 0.0887 | <0.001 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.72. *Pre and Post Stressful Incident SDNN for Participant #12 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 109 | 112 | 346 | 0.0433 | 0.0481 | 0.2803 |
| 2 | 103 | 35 | 227 | 0.0381 | 0.0597 | <0.001 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.73. *Pre and Post Stressful Incident MIBI for Participant #12 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI $p$ value |
|---|---|---|---|---|---|---|
| 1 | 109 | 112 | 346 | 0.5976 | 0.6179 | <0.001 |
| 2 | 103 | 35 | 227 | 0.6061 | 0.6447 | <0.001 |

*post-MIBI decreased from pre-MIBI and $p$ value $<.05$
**SI not valid for data analysis

Table C.74. *Pre and Post Stressful Incident RMSSD for Participant #13 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD $p$ value |
|---|---|---|---|---|---|---|
| 1 | 37 | 48 | 1016 | 0.0814 | 0.0717 | 0.1284 |
| 2 | 32 | 80 | 197 | 0.0532 | 0.0617 | 0.2141 |
| 3 | 105 | 60 | 791 | 0.0645 | 0.0572 | 0.1094 |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.75. *Pre and Post Stressful Incident SDNN for Participant #13 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-$p$ value |
|---|---|---|---|---|---|---|
| 1 | 37 | 48 | 1016 | 0.0634 | 0.0698 | 0.5439 |
| 2 | 32 | 80 | 197 | 0.0361 | 0.0771 | <0.001 |
| 3 | 105 | 60 | 791 | 0.0567 | 0.0457 | 0.0684 |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.76. *Pre and Post Stressful Incident MIBI for Participant #13 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 37 | 48 | 1016 | 0.7893 | 0.8177 | 0.0534 |
| 2 | 32 | 80 | 197 | 0.7554 | 0.7616 | 0.5673 |
| 3 | 105 | 60 | 791 | 0.8088 | 0.7748 | <0.001* |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.77. *Pre and Post Stressful Incident RMSSD for Participant #13 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 18 | 73 | 119 | 0.0442 | 0.0773 | 0.1097 |
| 2 | 93 | 73 | 741 | 0.0627 | 0.0936 | <0.001 |
| 3 | 22 | 90 | 82 | 0.0914 | 0.0529 | 0.0501 |
| 4 | 54 | 27 | 420 | 0.0592 | 0.0696 | 0.3293 |
| 5** | 36 | 7 | 200 | 0.0975 | 0.0663 | 0.3646 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.78. *Pre and Post Stressful Incident SDNN for Participant #13 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 18 | 73 | 119 | 0.0328 | 0.0791 | <0.001 |
| 2 | 93 | 73 | 741 | 0.0714 | 0.0664 | 0.5219 |
| 3 | 22 | 90 | 82 | 0.1114 | 0.049 | <0.001* |
| 4 | 54 | 27 | 420 | 0.0911 | 0.0459 | <0.001* |
| 5** | 36 | 7 | 200 | 0.0937 | 0.0466 | 0.0651 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.79. *Pre and Post Stressful Incident MIBI for Participant #13 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 18 | 73 | 119 | 0.7691 | 0.8048 | <0.001 |
| 2 | 93 | 73 | 741 | 0.7771 | 0.8466 | <0.001 |
| 3 | 22 | 90 | 82 | 0.7472 | 0.8568 | <0.001 |
| 4 | 54 | 27 | 420 | 0.7972 | 0.8496 | <0.001 |
| 5** | 36 | 7 | 200 | 0.7704 | 0.8081 | 0.1281 |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.80. *Pre and Post Stressful Incident RMSSD for Participant #14 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1** | 3 | 37 | 275 | 0.0128 | 0.0704 | 0.023 |
| 2 | 58 | 47 | 288 | 0.1265 | 0.1075 | 0.2732 |
| 3** | 5 | 39 | 125 | 0.0749 | 0.1181 | 0.2351 |
| 4 | 17 | 34 | 177 | 0.0995 | 0.1069 | 0.1037 |
| 5** | 2 | 56 | 130 | 0.1503 | 0.099 | 0.1244 |
| 6** | 2 | 67 | 66 | 0.1503 | 0.0936 | 0.1115 |
| 7 | 98 | 92 | 232 | 0.0812 | 0.0643 | 0.1796 |
| 8 | 21 | 67 | 101 | 0.082 | 0.0741 | 0.4434 |
| 9** | 0 | 32 | 80 | N/A | 0.0984 | N/A |
| 10** | 0 | 42 | 45 | N/A | 0.103 | N/A |
| 11** | 0 | 39 | 54 | N/A | 0.1092 | N/A |
| 12** | 6 | 68 | 136 | 0.0361 | 0.0592 | 0.2523 |
| 13 | 19 | 34 | 156 | 0.1137 | 0.1011 | 0.2982 |
| 14 | 19 | 29 | 49 | 0.1137 | 0.1197 | 0.0487 |
| 15 | 17 | 43 | 46 | 0.1196 | 0.0868 | 0.5 |
| 16** | 0 | 22 | 48 | N/A | 0.0509 | N/A |
| 17** | 0 | 19 | 29 | N/A | 0.0346 | N/A |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.81. *Pre and Post Stressful Incident SDNN for Participant #14 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1** | 3 | 37 | 275 | 0.0156 | 0.0593 | 0.0865 |
| 2 | 58 | 47 | 288 | 0.0886 | 0.0717 | 0.1386 |
| 3** | 5 | 39 | 125 | 0.0621 | 0.0811 | 0.5214 |
| 4 | 17 | 34 | 177 | 0.063 | 0.0806 | 0.2732 |
| 5** | 2 | 56 | 130 | 0.0442 | 0.0758 | 0.5766 |
| 6** | 2 | 67 | 66 | 0.0442 | 0.0676 | 0.6501 |
| 7 | 98 | 92 | 232 | 0.0672 | 0.0541 | 0.0374* |
| 8 | 21 | 67 | 101 | 0.0622 | 0.0754 | 0.3084 |
| 9** | 0 | 32 | 80 | N/A | 0.0655 | N/A |
| 10** | 0 | 42 | 45 | N/A | 0.0725 | N/A |
| 11** | 0 | 39 | 54 | N/A | 0.082 | N/A |
| 12** | 6 | 68 | 136 | 0.0307 | 0.0479 | 0.2457 |
| 13 | 19 | 34 | 156 | 0.0672 | 0.0817 | 0.3611 |
| 14 | 19 | 29 | 49 | 0.0672 | 0.0805 | 0.4115 |
| 15 | 17 | 43 | 46 | 0.0707 | 0.0649 | 0.679 |
| 16** | 0 | 22 | 48 | N/A | 0.0374 | N/A |
| 17** | 0 | 19 | 29 | N/A | 0.03 | N/A |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$

**SI not valid for data analysis

Table C.82. *Pre and Post Stressful Incident MIBI for Participant #14 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1** | 3 | 37 | 275 | 0.8438 | 0.851 | 0.6025 |
| 2 | 58 | 47 | 288 | 0.8338 | 0.8843 | <0.001 |
| 3** | 5 | 39 | 125 | 0.8844 | 0.8598 | 0.4534 |
| 4 | 17 | 34 | 177 | 0.842 | 0.8332 | 0.6738 |
| 5** | 2 | 56 | 130 | 0.8282 | 0.8823 | 0.3125 |
| 6** | 2 | 67 | 66 | 0.8282 | 0.8734 | 0.3729 |
| 7 | 98 | 92 | 232 | 0.8734 | 0.9037 | <0.001 |
| 8 | 21 | 67 | 101 | 0.8847 | 0.9079 | 0.1648 |
| 9** | 0 | 32 | 80 | N/A | 0.898 | N/A |
| 10** | 0 | 42 | 45 | N/A | 0.8899 | N/A |
| 11** | 0 | 39 | 54 | N/A | 0.8915 | N/A |
| 12** | 6 | 68 | 136 | 0.849 | 0.8691 | 0.1879 |
| 13 | 19 | 34 | 156 | 0.8602 | 0.8668 | 0.7554 |
| 14 | 19 | 29 | 49 | 0.8602 | 0.9235 | <0.001 |
| 15 | 17 | 43 | 46 | 0.8613 | 0.915 | 0.0114 |
| 16** | 0 | 22 | 48 | N/A | 0.8928 | N/A |
| 17** | 0 | 19 | 29 | N/A | 0.8849 | N/A |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.83. *Pre and Post Stressful Incident RMSSD for Participant #14 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 28 | 25 | N/A | 0.1007 | N/A |
| 2 | 10 | 85 | 136 | 0.0657 | 0.074 | 0.483 |
| 3** | 4 | 98 | 110 | 0.0366 | 0.1004 | 0.0581 |
| 4** | 0 | 77 | 80 | N/A | 0.093 | N/A |
| 5 | 24 | 24 | 159 | 0.0983 | 0.0993 | 0.4141 |
| 6** | 0 | 38 | 123 | N/A | 0.1266 | N/A |
| 7 | 22 | 26 | 192 | 0.1547 | 0.1102 | 0.1431 |
| 8** | 22 | 7 | 41 | 0.1547 | 0.085 | 0.1537 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.84. *Pre and Post Stressful Incident SDNN for Participant #14 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-$p$ value |
|---|---|---|---|---|---|---|
| 1** | 0 | 28 | 25 | N/A | 0.0679 | N/A |
| 2 | 10 | 85 | 136 | 0.0532 | 0.0571 | 0.7857 |
| 3** | 4 | 98 | 110 | 0.0383 | 0.0751 | 0.2035 |
| 4** | 0 | 77 | 80 | N/A | 0.0689 | N/A |
| 5 | 24 | 24 | 159 | 0.0618 | 0.0586 | 0.7991 |
| 6** | 0 | 38 | 123 | N/A | 0.0827 | N/A |
| 7 | 22 | 26 | 192 | 0.0938 | 0.0887 | 0.7919 |
| 8** | 22 | 7 | 41 | 0.0938 | 0.0667 | 0.3442 |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.85. *Pre and Post Stressful Incident MIBI for Participant #14 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI $p$ value |
|---|---|---|---|---|---|---|
| 1** | 0 | 28 | 25 | N/A | 0.9119 | N/A |
| 2 | 10 | 85 | 136 | 0.8688 | 0.9394 | <0.001 |
| 3** | 4 | 98 | 110 | 0.875 | 0.9355 | 0.0424 |
| 4** | 0 | 77 | 80 | N/A | 0.9422 | N/A |
| 5 | 24 | 24 | 159 | 0.9095 | 0.9506 | 0.0226 |
| 6** | 0 | 38 | 123 | N/A | 0.9157 | N/A |
| 7 | 22 | 26 | 192 | 0.9368 | 0.9405 | 0.8892 |
| 8** | 22 | 7 | 41 | 0.9368 | 0.8639 | 0.0394* |

*post-MIBI decreased from pre-MIBI and $p$ value $<.05$
**SI not valid for data analysis

Table C.86. *Pre and Post Stressful Incident RMSSD for Participant #15 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 62 | 49 | 622 | 0.108 | 0.0773 | 0.0151* |
| 2 | 54 | 42 | 462 | 0.1053 | 0.1262 | 0.0812 |
| 3** | 24 | 3 | 85 | 0.1205 | 0.1292 | 0.1671 |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.87. *Pre and Post Stressful Incident SDNN for Participant #15 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 62 | 49 | 622 | 0.1002 | 0.1247 | 0.1092 |
| 2 | 54 | 42 | 462 | 0.1315 | 0.1323 | 0.9687 |
| 3** | 24 | 3 | 85 | 0.1246 | 0.0502 | 0.2022 |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.88. *Pre and Post Stressful Incident MIBI for Participant #15 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 62 | 49 | 622 | 0.9572 | 0.9104 | 0.0354* |
| 2 | 54 | 42 | 462 | 0.9639 | 1.0328 | 0.0129 |
| 3** | 24 | 3 | 85 | 0.9434 | 1.073 | 0.0154 |

*post-MIBI decreased from pre-MIBI and $p$ value $<.05$
**SI not valid for data analysis

Table C.89. *Pre and Post Stressful Incident RMSSD for Participant #15 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 79 | 53 | 657 | 0.0895 | 0.1322 | 0.0144 |
| 2 | 82 | 37 | 229 | 0.112 | 0.1155 | 0.4113 |

*post-RMSSD decreased from pre-RMSSD and $p$ value <.05
**SI not valid for data analysis

Table C.90. *Pre and Post Stressful Incident SDNN for Participant #15 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 79 | 53 | 657 | 0.083 | 0.1073 | 0.0413 |
| 2 | 82 | 37 | 229 | 0.1068 | 0.0999 | 0.6445 |

*post-SDNN decreased from pre-SDNN and $p$ value <.05
**SI not valid for data analysis

Table C.91. *Pre and Post Stressful Incident MIBI for Participant #15 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 79 | 53 | 657 | 0.9474 | 1.0139 | <0.001 |
| 2 | 82 | 37 | 229 | 1.001 | 0.9798 | 0.2972 |

*post-MIBI decreased from pre-MIBI and $p$ value <.05
**SI not valid for data analysis

Table C.92. *Pre and Post Stressful Incident RMSSD for Participant #16 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1** | 29 | 3 | 369 | 0.1093 | 0.0372 | 0.0771 |
| 2** | 4 | 10 | 249 | 0.0957 | 0.0713 | 0.259 |
| 3 | 20 | 48 | 226 | 0.0603 | 0.0647 | 0.4011 |
| 4 | 26 | 22 | 270 | 0.1348 | 0.091 | 0.1725 |
| 5 | 12 | 42 | 176 | 0.14 | 0.0985 | <0.001* |
| 6 | 12 | 44 | 39 | 0.14 | 0.0469 | <0.001* |
| 7 | 31 | 69 | 333 | 0.0448 | 0.0603 | 0.2017 |
| 8 | 46 | 18 | 174 | 0.0423 | 0.054 | 0.0809 |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.93. *Pre and Post Stressful Incident SDNN for Participant #16 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1** | 29 | 3 | 369 | 0.0862 | 0.0239 | 0.0963 |
| 2** | 4 | 10 | 249 | 0.0869 | 0.0773 | 0.8123 |
| 3 | 20 | 48 | 226 | 0.0706 | 0.0713 | 0.9604 |
| 4 | 26 | 22 | 270 | 0.0993 | 0.0807 | 0.3331 |
| 5 | 12 | 42 | 176 | 0.0985 | 0.0623 | 0.0428* |
| 6 | 12 | 44 | 39 | 0.0985 | 0.0593 | 0.0227* |
| 7 | 31 | 69 | 333 | 0.038 | 0.0834 | <0.001 |
| 8 | 46 | 18 | 174 | 0.062 | 0.0577 | 0.7284 |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.94. *Pre and Post Stressful Incident MIBI for Participant #16 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1** | 29 | 3 | 369 | 0.743 | 0.7552 | 0.5761 |
| 2** | 4 | 10 | 249 | 0.7149 | 0.6953 | 0.7112 |
| 3 | 20 | 48 | 226 | 0.7453 | 0.7305 | 0.4362 |
| 4 | 26 | 22 | 270 | 0.7386 | 0.6897 | 0.0659 |
| 5 | 12 | 42 | 176 | 0.8177 | 0.6916 | <0.001* |
| 6 | 12 | 44 | 39 | 0.8177 | 0.7358 | 0.0163* |
| 7 | 31 | 69 | 333 | 0.6996 | 0.7364 | <0.001 |
| 8 | 46 | 18 | 174 | 0.7242 | 0.7188 | 0.7423 |

*post-MIBI decreased from pre-MIBI and $p$ value $<.05$
**SI not valid for data analysis

Table C.95. *Pre and Post Stressful Incident RMSSD for Participant #16 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1** | 18 | 8 | 940 | 0.0752 | 0.0558 | 0.2697 |
| 2 | 30 | 23 | 144 | 0.0594 | 0.0354 | 0.1601 |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.96. *Pre and Post Stressful Incident SDNN for Participant #16 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1** | 18 | 8 | 940 | 0.0641 | 0.0368 | 0.1206 |
| 2 | 30 | 23 | 144 | 0.0761 | 0.0286 | <0.001* |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.97. *Pre and Post Stressful Incident MIBI for Participant #16 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1** | 18 | 8 | 940 | 0.7327 | 0.6582 | <0.001* |
| 2 | 30 | 23 | 144 | 0.7563 | 0.7066 | <0.001* |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.98. *Pre and Post Stressful Incident RMSSD for Participant #17 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 109 | 28 | 554 | 0.0541 | 0.0562 | 0.1413 |
| 2 | 67 | 118 | 232 | 0.0398 | 0.0406 | 0.4378 |
| 3 | 67 | 29 | 256 | 0.0588 | 0.0658 | 0.0589 |
| 4** | 58 | 24 | 8 | 0.061 | 0.0659 | 0.1658 |
| 5** | 32 | 8 | 48 | 0.0569 | 0.0544 | 0.4932 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.99. *Pre and Post Stressful Incident SDNN for Participant #17 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 109 | 28 | 554 | 0.0479 | 0.0711 | <0.001 |
| 2 | 67 | 118 | 232 | 0.0506 | 0.0433 | 0.1467 |
| 3 | 67 | 29 | 256 | 0.0768 | 0.0665 | 0.3823 |
| 4** | 58 | 24 | 8 | 0.0775 | 0.0677 | 0.4522 |
| 5** | 32 | 8 | 48 | 0.0705 | 0.0371 | 0.0659 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.100. *Pre and Post Stressful Incident MIBI for Participant #17 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 109 | 28 | 554 | 0.7787 | 0.7322 | <0.001* |
| 2 | 67 | 118 | 232 | 0.8205 | 0.8377 | 0.0208 |
| 3 | 67 | 29 | 256 | 0.7505 | 0.798 | <0.001 |
| 4** | 58 | 24 | 8 | 0.7417 | 0.7917 | <0.001 |
| 5** | 32 | 8 | 48 | 0.7471 | 0.8164 | <0.001 |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.101. *Pre and Post Stressful Incident RMSSD for Participant #17 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 126 | 125 | 191 | 0.0498 | 0.0454 | 0.4299 |
| 2 | 75 | 126 | 184 | 0.0449 | 0.0476 | 0.0556 |
| 3 | 126 | 37 | 299 | 0.043 | 0.0394 | 0.2891 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.102. *Pre and Post Stressful Incident SDNN for Participant #17 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 126 | 125 | 191 | 0.0579 | 0.0517 | 0.2069 |
| 2 | 75 | 126 | 184 | 0.0609 | 0.0667 | 0.3837 |
| 3 | 126 | 37 | 299 | 0.0502 | 0.0405 | 0.1241 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.103. *Pre and Post Stressful Incident MIBI for Participant #17 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 126 | 125 | 191 | 0.8288 | 0.8202 | 0.2146 |
| 2 | 75 | 126 | 184 | 0.7763 | 0.7818 | 0.5511 |
| 3 | 126 | 37 | 299 | 0.8063 | 0.8117 | 0.5065 |

*post-MIBI decreased from pre-MIBI and *p* value $<.05$
**SI not valid for data analysis

Table C.104. *Pre and Post Stressful Incident RMSSD for Participant #18 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 163 | 124 | 648 | 0.0296 | 0.0336 | 0.1807 |
| 2 | 102 | 119 | 221 | 0.0421 | 0.0443 | 0.2604 |
| 3 | 69 | 146 | 165 | 0.0456 | 0.0325 | 0.1339 |
| 4 | 93 | 149 | 205 | 0.0359 | 0.032 | 0.0899 |
| 5 | 38 | 166 | 86 | 0.0348 | 0.0279 | 0.0271* |
| 6 | 130 | 85 | 210 | 0.0296 | 0.0545 | <0.001 |
| 7 | 118 | 53 | 216 | 0.045 | 0.0317 | 0.4671 |

*post-RMSSD decreased from pre-RMSSD and $p$ value $<.05$
**SI not valid for data analysis

Table C.105. *Pre and Post Stressful Incident SDNN for Participant #18 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 163 | 124 | 648 | 0.0404 | 0.0375 | 0.3754 |
| 2 | 102 | 119 | 221 | 0.0354 | 0.0578 | <0.001 |
| 3 | 69 | 146 | 165 | 0.0466 | 0.0368 | 0.0201* |
| 4 | 93 | 149 | 205 | 0.0368 | 0.0415 | 0.2078 |
| 5 | 38 | 166 | 86 | 0.0299 | 0.032 | 0.6187 |
| 6 | 130 | 85 | 210 | 0.0315 | 0.0498 | <0.001 |
| 7 | 118 | 53 | 216 | 0.041 | 0.0343 | 0.1429 |

*post-SDNN decreased from pre-SDNN and $p$ value $<.05$
**SI not valid for data analysis

Table C.106. *Pre and Post Stressful Incident MIBI for Participant #18 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI $p$ value |
|---|---|---|---|---|---|---|
| 1 | 163 | 124 | 648 | 0.6509 | 0.6809 | <0.001 |
| 2 | 102 | 119 | 221 | 0.6639 | 0.6644 | 0.9397 |
| 3 | 69 | 146 | 165 | 0.6474 | 0.6592 | 0.0691 |
| 4 | 93 | 149 | 205 | 0.6511 | 0.6611 | 0.051 |
| 5 | 38 | 166 | 86 | 0.6555 | 0.6532 | 0.677 |
| 6 | 130 | 85 | 210 | 0.6251 | 0.6511 | <0.001 |
| 7 | 118 | 53 | 216 | 0.6583 | 0.6866 | <0.001 |

*post-MIBI decreased from pre-MIBI and $p$ value <.05
**SI not valid for data analysis

Table C.107. *Pre and Post Stressful Incident RMSSD for Participant #18 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD $p$ value |
|---|---|---|---|---|---|---|
| 1 | 60 | 85 | 325 | 0.0605 | 0.0347 | <0.001* |
| 2 | 150 | 72 | 917 | 0.0397 | 0.0316 | 0.0904 |

*post-RMSSD decreased from pre-RMSSD and $p$ value <.05
**SI not valid for data analysis

Table C.108. *Pre and Post Stressful Incident SDNN for Participant #18 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-$p$ value |
|---|---|---|---|---|---|---|
| 1 | 60 | 85 | 325 | 0.0555 | 0.0313 | <0.001* |
| 2 | 150 | 72 | 917 | 0.0353 | 0.032 | 0.3431 |

*post-SDNN decreased from pre-SDNN and $p$ value <.05
**SI not valid for data analysis

Table C.109. *Pre and Post Stressful Incident MIBI for Participant #18 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 60 | 85 | 325 | 0.6771 | 0.6315 | <0.001* |
| 2 | 150 | 72 | 917 | 0.6412 | 0.6637 | <0.001 |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.110. *Pre and Post Stressful Incident RMSSD for Participant #19 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 28 | 52 | 203 | 0.0508 | 0.0461 | 0.4074 |
| 2** | 8 | 15 | 166 | 0.0303 | 0.0347 | 0.2782 |
| 3** | 7 | 15 | 304 | 0.0187 | 0.0499 | 0.106 |
| 4 | 32 | 37 | 296 | 0.0642 | 0.0383 | 0.126 |
| 5 | 64 | 11 | 278 | 0.0486 | 0.0653 | 0.0144 |
| 6** | 11 | 2 | 178 | 0.0501 | 0.0331 | 0.3447 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.111. *Pre and Post Stressful Incident SDNN for Participant #19 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 28 | 52 | 203 | 0.04 | 0.0318 | 0.1665 |
| 2** | 8 | 15 | 166 | 0.0195 | 0.0252 | 0.4587 |
| 3** | 7 | 15 | 304 | 0.0177 | 0.0315 | 0.1398 |
| 4 | 32 | 37 | 296 | 0.0442 | 0.0492 | 0.5407 |
| 5 | 64 | 11 | 278 | 0.0404 | 0.0416 | 0.9058 |
| 6** | 11 | 2 | 178 | 0.0343 | 0.0331 | 0.9685 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.112. *Pre and Post Stressful Incident MIBI for Participant #19 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 28 | 52 | 203 | 0.6859 | 0.6965 | 0.2278 |
| 2** | 8 | 15 | 166 | 0.6856 | 0.7 | 0.1445 |
| 3** | 7 | 15 | 304 | 0.6808 | 0.6573 | 0.0379* |
| 4 | 32 | 37 | 296 | 0.6968 | 0.693 | 0.7372 |
| 5 | 64 | 11 | 278 | 0.708 | 0.7017 | 0.6486 |
| 6** | 11 | 2 | 178 | 0.6833 | 0.6641 | 0.5581 |

*post-MIBI decreased from pre-MIBI and $p$ value <.05
**SI not valid for data analysis

Table C.113. *Pre and Post Stressful Incident RMSSD for Participant #19 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 54 | 48 | N/A | 0.0399 | N/A |
| 2** | 2 | 4 | 174 | 0.2111 | 0.1395 | 0.3193 |
| 3** | 0 | 0 | 141 | N/A | N/A | N/A |
| 4** | 6 | 1 | 309 | 0.0687 | 0.0 | 0.1565 |
| 5** | 6 | 0 | 46 | 0.0687 | N/A | <0.001 |
| 6** | 0 | 0 | 180 | N/A | N/A | N/A |

*post-RMSSD decreased from pre-RMSSD and $p$ value <.05
**SI not valid for data analysis

Table C.114. *Pre and Post Stressful Incident SDNN for Participant #19 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 54 | 48 | N/A | 0.0296 | N/A |
| 2** | 2 | 4 | 174 | 0.0221 | 0.0346 | 0.6637 |
| 3** | 0 | 0 | 141 | N/A | N/A | N/A |
| 4** | 6 | 1 | 309 | 0.0221 | N/A | N/A |
| 5** | 6 | 0 | 46 | 0.0221 | N/A | N/A |
| 6** | 0 | 0 | 180 | N/A | N/A | N/A |

*post-SDNN decreased from pre-SDNN and $p$ value <.05
**SI not valid for data analysis

Table C.115. *Pre and Post Stressful Incident MIBI for Participant #19 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1** | 0 | 54 | 48 | N/A | 0.6864 | N/A |
| 2** | 2 | 4 | 174 | 0.3438 | 0.668 | <0.001 |
| 3** | 0 | 0 | 141 | N/A | N/A | N/A |
| 4** | 6 | 1 | 309 | 0.6875 | 0.6875 | N/A |
| 5** | 6 | 0 | 46 | 0.6875 | N/A | N/A |
| 6** | 0 | 0 | 180 | N/A | N/A | N/A |

*post-MIBI decreased from pre-MIBI and *p* value <.05
**SI not valid for data analysis

Table C.116. *Pre and Post Stressful Incident RMSSD for Participant #20 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD *p* value |
|---|---|---|---|---|---|---|
| 1 | 13 | 15 | 633 | 0.0923 | 0.0778 | 0.1288 |
| 2 | 11 | 68 | 290 | 0.0745 | 0.0693 | 0.1638 |
| 3 | 19 | 28 | 173 | 0.0862 | 0.0768 | 0.487 |
| 4** | 19 | 7 | 44 | 0.0862 | 0.0498 | 0.2712 |
| 5 | 20 | 26 | 353 | 0.1069 | 0.0885 | 0.1309 |

*post-RMSSD decreased from pre-RMSSD and *p* value <.05
**SI not valid for data analysis

Table C.117. *Pre and Post Stressful Incident SDNN for Participant #20 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-*p* value |
|---|---|---|---|---|---|---|
| 1 | 13 | 15 | 633 | 0.0725 | 0.056 | 0.3615 |
| 2 | 11 | 68 | 290 | 0.0824 | 0.0662 | 0.344 |
| 3 | 19 | 28 | 173 | 0.0691 | 0.0646 | 0.7555 |
| 4** | 19 | 7 | 44 | 0.0691 | 0.0422 | 0.1885 |
| 5 | 20 | 26 | 353 | 0.0748 | 0.0854 | 0.5439 |

*post-SDNN decreased from pre-SDNN and *p* value <.05
**SI not valid for data analysis

Table C.118. *Pre and Post Stressful Incident MIBI for Participant #20 in Quantitative Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI $p$ value |
|---|---|---|---|---|---|---|
| 1 | 13 | 15 | 633 | 0.7308 | 0.7427 | 0.6344 |
| 2 | 11 | 68 | 290 | 0.7074 | 0.7758 | 0.0223 |
| 3 | 19 | 28 | 173 | 0.6818 | 0.7177 | 0.0812 |
| 4** | 19 | 7 | 44 | 0.6818 | 0.7724 | <0.001 |
| 5 | 20 | 26 | 353 | 0.7422 | 0.7494 | 0.762 |

*post-MIBI decreased from pre-MIBI and $p$ value <.05
**SI not valid for data analysis

Table C.119. *Pre and Post Stressful Incident RMSSD for Participant #20 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-RMSSD | Post-RMSSD | RMSSD $p$ value |
|---|---|---|---|---|---|---|
| 1 | 29 | 43 | 134 | 0.0546 | 0.0672 | 0.477 |
| 2 | 52 | 74 | 482 | 0.064 | 0.0703 | 0.2707 |
| 3** | 5 | 144 | 103 | 0.0363 | 0.0625 | 0.4958 |

*post-RMSSD decreased from pre-RMSSD and $p$ value <.05
**SI not valid for data analysis

Table C.120. *Pre and Post Stressful Incident SDNN for Participant #20 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-SDNN | Post-SDNN | SDNN-$p$ value |
|---|---|---|---|---|---|---|
| 1 | 29 | 43 | 134 | 0.0622 | 0.0589 | 0.7533 |
| 2 | 52 | 74 | 482 | 0.0711 | 0.066 | 0.5678 |
| 3** | 5 | 144 | 103 | 0.0178 | 0.0708 | <0.001 |

*post-SDNN decreased from pre-SDNN and $p$ value <.05
**SI not valid for data analysis

Table C.121. *Pre and Post Stressful Incident MIBI for Participant #20 in Verbal Reasoning Section*

| SI# | N(Pre-SI) | N(Post-SI) | Lapse(s) | Pre-MIBI | Post-MIBI | MIBI *p* value |
|---|---|---|---|---|---|---|
| 1 | 29 | 43 | 134 | 0.7899 | 0.7929 | 0.8378 |
| 2 | 52 | 74 | 482 | 0.8008 | 0.7937 | 0.5725 |
| 3** | 5 | 144 | 103 | 0.775 | 0.7703 | 0.6455 |

*post-MIBI decreased from pre-MIBI and *p* value $<.05$
**SI not valid for data analysis