SUBJECTIVE AND OBJECTIVE STRESS RESPONSES AMONG YOUNG AUTISTIC ADULTS

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ABSTRACT

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This study was conducted to examine the subjective (psychological) and objective (physiological) stress responses of autistic individuals guided by the Transactional Theory of Stress and Coping by Lazarus and Folkman (1984). Subjective stress responses were measured through a Visual Analog Scale (VAS) rating by the participants on their stress perception and objective stress responses were measured through heart rate variability (HRV) using a heart rate monitor as participants underwent a standardized online Trier Online Stress Test (TSST; Kirschbaum et al., 1993) protocol to stimulate a social evaluative stress protocol. A systematic and qualitative interview was followed to investigate the appraisal of participants' perception on the TSST. Literature suggests lack of insight and poor reporting of stressful experiences among autistic individuals. Participants consisted of 12 young adults with autism spectrum disorder (ASD) and 24 typically developing young adults currently attending college. Both subjective and objective stress quantitative analyses resulted in non-significant findings. However, findings suggested some between-group differences in subjective stress responses and objective stress responses for each phase of the stress stimulation (i.e., Baseline, Stress Task, Recovery). Particularly, higher observed stress perception and HRV were noted during Baseline and Recovery and lower observed stress perception and HRV were noted during the Stress Task in the ASD group. Further exploration of qualitative data findings revealed that both groups were

able to have insight and self-report physical stress response such as increased heart rate and sweating, further supporting the importance of the appraisal of the stressful experience.

Clinical, education, and research implications are also addressed. In terms of clinical implications, the current study highlighted young adults are susceptible to stress and can benefit from stress management intervention regardless of ASD diagnosis. Early intervention to teach autistic individuals stress management skills may also be beneficial. Furthermore, the use of objective measures can raise the awareness of one's stress response, and that the appraisal of one's subjective perception of stress is equally important in understanding individual differences in the stress experience. In terms of education implications, educators should train health professionals such as rehabilitation counselors in understanding diverse ways of stress manifestation and coping. They should also be trained to teach stress coping skills when working with clients, including autistic individuals. In terms of research implications, the unique methodology to combine psychological data with physiological data, as well as appraisal process to obtain cognitive information to gain a more holistic perspective on the stress experiences of participants. Future research recommends increasing sample size and diverse demographic participants, matching participants with ASD with those without, re-examining different methods to characterize potential similarities and differences among ASD, typically developing and other clinical groups, further examining not only the stress phase but also the baseline and recovery phases of the stress stimulation, improving the ASD screening to verify autism diagnosis, recruiting participants who have not received stress management intervention or training, examining the impact of in person and online TSST, and investigating the impact of comorbid conditions on stress responses in the ASD population.

Keywords: Autism, heart rate variability, visual analog scale, appraisal, TSST

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CHAPTER 1

INTRODUCTION

Stress is a ubiquitous phenomenon that everyone, to some extent, experiences it on a regular basis. In the psychological literature, stress is conceptualized as reciprocal, bidirectional, and a transactional process between individuals and their environment; it begins with cognitive appraisal of a stimulus which refers to an event or situation that affects them (Lazarus & Folkman, 1984). Our cognitive appraisal is our subjective response to stressful stimuli which we assess and evaluate to be harmful, a risk, a threat, or an opportunity for growth (Noret et al., 2018). Then, as a consequence of this cognitive appraisal, we engage in coping behavior which is strongly influenced by our personality (McCrae & Costa, 1986; Suls et al., 1996). Though the general population is known to engage in different styles of coping, clinical populations, such as autistic individuals, tend to use maladaptive means of coping in social situations which can negatively impacts their well-being (Schäfer et al., 2017).

The American Psychiatric Association defined autism spectrum disorder (herein referred to as autism) as a persistent neurodevelopmental disorder with two core features: (1) deficits in social communication and interaction and (2) restricted, repetitive patterns of behavior, interests, or activities (2013). In the United States, a steady increase in the prevalence of autism has been noted for more than two decades (Baio et al., 2018; Fombonne, 2003). Because of the aforementioned features of autism, autistic individuals have significant challenges navigating social interactions which often lead to stress, and this stress can lead to anxiety (Bruggink, 2016), depression (Mazefsky et al., 2014), anger (Scarpa & Reyes, 2011), self-injury and meltdowns (Mazefsky et al., 2013), family distress (Gulsrud et al., 2010), poor school outcomes (Roberts & Webster, 2020), and problems transitioning into adulthood (First et al., 2016). Researchers have

explored the difficulties with social skills in the context of autism and have found the significant co-occurrence of alexithymia in this population which may impact social situations. Furthermore, scholars summarized alexithymia as a personality trait which refers to an individual's inability to perceive different emotions and bodily sensations and emotion expression skills (Kinnaird et al., 2019). Scholars also found that autistic individuals have difficulty with the Theory of Mind which pertains to "knowing that other people know, want, feel, or believe things" (Baron-Cohen et al., 1985, p. 38). Because of these social skills challenges, autistic individuals have shown problems with emotion regulation, specifically using maladaptive emotion regulation strategies (Schäfer et al., 2017) that lead to negative feelings (Bruggink, 2016; Rieffe et al., 2011) and poor cognitive reappraisal (Mazefsky et al., 2012). Furthermore, research has indicated that autistic individuals exhibit a lack of insight and poor reporting of their stress perception and emotional states (Berthoz & Hill, 2005). These factors have contributed to stress often experienced in this population in social settings.

Although stress can be a subjective perception, it is manifested through our bodily reaction. Stress can be studied in different aspects through psychological, physiological, and psychophysiological perspectives. On the psychological level, stress is understood as the subjective stress response (i.e., cognitive appraisal) to stimuli (Cohen et al., 2016). Neuroticism personality, which pertains to the tendency to experience more negative life events (Magnus et al., 1993), has also been found to significantly co-occur with autistic individuals (Connor-Smith & Flachsbart, 2007; Schriber et al., 2014) which affects their ability to employ adaptive copings strategies after encountering a stressful stimulus (Schäfer et al., 2017). On the physiological level, stress occurs on the neuronal level where chemicals and neurotransmitters are released in response to stimuli (Everly & Lating, 2013; Hellhammer & Schubert, 2012). On the

psychophysiological level, one of the objective methods to study stress response is the vagus nerve's response to stimuli (Porges, 1995). This perspective recognizes that an objective measure such as heart rate, among many others, is impacted by psychological processes such as appraisal of stressful situations (Porges, 2003; 2009). It is reported that a higher heart rate variability (HRV) did not necessarily mean better functioning (Stein et al., 2005). However, a recent study has demonstrated that higher variability is associated to better emotion regulation in stressful situations (Cai et al., 2019). HRV is measured using a device that measures the heart's beat-to-beat interval across time (Evrengül et al., 2005; Umetani et al., 1998) and the heart's frequency spectra (e.g., high, low, very low frequencies; Cai et al., 2019; Hollocks et al., 2014). Autistic individuals were found to have lower HRV in comparison to controls during social situations (Cai et al., 2019; Cheng et al., 2020) which means, during social interactions, autistic individuals experience anxiety and are not able to employ adaptive coping behavior and accurate self-report of their stressful experience. Because previous studies have suggested that autistic individuals may not have the insight to evaluate and perceive stress, incorporating objective and subjective measures may provide further knowledge and richer understanding about the stress experienced in this population.

Statement of the Problem

The rate of autism has increased, and autistic individuals experience co-occurring conditions. Recent studies on the prevalence of autism reveal that one in 40 children is diagnosed with autism (Kogan et al., 2018; Maenner et al., 2020) while the overall rate of autism has steadily increased in the past 60 years (Baio et al., 2018; Fombonne, 2003). In addition, autistic individuals are at a higher risk for a number of psychiatric diagnoses (Hollocks et al., 2019; Tromans et al., 2018), neurologic diagnoses (Levy et al., 2010; Lukmanji et al., 2019), and other

medical diagnoses (Levy et al., 2010; Stevens et al., 2013). These conditions are often compounded by social skills challenges commonly found in this population (Tsermentseli, 2018; Velikonja et al., 2019).

The social interaction challenges experienced by autistic individuals have negatively impacted their lives. These challenges have resulted in many issues, including emotion regulation deficits (Aldao et al., 2010; Rieffe et al., 2011; Schäfer et al., 2017). Studies have suggested that many autistic individuals have difficulties with social-emotional insight and self-perception (Furlano et al., 2015; Hoza et al., 2012) and they also experience challenges with regulating emotions (Jahromi et al., 2012; Rieffe et al., 2011). Therefore, appraising stressful stimuli can become difficult for these individuals, which further leads to limited engagement of positive and adaptive coping strategies. Unfortunately, these difficulties with regulating emotions and appraising stressful experiences can negatively impact many life domains such as school, community engagement (First et al, 2016), friendship, life satisfaction (Mazurek, 2014), and work (Hedley et al., 2018).

Studies on subjective stress responses can be challenging given that self-reporting on the experience of stress can be abstract and requires insight. However, as mentioned previously, autistic individuals may lack insight about their own body's stress experience. Thus, using objective stress responses to validate the subjective stress responses by raising awareness of the body's stress response and promoting emotion regulation becomes crucial. It also allows researchers to use objective measures to validate the stress experience that is often abstract for autistic individuals.

Theoretical Framework

This study utilized the Transactional Model of Stress and Coping (TMSC). This model is

based on the Cognitive-Relational Theory of Stress which explains that an individual's stress experience is interactional between the environment and the individual (Lazarus & Folkman, 1984). This transaction dynamic begins with cognitive appraisal which pertains to the individual's phenomenological appraisal of the situation. This evaluation of the situation is an integral component of the individual's stress response because it incorporates the individual's goals and beliefs in relation to the stress experience (Noret et al., 2018). Furthermore, cognitive appraisal is divided into primary appraisal (Lazarus & Folkman, 1984) which pertains to the individual's initial appraisal of the situation as threat, challenge, or benefit (Lazarus, 1993) and secondary appraisal (Lazarus, 1993; Lazarus & Folkman, 1984) which follows the primary appraisal and pertains to the individual's reappraisal of the primary appraisal in relation to the individual's ability to manage and/or control the stressor (Graham, 2015; Raskauskas & Huynh, 2015). These appraisals and subsequent reappraisal of the stimulus then leads to coping (Enea & Rusu, 2020; Seymour et al., 2013).

According to the TMSC model, coping behaviors can be emotion-focused or focusing on controlling emotions or solution-focused (e.g., performing actions to overcome the stressor; Christmann et al., 2017). Some examples of emotion-focused coping include wishful thinking, withdrawal, emotion-coping, and support seeking (Connor-Smith & Flachsbart, 2007) whereas examples of solution-focused coping include acceptance, cognitive restructuring, positive thinking, distraction, taking a break, talking with others, and asking others for help (Compas et al., 2001; Skinner et al., 2003; Zhu et al., 2020). In addition, this framework incorporates the influence of anxiety and personality traits in individuals' approach when coping during stressful stimuli; the influence of these factors has been well-studied in the coping and stress literature.

Consequently, this framework provides fundamental and pertinent variables in which to understand stress experiences and processes among autistic individuals.

Overview of the Study

In the current study, the TMSC framework was utilized, and participants underwent a stress stimulation and the author of this research analyzed psychological and psychophysiological stress responses of these participants. A modified online version of the Trier Social Stress Test (TSST; Gunnar et al., 2021; Kirschbaum et al., 1993) was used, incorporating only the social task as previously done in another study with autistic participants (Dijkhuis et al., 2019). Recruited participants were grouped and composed of high functioning autistic individuals (HFASD) and typically developing (TD) individuals. Subjective and objective stress responses, as well as short interviews from these groups were then gathered and analyzed. Throughout this study, use of the term "autism" and "ASD" is used interchangeably to pertain to autistic individuals or individuals with ASD. In addition, throughout this study, use of the term "objective" stress responses will refer to the psychophysiological stress response that is measured through HRV.

Purpose of the Study

The purpose of the study was to examine the subjective (psychological) and objective (psychophysiological) stress responses of autistic individuals. Self-reported subjective stress responses were measured through Visual Analog Scale (VAS) based on perceived stress and objective stress responses were measured based on HRV which was obtained from participants' heart rates using photoplethysmography (PPG) via a heart rate monitor. Analysis of these data using quantitative methodology enabled further understanding of discrepancies and/or congruences in the stress responses of autistic individuals. Finally, a brief interview asking

participants to discuss and appraise on the stressful stimulation activity was done to gain insight about their stressful experiences.

Research Questions and Hypotheses

The research questions and hypotheses for the current study are indicated below.

RQ 1. Does the subjective stress response of autistic individuals differ from the subjective stress response of those without autism within each of the three phases (i.e., Baseline, Stress Task, Recovery)?

H.1.a. The mean Baseline VAS scores for autistic individuals will be significantly lower when compared to the mean Baseline VAS scores of individuals without autism.

H.1.b. The mean Stress Task VAS scores for autistic individuals will be significantly lower when compared to the mean Stress Task VAS scores of individuals without autism.

H.1.c. The mean Recovery VAS scores for autistic individuals will be significantly lower when compared to mean Recovery VAS scores for individuals without autism.

RQ 2. Do the objective stress responses of autistic individuals differ from the objective stress responses of those without autism during each of the three phases (i.e., Baseline, Stress Task, Recovery)?

H.2.a. The high frequency (normal units) HRV index from autistic individuals will be significantly lower when compared to individuals without autism during the Baseline.

H.2.b. The high frequency (normal units) HRV index from autistic individuals will be significantly lower when compared to individuals without autism during the Stress Task.

H.2.c. The high frequency (normal units) HRV index from autistic individuals will be significantly lower when compared to individuals without autism during the Recovery.

RQ 3. What is the relationship between the subjective stress responses (VAS) Baseline-to-Stress-Task phase difference and the objective stress response (HRV) Baseline-to-Stress-Task phase difference within each group?

> ***H.3.a.*** Autistic individuals will show a negligible-to-small and non-significant correlation between subjective (mean Stress Task – mean Baseline Phase) difference scores and objective (Stress Task – Baseline Phase) difference scores.
>
> ***H.3.b.*** Typically developing individuals will show a medium-to-large, significant correlation between subjective (mean Stress Task – mean Baseline Phase) difference scores and objective (Stress Task – Baseline Phase) difference scores.

RQ 4. How do individuals with and without autism describe their experience of stressful situations? (*Exploratory*)

Summary

This study sought to examine the psychological and psychophysiological stress responses of autistic individuals during a stressful situation using an online stress simulation protocol. Prospective participants were contacted via phone call or email for screening to determine eligibility for the study. After determined eligible to participate, a request for participation was sought. Two meetings were then scheduled for each participant: the first was to teach participants how to set up the online stress stimulation protocol (around 15 minutes) and the second to conduct the online stress stimulation (around 90 minutes). All participants completed demographic information and psychological questionnaires prior to the online stress stimulation. Participants underwent a modified version of the online Trier Social Stress Test using Zoom technology (Gunnar et al., 2021; Kirschbaum et al., 1992) to test psychological and psychophysiological stress responses. Quantitative data were collected from subjective

(psychological) and objective (psychophysiological) stress responses. Brief interviews were conducted with all participants to gather information about the stressful stimulation experience. Statistical analyses were conducted using the IBM Statistical Package for the Social Sciences (SPSS; IBM Corp., 2020) version 27.0.

Definition of Terms

The following terminologies are defined:

Stimulus. A stimulus is any event or situation that affects the person; this can also arise from within the individual (i.e., physiological or neurological) or the environment.

Stress. Stress can be defined in three ways: (1) on the psychological level, stress pertains to personal meanings that individuals put upon a stimuli which cause negative feelings of arousal to the individual, usually stemming from major changes in an individual's life (Graham, 2015; Long & Marsland, 2011); (2) on the biological level, stress pertains to neurochemical mechanisms concerning which the body tries to maintain an internal homeostasis or balance (Everly & Lating, 2013); (3) and on the psychophysiological level, stress pertains to the role of the vagus nerve to regulate emotion and perception (Porges, 1995, 2009).

Stressor. A stressor is any stimulus that produces a physiological or behavioral response (Lazarus & Folkman, 1984).

Cognitive Appraisal. Cognitive appraisal is an evaluative cognitive process an individual engages in to determine whether a stimulus, either at one time or over a period of time, induces stress (Lazarus & Folkman, 1984).

Coping. Coping pertains to an active behavior in which an individual engages in response stimuli that is perceived as stressful (Lazarus & Folkman, 1984).

Heart Rate Variability (HRV). Heart rate variability pertains to the variations of the heart rate often used in psychophysiology to measure stress response (Lacey & Lacey, 1958; Porges, 2007; Stern, 1964) and adaptation and recovery from stressful stimuli (Lehrer et al., 2020).

Respiratory Sinus Arrhythmia (RSA). Respiratory sinus arrhythmia is an index or measurement of HRV (Cheng et al., 2020) which pertains to the oscillations (i.e., troughs or dips and amplitudes or raises) of the heart rate; these oscillations take place in the heart's sino-atrial node which are influenced by breathing (Lehrer & Gevirtz, 2014).

CHAPTER 2

REVIEW OF THE LITERATURE

A significant portion of the autism literature reveals heightened deficits in interpersonal relationships (Vuori et al., 2017) among members of this population. These deficits include discrepancies in self-reporting (Hoza et al., 2012; Johnson et al., 2009; Lerner et al., 2012; Locke & Mitchell, 2016; McQuade et al., 2011; Schriber et al., 2014), exaggeration of experiences (Vuori et al., 2017) and overestimation of capacities (Furlano et al., 2015). To further understand these deficits, this chapter covers an introduction about autism, a framework to guide how stress can be explained in addition with its related constructs (i.e., stress, cognitive appraisal, coping, and personality), and a discussion on key topics unique to autism (e.g., social impairment, alexithymia, Theory of Mind and emotion regulation) is presented. Afterwards, a review on different ways to define stress and how it can be measured are provided.

Autism Spectrum Disorder

A brief history of the etiology of autism highlights the expansion and shift of our understanding regarding this condition. The earliest record in the literature regarding the description of the autism condition, as we currently define it, was in 1798 by a French physician Jean-Marc Gaspard. This accounts for a young boy who lived in the woods by himself for 11 years. The boy was aloof and had severe language difficulties (Itard, 1932). Then in 1908, over a hundred years later, it was speculated that Heller's disease was not an illness sui generis or an illness in and of itself (Fitzgerald, 2019); this disease would later be classified as part of the autism spectrum disorder. Later, a Swiss psychiatrist Paul Eugen Bleuler in 1910, coined the word 'autism' for the first time to describe children patients with schizophrenia (Cook & Willmerdinger, 2015). In the 1940s, case reports of 11 patients who appeared to manifest similar

characteristics of aloneness, obsessiveness, repetitiveness, and outstanding recall were described (Kanner, 1943). Autism was explained as a condition in which parents and relatives contribute to the child's "limited genuine interest in people" and that the children came from "highly intelligent parents" (Kanner, 1943). Then, a few decades later, the etiology of autism started to shift from a psychogenic perspective to a biological perspective (Cook & Willmerdinger, 2015). For instance, in the 1970s, autism was linked with a neurological disease (Chess, 1971; Wolff, 2004). Most recently, brain imaging shows the difference in neuropsychiatry (Di Martino et al., 2014) and genetic make-up (Steinman, 2020) could provide additional insight about the autism population. Though these findings are novel, autism is currently understood as a spectrum disorder (American Psychiatric Association, 2013; Lord et al., 2000).

Characteristics

Autism is currently characterized and diagnosed according to the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed., American Psychiatric Association, 2013). The American Psychiatric Association defined autism as a persistent neurodevelopmental disorder that manifests in two core areas namely 1) deficits in social communication and social interaction and 2) restricted, repetitive patterns of behavior, interests, or activities. The first core area involves deficits in social-emotional reciprocity; deficits in non-verbal communication in social interactions; and deficits in developing, maintaining, and understanding social relationships. The second revolves around repetitive motor movements using objects or speech; inflexible adherence when following routines or schedules; highly restricted, fixated, or perseverated interests; and hyper- or hyporeactivity to sensory input or unusual interest in sensory stimuli. Although fields have provided further insight about this condition (Frith & Happé, 1994), autism has been widely accepted as a pervasive neurodevelopmental disorder (American Psychiatric

Association, 2013). In addition, personality characteristics have been linked with autism symptomatology (Schriber et al., 2014) and a significant portion of the literature reports discrepancies in social competence (Hoza et al., 2012; Johnson et al., 2009; Lerner et al., 2012; Locke & Mitchell, 2016; McQuade et al., 2011; Schriber et al., 2014), specifically inflation (Vuori et al., 2017) and overestimation (Furlano et al., 2015) of performance in this population.

Prevalence

Recent studies investigated the prevalence of autism in the United States and revealed important and interesting findings. Researchers utilized a surveillance system to estimate the prevalence of autism in this multi-state study within 11 Autism and Developmental Disabilities Monitoring sites (Baio et al., 2018). The overall prevalence of autism was found 16.8 per 1,000 or approximately one in 59 children. Though rates varied by sex and race, rates were high on non-Hispanic white children. Another study utilized a national survey of parent reports of their children and found that one in 40 children had autism (Kogan et al., 2018; Maenner et al., 2020). Though earlier reports on the prevalence of autism reported 1 in every 2,500 children (Baron-Cohen et al., 1985), in the past 60 years, large scale studies have revealed that the prevalence of autism actually has steadily increased (Baio et al., 2018; Fombonne, 2003). In addition, the extant literature reveals prevalent association of autism with other diagnoses and some of these include developmental diagnosis (Levy et al., 2010; Rubenstein et al., 2018), psychiatric diagnosis (Hollocks et al., 2019; Levy et al., 2010; Rosen & Davison, 2003; Tromans et al., 2018), neurologic diagnoses (Levy et al., 2010; Lukmanji et al., 2019; Mouridsen et al., 2013; Rubenstein et al., 2018), and other medical diagnoses (Levy et al., 2010; Stevens et al., 2013). Despite these associations, there is still no known biological or physiological test for autism diagnosis (Amaral, 2017; Amaral et al., 2008).

For the next section of this chapter, a discussion on a framework to conceptualize stress and coping is presented. After which, this review discusses other autism attributes and characteristics (i.e., Social Skills Impairment, Alexithymia, Theory of Mind, and Emotion Regulation) to provide further elaboration on the challenges experienced by this population in social contexts.

The Transactional Model of Stress and Coping

The Transactional Model of Stress and Coping conceptualizes stress perception as mutually reciprocal, bidirectional, and transactional between individuals and their appraisal of the environment or the stressor (Lazarus & Folkman, 1984). This model is based on the Cognitive-Relational Theory of Stress which posits that stress results from a dynamic interaction between environmental or life events (e.g., demands, ambiguity, or constraints), personal characteristics (e.g., goals, beliefs), and mediating processes (e.g., cognitive appraisal, coping; Costa et al., 2017; Lazarus & Folkman, 1984). It highlights that the cognitive appraisal of the stressor influences coping behaviors such as emotion regulation (emotion-focused) or actively doing something to resolve the stressor (problem-focused; Lazarus & Folkman, 1984). Furthermore, this model divides cognitive appraisal into three parts: primary, secondary, and reappraisal. The relation between these two appraisals is circular or transactional, meaning that appraisal moves from the appraisal of the environment (primary), then to the person (secondary), and then back to the environment and back to the person (reappraisal); neither one precedes the other and there is no limit to the reappraisal (Lazarus & Folkman, 1984). This appraisal process begins with a stressful stimulus.

Stress

Stress arising from stimuli is the initial factor that has been used to explain the stress and

coping phenomenon. The perception of stress begins with the stimuli. The personal meaning that individuals attribute to stressful stimuli has long been recognized in the literature (Lazarus, 1966). These distinct and personalized meanings were identified as *harm* which pertains to psychological damage that was done to the person, *threat* which pertains to an expectation of harm, or *challenge* which pertains to the difficulty one feels about overcoming the stimulus. This proposition enables us to view stress in a multidimensional perspective as opposed to a unidimensional, physiological, or activation model (Selye, 1936, 1998) which will be discussed later. Emotion takes place after arousal from a stimulus and occurs before cognitive appraisal (Duffy, 1962; Lazarus & Folkman, 1984). Emotions come from the evaluation of the significance of the stimuli (Lazarus & Folkman, 1984) and are found to have strong correlations with behavior activities people employ in response to stress (Christmann et al., 2017). Furthermore, a recent conceptualization of positive emotions has been linked with emotion regulation from stressful events (Waugh, 2020).

The environment is another factor that has been linked to stress. Though traditional models of stress focus on the stimulus-response (S-R) model (Selye, 1936; Stern, 1964), the stimulus comes from the environment and the individual may affect the environment or select which environment to be in (Lazarus & Folkman, 1984). Recent findings on the influence of environment in stress appraisal revealed stress experiences varied depending on specific environments (e.g., social or isolated; Liu et al., 2018), it induced certain emotions (Stigsdotter et al., 2017), and it affected individuals' health which led psychological stress (Marshall, 2019). Even though the environment plays a significant role in cognitive appraisal of the stimuli (Lazarus, 1974), personality, too, has been found to influence psychological stress experiences (McCrae & Costa, 1986; Suls et al., 1996). Personality has been linked to interests (Larson et al.,

2002) which are part of the person's characteristics (Spokane & Decker, 1999). More of a discussion on personality is presented later in this chapter. Even though individuals may experience the same environmental stressor, they may appraise the same stressful situation differently (Ursin & Eriksen, 2004). For autistic individuals, environmental stressors have mainly focused on interpersonal contexts.

Studies on the stress experienced by members of the autism population highlight the interpersonal nature of their stressor. Studies among the autism population found challenges in recognizing vocalized emotion (Hobson, 1986), recognizing people's faces (Sasson et al., 2007), and facial expression in social situations (Trevisan et al., 2018). One study reported problems with establishing friendships and having increased quality of these relationships (Mazurek, 2014). Another study reported challenges with accessing community support services (e.g., vocation and higher education services), managing multiple responsibilities associated with these services, and community engagement (First et al., 2016). From a developmental perspective, these problems in interpersonal relationships can be stressful as an autistic child develops and then later transitions into adulthood (Hedley et al., 2018). Though specific metacognitive skills were linked with reducing symptoms of autism (Leung et al., 2016), a recent systematic review on the interventions focusing on emotion regulation for this population reports that research on this topic is yet to be fully explored (Cibralic et al., 2019). Furthermore, the lack of ability to mitigate the effects of life stressors in this population have resulted into problems with emotion regulation (Aldao et al., 2010, 2010; Gulsrud et al., 2010; Rieffe et al., 2011; Schäfer et al., 2017).

Cognitive Appraisal

There are three parts to cognitive appraisal: primary appraisal, secondary appraisal, and

reappraisal (Lazarus & Folkman, 1984). The appraisal of a situation starts with an event called a stimulus which is defined as any event (e.g., psychological or environmental) that affects the person and this recognition of the event leads to the primary appraisal (Lazarus & Folkman, 1984). In the primary appraisal, individuals evaluate the severity of the stressor, their susceptibility to the stressor (Graham, 2015), and the importance and relevance of the stressor to them in terms of their goals and beliefs (Noret et al., 2018). The transaction that occurs during this process varies uniquely depending on the person and the circumstance (Graham, 2015). Individuals may assess whether the stressor is positive, irrelevant, stressful (Cousino & Hazen, 2013; MacLean et al., 2019), or benign (Lazarus & Folkman, 1984). If individuals experience similar stressors, there can still be differences in the primary appraisal, and this is attributed to individual or group sensitivity and vulnerability (Lazarus & Folkman, 1984). Individuals may also appraise stressful situations as something that is harmful, a risk, a threat, or an opportunity for growth (Noret et al., 2018).

The initial cognitive appraisal is followed by a secondary appraisal and subsequent reappraisals. In the secondary appraisal, individuals assess their capacity to cope in relation to their primary appraisal (Lazarus & Folkman, 1984). Just as primary appraisal varies among individuals, secondary appraisal is also diverse because it relates to the individual's interpretation of innate abilities to control the stressor (Newton & McIntosh, 2010). Secondary appraisal focuses on the individual's perception of the ability to manage and/or control the stressor (Graham, 2015; Raskauskas & Huynh, 2015). Specifically, the individual evaluates whether any given stressor will exceed his/her/their personal resources (Long & Marsland, 2011). This evaluation of inherent resources to manage stressful circumstances (Kilby et al., 2018; Noret et al., 2018) involves the individual's capacities to cope (Lazarus & Folkman, 1984).

The interplay between primary and secondary appraisal shapes the intensity of the perceived and experienced stressor and the strength and characteristic of the individual's emotional reaction; this process occurs simultaneously and are not separate (Lazarus & Folkman, 1984). During reappraisal, an individual considers information from the primary appraisal which informs the individual's perception and eventual behavior. What distinguishes reappraisal from the aforementioned appraisals is that it follows an earlier appraisal, it can be the result of earlier cognitive efforts, and it can mediate the effects of chronic stressors (Cincotta et al., 2011; Jamieson et al., 2013; Lazarus & Folkman, 1984). Unfortunately, cognitive appraisal topics pertaining to young adults with ASD are scant in the empirical literature.

After a thorough review of the literature, the researcher of this study found two studies on cognitive appraisal. On a physiological level, one study examined the effects of cognitive appraisal among pregnant women who experienced a similar distressful event and its effects on their unborn child. Researchers found that the effects of the pregnant mother's cognitive appraisal of her ability to cope during a stressful life event can be transmitted to the fetus through experiences of distress during pregnancy as indicated by the change in DNA methylation. DNA methylation pertains to the formation of the methyl group in the DNA that regulates gene expression and alterations of this formation have been found to influence cognitive function and neuropsychiatric disorders. On a psychological level, another study used the TMSC to understand the influence of religion in the coping and appraisal process (Newton & McIntosh, 2010). Researchers obtained survey information from 103 parents of children with disabilities, 90 of which were mothers. They found that religious beliefs mediated the relationship between cognitive appraisals and coping strategies in that having a positive image toward God related to viewing stressors in life as challenging and beneficial as opposed to as a loss. In addition, those

who viewed God positively perceived God to be in control and felt greater perceived control over their stressors.

The researcher of this study literature that examined cognitive appraisal in children with autism. The first study contrasted autistic children with non-autistic children in their ability to appraise emotions from videotapes and drawings (Hobson, 1986). The average age of the children were 15 and 14 for autistic and non-autistic groups respectively and they had to match videotaped expressions and vocalizations with drawings. The study reported that though both autistic and non-autistic autistic children recognized that the drawings represented people, autistic children had significant impairment in matching these expressions with drawings when compared with non-autistic children. The second study utilized a survey questionnaire to examine the emotion regulation and appraisal of participants with autism traits (Albein-Urios et al., 2020). Researchers found a negative relationship between reappraisal and autism trait score and a significant positive relationship between suppression and autism trait score. Another study investigated the cognitive appraisals among children with autism and reported specific coping styles associated with theory of mind or the ability to infer own and other people's mental states (Sharma et al., 2014). Limited studies have been reported on cognitive appraisals of young adults with ASD. Though the TMSC framework highlights the dynamic interaction between cognitive appraisal and reappraisal, its application of cognitive appraisal in the autism population is severely lacking.

Coping

Coping has been defined as a transactional process (Suls et al., 1996). Historically, coping was initially defined as an intermediate process between stressors and health outcomes (Enea & Rusu, 2020) and that it mediates behavior and stress (Seymour et al., 2013) and

manifests itself in psychological and physiological well-being and functioning (Sloper et al., 1991). Researchers have explained this phenomenon as multidimensional including thoughts and behaviors, is process-oriented, and is purposeful and requires effort (Lazarus & Folkman, 1984). The overarching definition of coping was explained by researchers as "constantly changing cognitive and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person" (Lazarus & Folkman, 1984, p. 141). Contrasting coping from adaptation, they further explained that coping is a subset of adaptational behaviors, that while coping is an active behavior, adaptation is automatic. They further explained the difficulty of teasing out coping from adaptation because, in novel or nonroutine experiences, individuals may employ coping. However, when they experience the event over and over while employing similar coping behavior, the coping behavior becomes adapted behavior because it becomes automatic. In relation to stress, stress occurs when the environmental stressors overwhelm individuals' resources (Enea & Rusu, 2020) and various ways of coping influence the impact of stressors through behavioral and emotional coping strategies (Lazarus & Folkman, 1984). Examples of coping resources that can be employed during stressful situations include physical resources (e.g., health and energy), social resources (e.g., social networks and support systems), and psychological resources (e.g., belief systems and executive functioning skills; Sloper et al., 1991). These scholars suggest that when individuals experience stress, they can engage in personality-driven emotion-focused or solution-focused style of coping.

Emotion-focused. Emotion-focused coping (also referred to as emotion-oriented, disengagement, or emotion-coping) serves to regulate emotional response through emotion-focused strategies (e.g., avoiding the stressor to not have to address it) (Laubmeier et al., 2004;

Lazarus & Folkman, 1984; Peer & Hillman, 2014). It is found to be positively correlated with personality factors such as perseveration and emotional reactivity and negatively correlated with endurance (Szrajda et al., 2017); negatively predict agreeableness and conscientiousness (Melendez et al., 2019); and optimism (Carver & Connor-Smith, 2010). Furthermore, researchers have identified this coping style to predict a neurotic personality which have been linked to problematic coping strategies such as wishful thinking, withdrawal, emotion-coping, support seeking (Connor-Smith & Flachsbart, 2007) and ineffective use of coping strategies which leads to anxiety (Ribadier & Varescon, 2019). On a longitudinal perspective, neuroticism was predictive of depressive symptoms (Andrews et al., 2010).

Solution-focused. Solution-focused coping (also referred to as problem-oriented, engagement, or task-oriented coping) has a similar role just as in emotion-focused coping which is to regulate an emotional response. This coping focuses on actively finding solutions in relation to the individual and the stress experience (Compas et al., 2001). Examples include problem-solving, information seeking (Compas et al., 2001), positive thinking, and distraction (Skinner et al., 2003), taking a break, talking with others, and asking others for help (Zhu et al., 2020). This style of coping is found to positively predict openness to experience, agreeableness (Melendez et al., 2019), conscientiousness, extraversion (Connor-Smith & Flachsbart, 2007; Szrajda et al., 2017), and extraversion (Ribadier & Varescon, 2019). In addition, researchers have found that age moderated the use of solution-focused coping (Carver & Connor-Smith, 2010) and immature defense coping mechanisms (Oh et al., 2019) which affects subjective well-being (McCrae & Costa, 1986).

Even though coping among caregivers and family members of autistic individuals has extensively been studied (Costa et al., 2017; Dunn et al., 2001; Enea & Rusu, 2020; Hastings et

al., 2005; Manning et al., 2020; Pottie & Ingram, 2008; Seymour et al., 2013; Sivberg, 2002), in light of recent global and national events such as the effects of the Coronavirus disease 2019, (COVID-19; Johns Hopkins University Center for Systems Science and Engineering, 2020), autistic individuals experience heightened anxiety that may influence their ability to cope. They feel anxiety and social isolation (Ahlers et al., 2017) especially in social environments (Spain et al., 2017). Some of their challenges include environmental changes and disrupted routines (Ameis et al., 2020) which often lead to anxiety (Trembath et al., 2012). Though autistic individuals have been reported to experience difficulty with expressing insight and self-perception (Berthoz & Hill, 2005; Furlano et al., 2015; Hoza et al., 2012), systematic reviews report they can benefit from behavioral and cognitive interventions to alleviate anxiety symptoms (Cachia et al., 2016; Kreslins et al., 2015; McVey, 2019; Spain et al., 2018). Those who tended to employ a disengaged coping style (e.g., avoidance, denial, or distraction) had higher levels of emotional problems and were unable to use adaptive coping (Khor et al., 2014) and had increased anxiety (Khor et al., 2014). Though the literature reveals negative coping styles such as avoidance (Chin et al., 2017), humor (Dachez & Ndobo, 2018), worry, and rumination (Rieffe et al., 2014) in this population, positive coping was also found to be used in stressful situations (Lee et al., 2012). However, when these positive coping styles are employed, they were found to be ineffective (Lee et al., 2012) which emphasizes the need for specifically adapted interventions to help with managing anxiety in this population (Spain et al., 2015). The experience of anxiety in this population can be further explained by personality factors (Raffety et al., 1997).

Personality

The concept of personality has been linked to interest (Larson et al., 2002), self-efficacy,

and self-concept which are parts of a person's trait characteristic (Spokane & Decker, 1999). It plays a significant role in the perception and appraisal of stressful situations (Lazarus & Folkman, 1984). These trait characteristics have been conceptualized as the Big Five model (McCrae & Costa, 2004). This has been empirically validated (McCrae & Costa, 2008) and meta-analytic studies in multiple fields have been conducted to understand human traits and personality characteristics (D'Iorio et al., 2018; Schäfer & Mehlhorn, 2017; Zhou et al., 2017) in relation to coping (Barańczuk, 2019; Compas et al., 2017; Connor-Smith & Flachsbart, 2007; Zellars & Perrewé, 2001). These traits are Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness and are typically measured using the NEO Personality Inventory.

Neuroticism. Neuroticism refers to individuals' negative affect and tendency to experience more negative life events. Individuals who tend to be neurotic are more likely to put themselves in situations that foster negative affect (Magnus et al., 1993). This trait has been found to be an integral source of negative affect (Connolly & Viswesvaran, 2000) and it has been linked with worry (Barańczuk, 2019).

Extraversion. Extraversion refers to individuals' predisposition for positive emotions because they tend to spend time in social and interpersonal relationships (Judge et al., 2002). Extraversion was found to be positively related to cognitive reappraisal and negatively related to suppression and rumination (Barańczuk, 2019) and individuals with this trait tend to seek out positive events in their lives (Magnus et al., 1993).

Openness to Experience. Openness to Experience is a trait related to creativity and divergent thinking which predisposes individuals to feel good and bad experiences in the same

intensity. This pertains to individual predisposition to feel good and bad events more deeply (Judge et al., 2002).

Agreeableness. Agreeableness refers to individuals' tendency to get along well with others in satisfying relationships that often lead to well-being and happiness. Individuals who score low on this trait tend to be aggressive, antagonistic, and hostile (D'Iorio et al., 2018). They tend to get along well with others and have lesser interpersonal struggles (Zhou et al., 2017) which results in satisfying relationships (Organ & Lingl, 1995).

Conscientiousness. Conscientiousness refers to the tendency to be involved in work situations which can lead to satisfaction (Judge et al., 2002). Individuals who have this trait tend to use problem-focused coping, are persistent, are organized (Zhou et al., 2017), are more disciplined and have a tendency to be successful (Karbasdehi et al., 2018). In the autism population, multiple studies have examined how these personality traits relate with coping behavior.

Even though the Big Five Personality dimensions do not predict the severity of autism (Wakabayashi et al., 2006), the role of personality in this population still provides insight into how stressful situations are handled by members of this population. Literature reveals extraversion and agreeableness (Austin, 2005; Barger et al., 2014; Karbasdehi et al., 2018; Schwartzman et al., 2016; Wakabayashi et al., 2006) and openness to experience (Austin, 2005; Barger et al., 2014; Karbasdehi et al., 2018; Schwartzman et al., 2016) are lower in autistic individuals. This is salient because, for instance, individuals with low extraversion might prefer to be alone (Karbasdehi et al., 2018) leading to less opportunities to experience positive emotions (DeYoung et al., 2007); those with low agreeableness might be uncooperative, inflexible, and impatient (Karbasdehi et al., 2018); and those who are not open to experiences may have

difficulty accepting societal norms and expressing own emotions (Silani et al., 2008). Furthermore, even though there were no gender differences found in personality characteristics when studies compared the autism group with typically developing controls (Barger et al., 2014; Schriber et al., 2014), the literature is replete with findings indicating autistic individuals tend to be neurotic (Austin, 2005; Barger et al., 2014; Karbasdehi et al., 2018; Schriber et al., 2014; Schwartzman et al., 2016; Wakabayashi et al., 2006). Meta-analytic reviews also found that neuroticism is significantly higher in this population (Lodi-Smith et al., 2018; Vuijk, 2018) which can be detrimental because these negative emotions lead to lower subjective-wellbeing and more stress (Schriber et al., 2014). These findings further emphasize that autistic individuals experience greater emotion regulation which often occurs in social interaction situations.

Social Skills Impairment

As previously mentioned, impairment in social communication is a major deficit among autistic individuals. Social skills impairment among autistic individuals has been examined psychologically and physiologically. Social skills impairment such as difficulty with eye contact, facial expression, gesture, and shared enjoyment (Bishop et al., 2016); difficulty evaluating emotional content of social situations (Sasson et al., 2007); and difficulty in emotion perception and processing (Velikonja et al., 2019) have been identified in the literature were examined to be different in this population as well. Furthermore, researchers have found that internalizing and externalizing problems is much higher among autistic individuals, and these significantly affect their social interactions. These factors get worse when the individual has anxiety (Factor et al., 2017) and the use of reappraisal (Goldsmith & Kelley, 2018) and metacognitive processes such as initiation, planning, and organization help alleviate difficulties during social interactions (Leung et al., 2016). Even though lack of facial recognition contributes

to social skills impairment in autistic individuals (Sasson et al., 2007), social skills (Tsermentseli, 2018) were found to improve social interactions through enhanced executive functioning (Lieb & Bohnert, 2017), emotion regulation (Goldsmith & Kelley, 2018), and reward processing (Clements et al., 2018). Furthermore, bodily processes such as decreased amygdala activation (Baron-Cohen et al., 1999; Kleinhans et al., 2016), reduced gamma activation as shown in event-related potentials (Dawson et al., 2005), and decreased anterior mid-cingulate and anterior insula portions of the brain (Fan et al., 2014) were found to influence social skills challenges among autistic individuals. In addition, facial processing of emotions have been found to be impaired among autistic individuals as young as three years old (Dawson et al., 2005). Other studies found atypical reward processing (Clements et al., 2018) and neurological processes (Mundy & Markus, 1997) influence social skill impairments. Similarly, impaired brain development, particularly neural connections in the limbic system also contribute to social challenges experienced in this population (Ameis & Catani, 2015). These social skills challenges could be further explained by psychological processes such as alexithymia.

Alexithymia

To further elucidate on the social interaction challenges of autistic individuals, scholars have also explored the influence of alexithymia among autistic individuals. This inability to perceive internal and external states of self and others is a personality trait phenomenon referred to as alexithymia. Alexithymia was first defined in 1973 as the person's inability to recognize and distinguish between emotions and bodily sensations and subsequent expression of these emotions (Sifneos, 1973). The conceptualization of alexithymia symptoms has changed over time (Poquérusse et al., 2018) from "emotional agnosia" or inability to perceive facial expressions, body language, or tone of voice (Sifneos, 1973) to "feeling aphasia" or the inability

to communicate feelings (Sifneos, 1996). Currently, alexithymia is defined as a difficulty in identifying and describing feelings and bodily (or physiological) sensations and having a limited cognitive capacity to process affective stimuli (Cook et al., 2013; Nemiah, 1977; Vermeulen et al., 2006). Researchers in this field have further divided alexithymia into two categories (Vorst & Bermond, 2001). Type I alexithymia pertains to a low degree of conscious recognition of emotional arousal and low degree of emotional cognition regarding this arousal. Type II alexithymia pertains to a high degree of conscious recognition of emotional arousal with a low degree of degree of emotional cognition (Berthoz & Hill, 2005; Gaigg et al., 2018; Vorst & Bermond, 2001).

Recent studies examined the intersection between alexithymia and autism (Poquérusse et al., 2018). Even though cognitive, linguistic, and behavioral difficulties have long been recognized in autistic individuals (Baron-Cohen et al., 1985; Denckla, 1986; Frith, 1991; Hermelin & O'Connor, 1970; Rapin & Dunn, 1997; Rogers & Pennington, 1991) the idea that there is a potential relationship between alexithymia and autism began in the mid-1990s (Poquérusse et al., 2018). Since then, the co-occurrence of alexithymia and autism has been widely examined and a recent meta-analysis reveals 50% prevalence rate of alexithymia amongst autistic individuals (Kinnaird et al., 2019) versus a prevalence of only 10% in the general population (Bird & Cook, 2013; Salminen et al., 1999). Unfortunately, the exact relationship between alexithymia and autism remains unknown (Poquérusse et al., 2018), but the concept of the Theory of Mind provides additional insight on these social interaction challenges.

Theory of Mind

Researchers first coined the concept of the Theory of Mind more than 40 years ago (Premack & Woodruff, 1978). In their study, Theory of Mind was investigated in chimpanzees.

Theory of Mind pertains to the ability to impute mental states (e.g., purpose, intention, doubt, etc.) to the self and others. Theory of Mind revolves around inferences which one has that can be used to predict behavior. For instance, in their study, a chimpanzee was shown a video of a human struggling with a problem (e.g., reaching behind a locked cage). Afterwards, the chimpanzee was shown several photographs which showed the solution to the problem; in this example, a key to open the locked cage. The chimpanzee was able to select the right photographs in each problem scenario thereby concluding that the chimpanzee could understand the mental state of another being or empathy. This conceptualization of empathy was then proposed and tested in humans, particularly those with autism (Baron-Cohen et al., 1985).

The concept of the Theory of Mind has been examined in research. Applying the definition of the Theory of Mind to human beings, researchers extended its definition to "knowing that other people know, want, feel, or believe things" (Baron-Cohen et al., 1985). In other words, Theory of Mind refers to regarding or imputing other people's knowledge, wants, feelings, or beliefs about themselves or their situation. Conceptualization of this theory was later revised to the ability "to be able to reflect on the contents of one's own and other's minds" and further highlights a person's ability to infer mental states (e.g., beliefs, desires, intentions, imaginations, emotions, etc.; Baron-Cohen, 2000). In addition, Theory of Mind has been expanded upon leading researchers to conceptualize two different processes of Theory of Mind (Tager-Flusberg, 2000). The first is the social-cognitive (also known as Cognitive Theory of Mind) which is based on an understanding of the mind as a representational system (e.g., emotion recognition, response and reflection). The second is the social-perceptual (also known as Affective Theory of Mind) which is based on the individual's judgment of another person's mental state which includes facial communication, gestures, tone of voice, and actions (e.g.,

taking another person's perspective, cognitive flexibility; Mathersul et al., 2013; Pedreño, 2017; Tager-Flusberg, 2000). For autistic individuals, Theory of Mind principles are known to be a challenge (Williams, 2010).

To address social interaction challenges in the autism population, interventions using the Theory of Mind and other social interaction interventions have been explored. A recent meta-analytic study revealed that autistic individuals have significant social cognitive impairments in theory of mind and in emotion perception and processing (Velikonja et al., 2019). In addition, studies revealed Theory of Mind interventions predict the level of autism severity (Hoogenhout & Malcolm-Smith, 2017) and Theory of Mind skills mediated the relationships between autism symptoms and social skills (Berenguer et al., 2018). Furthermore, Theory of Mind has been associated with social communication symptoms and restricted and repetitive behaviors (Jones et al., 2018) and multiple interventions using Theory of Mind have focused on helping autistic individuals learn social interaction skills (Begeer et al., 2010, 2011; Berenguer et al., 2018; Hoogenhout & Malcolm-Smith, 2017; Jones et al., 2018; Marraffa & Araba, 2016). Other interventions focusing on communication activities, initiation or requests, and responses (Babb et al., 2020); behavioral and social reciprocity (Sagayaraj et al., 2020); physical therapy (Healy et al., 2018); music (Su Maw & Haga, 2018); and individual interventions, as opposed to group interventions (Sowa & Meulenbroek, 2012) have contributed to enhance social interactions in this population. Even though social skills interventions were found to be moderated by age (Fuller & Kaiser, 2020), if autistic individuals do not develop these skills early in life they will be subjected to emotion regulation challenges later in life.

Emotion Regulation

Even though little is known regarding emotion regulation in youth with autism (Mazefsky

et al., 2013), findings from the extant literature report commonality in emotion regulation difficulty vastly reported in this population (Bruggink, 2016; Samson et al., 2015; Sukhodolsky et al., 2013). Autistic individuals are known to have difficulty with emotion recognition (Uljarevic & Hamilton, 2013) and that their emotion regulation pattern is described as fragmented and they are not able to understand emotions and their own emotional experience (Rieffe et al., 2011). While it is unclear whether autistic individuals have difficulty with emotion regulation or emotion generation (Gross & Feldman Barrett, 2011), a recent meta-analytic study reveals that members of this population experience more prevalent mental health disorders compared to the general population (Lai, 2019). The literature on emotion regulation among autistic individuals reports less use of adaptive behaviors such as reappraisal, problem-solving, and mindfulness (Aldao et al., 2010). Furthermore, autistic individuals have been found to use more maladaptive behavior such as worrying, rumination (Rieffe et al., 2011), avoidance and venting (Jahromi et al., 2012). Research has found that autistic individuals have difficulty with self-reporting stressful situations (Berthoz & Hill, 2005; Bishop-Fitzpatrick, Mazefsky, et al., 2017; Hill et al., 2004) and the use or reappraisal occurs less in this population when confronted with negative stimuli (Bruggink, 2016; Samson et al., 2015; 2015). A meta-analytic study reported autistic individuals used maladaptive emotion regulation strategies frequently (Schäfer et al., 2017) which lead to anxiety (Bruggink, 2016; Samson et al., 2015; Sukhodolsky et al., 2013), depression (Mazefsky et al., 2014; Rieffe et al., 2011; Santomauro et al., 2017), anger (Samson et al., 2015; Scarpa & Reyes, 2011), and lack of cognitive flexibility or cognitive reappraisal (Mazefsky et al., 2012). Unfortunately, these negative outcomes enhance the impact of stress in this population.

Measuring Stress as a Construct

The conceptualization of stress changed over time. A stress and coping research scholar summarized the history of the term stress and how it came to be used in the physiological sciences today (Lazarus, 1993). Early use of the word stress dates back in the 14th century then, later, in the 17th century, Robert Hooke, a famous physicist-biologist used the term in civil engineering to explain resilience structure design. Terms such as load (the weight), stress (the area where the load hits), and strain (the deformation resulting from stress on a given load) were used. This notion of stress was later used in the 20th century to conceptualize models of stress in physiology and psychology. One of the most influential notions about stress in the physiological sciences was conceptualized by Hans Selye, an endocrinologist, who borrowed the word 'stress' from engineering to explain causes of certain human physiological conditions (Selye, 1936, 1998). His research reported that when the body is exposed to certain short-term non-specific noxious agents such as drug administration, certain temperatures, or clinical surgery procedures, it experiences a syndrome as a "generalised effort … to adapt … to new conditions" and explained this phenomenon as the "General Adaptation Syndrome." He later specified this general conceptualization of stress to eustress (the good kind of stress) and distress (the bad; Selye, 1974); though exact differences and mechanisms between these two were not elaborated (Lazarus, 1993). Further conceptualizations of stress stemmed from after World War II and terms such as "battle fatigue," "war neurosis," and "shell shock" were used to explain combat dysfunction experiences; though this idea was not complete because other sources of stress are later found in ordinary life situations such as academics, illnesses, and significant life events such as marriage (Lazarus, 1993). This led to another idea of the mechanism of stress, particularly one coined by John Mason who argued that for a situation to induce a stress response

by the body, the situation needs to be appraised as novel, unpredictable, or beyond the person's control (Mason, 1968). Research in this area revealed that the human body's hormones are susceptible to psychological phenomenon of stress as opposed to physiological as what previously was conceptualized (Mason, 1975). Even though the conceptualization of stress has been studied traditionally through epidemiological, psychological, and biological or physiological research (Cohen et al., 2016), recent advancements in the study of human stress have shown a complex interaction between physiological and psychological and psychophysiological perspectives.

Physiological Level

Researchers have examined the complex physiological processes and summarized the two physiological systems involved in stress response (Everly & Lating, 2013). The beginning of these processes occurs at the neuronal level. Chemical or electrical signals are received by the postsynaptic membranes of the dendrites (short extensions of the nerve cell) which then travel through the dendrites and then to the cell body. And then, this neural impulse or signal goes through the presynaptic membrane of the cell body across the synaptic cleft or gap between dendrites. In addition, chemical substances called neurotransmitters located across the synaptic cleft enable the inhibition or stimulation at the postsynaptic membrane of the next neuron. The mechanism of the inhibition or stimulation at this level occurs through the exchange of electrons from positively charged sodium (Na^+) molecules with negatively charged chloride (Cl^-) molecules. This exchange of charges or actual firing of the neuron is called depolarization (Robertson et al., 2020) has been used in stress research to measure electrophysiological phenomenon (Cavanagh & Allen, 2008; Sunwoo et al., 2019) to measure hormonal (e.g., cortisol) and neurotransmitter (e.g., catecholamines) responses to stress (Hellhammer &

Schubert, 2012; Kirschbaum et al., 1993; Labuschagne, 2019; Pulopulos et al., 2018). On the physiological systems level, the body's response to stress is twofold.

The body's response to stress takes place using two physiological systems. The first system is the sympathetic-adrenomedullary (SAM) system that stimulates the spinal cord neurons to secrete catecholamines such as epinephrine and norepinephrine (Vollmer, 1996). It is a component of the autonomic nervous system (ANS), also referred to as the "Fight-or-Flight" response (Everly & Lating, 2013), which is responsible for maintaining the body's internal homeostasis or balance. These neurotransmitters then affect various organs of the body such as the heart by increasing cardiac output, muscles by vasodilation, and skin and gut by constriction of blood vessels which results in increased blood supply to the brain and muscles (Everly & Lating, 2013). This process ensures an increase in blood pressure, respiration, and heart rate during psychosocial stress situations (Zappetti & Avery, 2019). The second system is the hypothalamic-pituitary-adrenocortical (HPA) system. This system is responsible for producing glucocorticoids in the adrenal cortex which releases corticotropin-releasing hormone (CRH) and arginine vasopressin (VSP), which then travels to the anterior pituitary to release adrenocorticotropic hormone (ACTH; Cool & Zappetti, 2019). The ACTH interacts with cellular receptors in the cortex of the adrenal gland to stimulate the production and release of glucocorticoids which attach to mineralocorticoid receptors (MR) and glucocorticoid receptors (GR; Doom & Gunnar, 2013). The secretion of glucocorticoid in the MRs and GRs is believed to be responsible with long-term gene expression adaptation to stress (Herman, 2012). Researchers have found MRs mediate basal condition levels to maintain neuronal responsiveness and GRs impair learning and memory on the neurological level, though the reason is still unknown, and these basal levels enable epinephrine and norepinephrine to be effective during stress situations

(Gunnar & Quevedo, 2007). Overall, during stress, the SAM and HPA systems are physiologically balanced by the body in a condition known as allostasis (McEwen & Seeman, 1999; Zappetti & Avery, 2019) and doing so enables the body's physiological systems to work together to re-establish pre-stressor conditions (Ganzel et al., 2010). Literature also defines stress response as allostatic load which has been reported to be linked with physical health when experienced in moderation (Gunnar & Quevedo, 2007) and poor adaptation when experienced in chronic levels (Segerstrom & Miller, 2004; Zappetti & Avery, 2019).

Psychological Level

Similarly, stress has been conceptualized at the psychological level. Early understanding of stress in the psychological perspective posited stress as a stimulus (Walinga, 2014). This formulation explained that life events such as death of a spouse, divorce, marital separation, time in jail, death of a close family member, and personal injury or sickness induced a sense of adaptation or coping behavior (Holmes & Rahe, 1967). Though an individual determines the degree or intensity of the stressor, life events require the same level of adjustment in every person (Walinga, 2014). Another conceptualization of stress, and perhaps the most seminal in the stress literature, was constructed by Lazarus and Folkman in the 1980s (Lazarus & Folkman, 1984). They defined stress as any stimulus which can include major changes in the person's life (e.g., divorce, giving birth, natural disasters, cataclysmic events, or any other environmental stimuli) and negative experiences that can be construed as harmful or threatening. They further explained that stress is not a single variable but rather a concert of many other variables and processes that first starts with the cognitive appraisal of an event. This subjective interpretation of a stimulus is viewed as transactional and phenomenological which centers on the cognitive appraisal or the individual's personal construction of the stimulus. Appraisal of these stimuli as

threats is influenced by imminence of harm or danger, intensity, duration, the possibility of the individual to control the event, and the individual's self-efficacy to overcome the stimulus (Cohen et al., 2016). As discussed early in this chapter, stress begins from a stimulus which is perceived as harm, threat, or a challenge and an individual appraises and reappraises this stimulus along with personal characteristics. The individual then engages in coping behavior because of the initial appraisal and subsequent reappraisals.

Psychophysiological Level

Researchers have examined the concept of psychophysiology to understand stress phenomenon (Blascovich & Mendes, 2010; Cacioppo et al., 2000; Porges, 2007). Even though psychophysiology began around 60 years ago (Stern, 1964), scientific examinations in this topic began as early as the 19th century (Cacioppo et al., 2000). While approaches in psychophysiology have focused on stimulus-response (S-R) paradigms to understand human psychological response to stimulus (Stern, 1964) and HRV studies to understand mental states (Lacey & Lacey, 1958; Porges, 2007), recent studies utilizing HRV have underscored its role in human adaptation and recovery from a stressful stimuli (Lehrer et al., 2020). As mentioned in Chapter 1, the current study used the term objective stress responses to refer to the psychophysiological measure such as the heart rate variability (HRV). The distinction between physiological psychology, a subdivision of behavioral neuroscience, which focuses on manipulating or treating physiology to treat and understand human behavior (Teuber, 1955) and psychophysiology which utilizes various biofeedback devices and integrating nervous system processes to understand psychology (Slonim, 2014) becomes significant because of how these disciplines conduct physiological research associated with psychological constructs influenced by the body's physiological processes (Gordijn et al., 2013; Izawa et al., 2008; Lehrer et al., 2020; Lehrer &

Gevirtz, 2014; Porges, 2007; Soravia et al., 2009). In addition, psychophysiology emphasizes the relationship between neuropsychological and psychological mechanisms (Porges, 1995) and assumes that the nervous system provides a focal point for measurement (Porges, 2003). Examples of the use of psychophysiological methods to investigate mental states (Pulopulos et al., 2018) and members of clinical populations such autism (Kim et al., 2020), schizophrenia (Liu et al., 2017), and anxiety (Hamm, 2020). Over time, as sophisticated neuroscientific instruments became more available (Porges, 2003) studies in psychophysiology have utilized the use of electrocardiogram to predict mental work capacities (Bal et al., 2010; Parent et al., 2019), electroencephalogram to measure event-related potential of the brain to measure emotion regulation (Pang et al., 2019), and functional magnetic resonance imaging to examine the role of reward processing in depressed states (Keren et al., 2018).

The Polyvagal Theory. Other conceptualizations within psychophysiology have proposed the Polyvagal Theory to explain the stress phenomenon (Porges, 1995; 2003; 2007; 2009). Stephen W. Porges, the leading scholar in the conceptualization of this theory proposed that the vagus nerve's neurophysiological and neuroanatomical features serve to explain different adaptive and behavioral mechanisms (Porges, 2007). Furthermore, he adds this explanation provides three insights regarding the body's autonomic nervous system regulation: (1) that the influence of the vagus nerve to the heart in response to stimuli enables social engagement but the withdrawal of this influence leads to a fight and flight response by the sympathetic nervous system; (2) that there is a relation between the function and anatomy of the facial and visceral nerves; and (3) that neuroception (a new concept introduced by this theory), a non-conscious risk assessment appraisal (Slonim, 2014) helps to distinguish safe and dangerous situations (Porges, 2007) and explains how certain environmental situations may elicit certain physiological

processes such as those associated with fight-flight or social interactions (Porges, 2009). The myelinated nerves of the vagus function as a vagal modulator (which is also referred to as vagal break) which inhibits the sympathetic nervous system's influence on the heart (Porges, 2003). Furthermore, the vagus nerve innervates the heart's sino-atrial (SA) node which is the heart's pacemaker and high vagal tone leads to the vagus nerve's ability to inhibit or limit the SA node, and a low vagal tone leads to reduced ability of the vagus nerve to reduce the inhibition of the SA node (Porges, 2007). In other words, the increases and decreases in the inhibitory vagal control to the heart decreases or increases the heart rate respectively (Porges, 2007). In clinical research, vagal tone is quantified using the RSA (Lewis et al., 2012; Slonim, 2014) which is linked with social stress responses (Bishop-Fitzpatrick, Mazefsky, et al., 2017; Corbett et al., 2021) that indicates an individual's adaptive social functioning (Edmiston et al., 2016). Multiple scholars have used experimental research designs to further examine negative social stress responses in relation to poor RSA vagal tone (i.e. indicated by lower HRV; Benjamin et al., 2020; Cheng et al., 2020; Conder & Conder, 2014; Evrengül et al., 2005; Guy et al., 2014). The literature in autonomic regulation reveals that clinical populations have deficits in vagal functions (Cai et al., 2019; Cheng et al., 2020; Harder et al., 2016; Schaaf et al., 2015; Thapa et al., 2019) and these deficits have direct implications on autonomic nervous system regulation (Porges, 1995).

For this study, the Trier Social Stress Test (Kirschbaum et al., 1992; Kirschbaum et al., 1993) was be used to induce a psychological and physiological stress response. The TSST was first introduced in Germany in the early 1990s. Researchers from the University of Trier conducted four experiments to test the sex differences on the endocrine stress response from salivary cortisol levels of participants undergoing psychological stresses. In their original study,

researchers created a stress protocol which is consists of a 10-minute baseline recording of cortisol levels. Afterwards, participants began a speaking task (5 minutes) which was then followed by an arithmetic task (5 minutes). For the speaking task, participants were informed they would be evaluated for their nonverbal communication and were then asked to provide a speech to convince the research "confederates" why they were the best candidate for a job position. For the arithmetic task, participants were asked to count backwards from 1022 by 13, starting from the beginning upon every mistake. Afterwards, participants were given a 50-minute rest. Each segment (i.e., baseline, stress tasks, and rest) of the study was conducted at different rooms and participants were ushered into each of these rooms during the study. Also, during the study, salivary cortisol levels are measured at multiple time points (Labuschagne, 2019). Over time, the TSST has become a common procedure (Cheng et al., 2020) and has been the gold standard (Shields & Slavich, 2017) for inducing stress in laboratory settings to measure psychophysiological stress.

Even though the TSST has a standard procedure, there are variations in it that scholars have utilized to induce stress. Variations of the TSST have incorporated visual analog scales (Hellhammer & Schubert, 2012; Strahler et al., 2010), group settings (von Dawans et al., 2011), utilizing only women facilitators (Goodman et al., 2017), and online administration (in response to pandemic stress; Gunnar et al., 2021). As previously mentioned, the TSST has two portions: the arithmetic and the speaking tasks and while some scholars have varied the duration of the speaking task anywhere from three to 10 minutes, others have altered the arithmetic subtraction by using 17 instead of 13 (Strahler et al., 2010). Likewise, others have investigated the impact of negative feedback from study facilitators during interactions with participants as opposed to providing a neutral effect (Goodman et al., 2017). A meta-analytic study contrasted other

physiological responses used in the TSST beyond the traditional cortisol response and some of these physiological responses include heart rate, cardiac output, RSA, blood pressure, and HRV (Seddon et al., 2020). Because of these variants, it is important to consider the pros and cons of this experiment protocol.

The strengths and weaknesses of the TSST have been identified by scholars. Regarding strengths, systematic reviews reported that TSST provides a valid procedure to induce an acute stress response (Allen et al., 2017). In addition, it has shown reliable results to induce physiological stress in children, adolescents (Seddon et al., 2020), as well as adults (Shields & Slavich, 2017). In addition, it is reported to have ecological validity, reliability, and robustness in inducing psychophysiological stress responses (Shields & Slavich, 2017). In contrast, criticisms or weaknesses of the TSST include the fact that it is not standardized and researchers conduct variants of this protocol (Cheng et al., 2020) as previously described. Furthermore, the use of three facilitators makes the study resource intensive especially if running the TSST study multiple times per week by several people (Shields & Slavich, 2017). The duration of the study (60+ minutes) may affect the effect size (Goodman et al., 2017) referring to the treatment and habituation effect that may be induced by TSST (Allen et al., 2017). Despite these variations, the TSST has been used to study stress experiences in clinical populations.

TSST in the Autism Population

Autistic individuals have been found to be physiologically different when compared to non-clinical populations. Physiological differences (Bal et al., 2010; Lydon et al., 2016; Schoen, 2009; Stiegler & Davis, 2010) and neurological differences (Cai et al., 2019; Cheng et al., 2020; Harder et al., 2016; Kim et al., 2020; Schaaf et al., 2015; Thapa et al., 2019) have been found among autistic individuals. Specifically, higher cortisol levels in the morning (Corbett et al.,

2006) and during anticipatory stress (Taylor et al., 2018) were found elevated. Generally, there is evidence in the literature showing a reduced cortisol response (Corbett et al., 2021; Edmiston et al., 2017; Levine et al., 2012) which may affect their ability to cope during stressful situations. Because the TSST procedure allows participants to be in a quiet and calm setting and then be placed in a stress stimulation shortly thereafter, researchers have been able to sufficiently detect physiological stress responses in control and clinical populations who underwent the TSST. This sudden experience of a stressful stimulus allows researchers to measure an acute increase in physiological response to stress using cortisol and HRV.

Researchers have utilized the TSST to measure stress response and found physiological differences in stress response among autistic individuals and controls. The TSST was found to be a reliable way to evaluate statistically significant changes in physiological stress responses (Cheng et al., 2020). Findings using this procedure revealed blunted cortisol (Corbett et al., 2021; Edmiston et al., 2017; Hollocks et al., 2014; Levine et al., 2012), higher systolic blood pressure (Bishop-Fitzpatrick et al., 2017), and higher heart rate (Hollocks et al., 2016) among autistic individuals in response to stress when compared to TD controls. When age groups were compared within autistic individuals, young adults showed higher cortisol levels than adolescents (Taylor et al., 2018). Furthermore, a recent meta-analytic study of HRV among autistic individuals who underwent the TSST revealed three interesting findings on the physiological response of this population to stress (Cheng et al., 2020). First, lower baseline HRV and HRV following a stressor is significantly lower in individuals with ADS than in controls. Second, RSA is significantly lower during baseline, social and cognitive stress tasks, and debriefing. And third, parasympathetic HRV indices (e.g., pNN50, HF) revealed significant intergroup differences though SDNN and RMSSD do not.

In summary, autistic individuals experience heightened stress from social contexts and, unfortunately, the empirical literature reports challenges in self-reporting and appraisal by members of this population. Literature reveals that these social skills impairments can be attributed to alexithymia, Theory of Mind, and emotion regulation and have negatively impacted their well-being. Expanding research findings on the appraisal by including a psychophysiological measure such as RSA can help further clarify the appraisal process during stressful situations in this population. In addition, the use of RSA can help raise awareness of the physiological nature of stress in this population which can be utilized to help elicit in-depth information on their cognitive appraisal process.

CHAPTER 3

METHODOLOGY

This section discusses the research design, research questions, data preprocessing, data management, and data analysis.

COVID-19 Disclaimer

During the data collection of the study, the Coronavirus disease 2019, (COVID-19; Johns Hopkins University Center for Systems Science and Engineering, 2020) was in effect. Subsequently, university policies have altered during the entire study duration from restricted indoor face-to-face contact to allowing outdoor face-to-face contact. To adhere to university policies at Michigan State University, the heart rate trackers were mailed to participants to avoid having to meet them in-person and participants were then instructed how to use the tracker via phone call, text, email, or Zoom. Afterwards, participants were given special instructions to mail the trackers back after completion of their participation. Later, university guidelines eased, and the heart rate trackers were given to participants in-person following university guidelines on social distancing and in-person meetings. In addition, the COVID-19 pandemic has resulted to multiple points in delay in study recruitment.

Research Design

The purpose of the present study was to examine the subjective (psychological) and objective (psychophysiological) stress responses of autistic individuals. It utilized a quantitative descriptive research design (Curtis et al., 2015). Participants underwent an online stress stimulation similar to a previous study (Gunnar et al., 2021) and subjective and objective stress responses were obtained. For exploration, participant interview data were also gathered and briefly scanned to provide a bit more information about participant stress experiences. This was

done to help clarify and appraise the stress experience of autistic individuals in comparison to typically developing individuals.

Participants

Participants were recruited via word of mouth and flyers posted on campus and contact with various academic programs at a midwestern university and western university in the United States. Inclusion criteria consisted of individuals who were 16-26 years old, non-smokers, do not take cardiovascular medications, do not regularly consume alcohol, and those who did not have COVID-19 symptoms. Exclusion criteria were individual lack a stable internet connection, who did not have access to a 13" computer screen, was not able to find a quiet and private place for 2 hours, was allergic to Velcro, and/or who did not have a phone with a front-facing camera feature. (Sample characteristics are described at the beginning of the result section.)

Measures

UMI Care Device. The UMI Care Device is a commercial device that has been used inclinical studies to assess physiological stress (UMI Lab Technology, n.d.). This device is designed to capture PPG which is an analog of electrocardiogram data typically used in HRV analyses (Wittenberg et al., 2020). This device captures the heart rate and heart rate frequency bands (Elgendi et al., 2016; Fleming & Tarassenko, 2007; Jong et al., 2017) at 0.15 to 0.40 Hz (high frequency or HF), 0.04 to 0.15 Hz (low frequency or LF), and at 0.0033 to 0.04 Hz (very low frequency or vLF). For this study, heart rates were obtained, and the resulting file was then processed into Kubios software (Tarvainen et al., 2014) to obtain the HRV indices (more details were described in the data processing section). This device was strapped on to the arm of the participant above or below the elbow and the participant wore this device during the duration of the stress stimulation.

Visual Analog Scale. Visual Analog Scale (VAS; Aitken, 1969) is a common tool to measure psychological stress responses. VAS has been utilized in TSST studies to measure anxiety and emotional insecurity (Hellhammer & Schubert, 2012); stress states (Kudielka et al., 1999); anxiety and tension (von Dawans et al., 2011); and pain (Sakulsriprasert et al., 2020). In the current study, subjective stress perception was measured in the scale of 1 thru 10 where 1 denotes the least stress and 10 denotes the greatest stress. Participants were asked about their perceived stress at multiple points during the stress stimulation (see Figure 1).

Procedures

The Recruitment, Screening, Preparation, Stress Stimulation, and Interview procedures are outlined. Details regarding the Zoom set up, how to use the heart rate tracker, and restricted physical activities and consumption of certain beverages are provided in the Appendices section.

Recruitment. Recruitment flyers (see Appendix C) were posted at various buildings and program departments in a midwestern and western university in the United States. In addition, recruitment flyers and email were sent to managers and staff leaders who service persons with disabilities housed within colleges, universities, statewide associations, disability advocacy groups, and local rehabilitation agencies.

Screening. After recruitment, participants were contacted via phone or via Zoom for screening. Participants were screened based on physiological attributes or behavior that influence HRV (e.g., smoking habit, taking cardiovascular medications, habitual alcohol consumption), and symptoms of COVID-19 (see Appendix D). Those who passed the screening were asked to participate in the online stress stimulation and the researcher scheduled to meet with each participant to prepare for the online stress stimulation and then to conduct the stress stimulation.

Preparation. The researcher met with each participant in person or via Zoom. The heart rate trackers were either mailed or handed to each participant in person based on participant preferences. During this meeting, participants were taught how to set up the Zoom meeting window and were taught how to use the heart rate tracker. Participants were also informed of the stress stimulation logistics such as Zoom link, passcode, video recording and lighting, sound, chat box, interview, and involvement of two facilitators to help with the study. For participants who received the heart rate trackers in the mail, these instructions (see Appendix F) were conducted via Zoom. Consent forms were given to participants, and these were signed in person or electronically, depending on participant preference (see Appendix E). All participants were asked to refrain from certain activities and consumption of certain beverages on the day of the online stress stimulation. A second meeting was scheduled and the Zoom information for this meeting was sent to each participant. Each participant had a unique Zoom link and passcode.

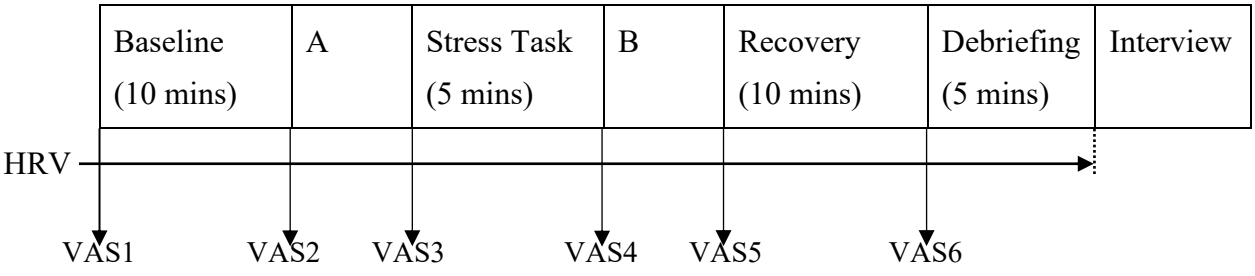
Stress Stimulation. The researcher conducted a modified version of the online Trier Social Stress Test (TSST-OL; Gunnar et al., 2021). All participants underwent the online stress stimulation in the afternoon and early evening between 1:00 pm and 6:30 pm and participants wore the heart rate device for about 35 minutes in total during the stress stimulation. At the beginning of each online stress stimulation, each participant was reminded of the option to discontinue participation in the study at any point without question. Before starting the stress stimulation, the researcher ensured that each participant adhered to refraining from certain physical activities and consuming certain beverages. The entire stress stimulation and interview were recorded using Zoom software.

The stress stimulation is composed of four phases: 1) Baseline (10 minutes), 2) Stress Task (5 minutes), 3) Recovery (10 minutes), and 4) Debriefing (5 minutes). Each participant

wore the heart rate tracker and heart rates were measured and recorded throughout the entire stress stimulation. Each participant rated their perceived stress level using the VAS at the beginning and at the end of each phase. During Baseline, each participant remained quiet in Zoom's Main Room listening to soft YouTube music. Afterwards, each participant was sent to a breakout room in Zoom for the Stress Task. During the Stress Task, each participant was given a scenario and was asked to respond to it. Afterwards, the participant was sent back to the Main Room for the Recovery. During Recovery, each participant remained quiet in the Main Room listening to the same YouTube music, similar to the procedure during Baseline. Afterwards, each participant entered the Debriefing phase. During which, each participant was debriefed for 5 minutes, making sure that the participant is safe and plans for retrieving the heart rate tracker was discussed. After this phase, each participant was asked to take off the heart rate tracker. After which, each participant underwent an interview to discuss their experience going through the online stress stimulation and overall stress management as a person. A detailed overview of the online stress stimulation is shown in Figure 1.

Figure 1.

Overview of the Online Stress Stimulation



Note. The participant starts off in the Main Room in Zoom. Letter A denotes sending the participant to Room 1 and letter B denotes sending the participant back to the Main Room. HRV is measured from Baseline until the end of Debriefing.

Research Questions and Hypotheses

The research questions and hypotheses for the current study are indicated as follows.

RQ 1. Does the subjective stress response of autistic individuals differ from the subjective stress response of those without autism within each of the three phases (i.e., Baseline, Stress Task, Recovery)? (For this research question, each participant will have their VAS for each phase represented by the average of the VAS scores from the beginning and end of the phase [e.g., average of Baseline T1 and T2, average of Stress Task T3 and T4, and average Recovery T5 and T6]. The group mean VAS average scores will then be compared across groups within each phase.)

> ***H.1.a.*** The mean Baseline VAS scores for autistic individuals will be significantly lower when compared to the mean Baseline VAS scores of individuals without autism.
>
> ***H.1.b.*** The mean Stress Task VAS scores for autistic individuals will be significantly lower when compared to the mean Stress Task VAS scores of individuals without autism.
>
> ***H.1.c.*** The mean Recovery VAS scores for autistic individuals will be significantly lower when compared to mean Recovery VAS scores for individuals without autism.

RQ 2. Do the objective stress responses of autistic individuals differ from the objective stress responses of those without autism during each of the three phases (i.e., Baseline, Stress Task, Recovery)? (The HRV index [referred to as objective stress response above] is represented by a single overall score for each phase.)

> ***H.2.a.*** The high frequency (normal units) HRV index from autistic individuals will be significantly lower when compared to individuals without autism during the Baseline.

H.2.b. The high frequency (normal units) HRV index from autistic individuals will be significantly lower when compared to individuals without autism during the Stress Task.

H.2.c. The high frequency (normal units) HRV index from autistic individuals will be significantly lower when compared to individuals without autism during the Recovery.

RQ 3. What is the relationship between the subjective stress responses (VAS) Baseline-to-Stress Task phase difference and the objective stress response (HRV) Baseline-to-Stress Task phase difference within each group? (For this research question, each participant's Baseline score will be subtracted from their Stress Task score. This was done for ease of interpretation [i.e., positive value indicates higher than Baseline, while negative value indicates lower than Baseline]. For the VAS, this will involve the phase average score for each participant [i.e., average Stress Task AS – average Baseline VAS]. For the HRV, this will involve the single HRV Index for the phase for each participant [i.e., Stress Task HRV Index – Baseline HRV Index].)

H.3.a. Autistic individuals will show a negligible-to-small and non-significant correlation between subjective (mean Stress Task – mean Baseline Phase) difference scores and objective (Stress Task – Baseline Phase) difference scores.

H.3.b. Typically developing individuals will show a medium-to-large, significant correlation between subjective (mean Stress Task – mean Baseline Phase) difference scores and objective (Stress Task – Baseline Phase) difference scores.

RQ 4. How do individuals with and without autism describe their experience of stressful situations? (*Exploratory*)

Data Preprocessing

Subjective stress response data were obtained using the VAS. To account for

participants' stress perception at each phase of the stress stimulation (i.e., Baseline, Stress Stimulation, and Recovery), the differences in VAS scores at the beginning and end of each phase were computed and their absolute values were obtained.

Objective stress response data were collected by gathering the heart rate per second for each participant using the UMI Care Device. This device captured the PPG data which was then uploaded into an Excel spreadsheet. A manual calculation of the heartbeat per minute using Excel function was done to obtain the inter-beat intervals (IBI) in millisecond. This was done by dividing each heartbeat from the PPG data by 60,000 to calculate the heartbeat per millisecond per minute. The resulting file was then saved as a .txt file and then analyzed using Kubios HRV software (version 3.4.3; Tarvainen et al., 2014) and time-domain indices (i.e., SDNN, RMSSD and NN50) and frequency domain indices (i.e., high and low frequencies) were obtained as were done in previous studies (Cai et al., 2019; Evrengül et al., 2005; Hollocks et al., 2019; Montano et al., 2009; Umetani et al., 1998) and in HRV studies involving the ASD population (Cheng et al., 2020). The Task Force of the European Society of Cardiology and the North American Society for Pacing and Electrophysiology recommends *manual* identification of ectopic beats of HRV data (Laborde et al., 2017; Malik, 1996). However, it has been argued that there is no consensus on the type of preprocessing method for HRV artefact correction and errors and misreporting can occur when HRV data is manually edited (Peltola, 2012). Therefore, an automatic correction embedded within the Kubios HRV software was utilized as was previously done in other studies to correct for ectopic and misplaced beats (Aranda et al., 2017; Lipponen & Tarvainen, 2019; Plaza-Florido et al., 2021). Table 1 shows the unit of measurement for each HRV index in this study.

Table 1.

Heart Rate Variability Index Unit of Measurement

Parameter	Unit	Description
Time Domain Measures		
RMSSD	millisecond	Root mean square of successive RR interval differences
NN50	beats	Successive RR intervals that differ by more than 50 milliseconds
Frequency Domain Measures		
LF	normal units	Relative power of the low frequency band in normal units
HF	normal units	Relative power of the high frequency band in normal units

Note. Adapted from "An Overview of Heart Rate Variability Metrics and Norms" by F. Shaffer, J. P. Ginsberg, 2017, Frontiers in Public Health, 5, 258. Copyright 2017 by the Frontiers in Public Health.

In addition, heart rate data were broken down in accordance with the different phases of the online stress stimulation. Even though the overall study duration was 30 minutes (i.e., 10 minutes baseline, five minutes stress task, 10 minutes recovery, and five minutes debriefing), the average heart rate sample obtained across participants was 36 minutes and 13 seconds. After preprocessing of the heart beats, the obtained sample duration was 31 minutes (1860 seconds) with one sample having 1859 seconds. The difference is due to participant instruction at the beginning and at the end of the study and the lag in time moving participants through different virtual rooms in Zoom; this lag was due to, sometimes, poor internet connectivity on the part of the researcher and/or the participants.

Data Management

Normality checks and effect sizes were computed for all subjective and objective stress responses. Assumptions for normality were conducted for all subjective and objective stress responses and objective stress responses using histograms, boxplots, and Shapiro-Wilk tests. Cohen's *d* effect sizes for each variable were computed by using the IBM Statistical Package for the Social Sciences (SPSS; IBM Corp., 2020) version 27.0.

Data Analysis

Descriptive statistics were computed for all demographic variables such as age, gender, education. Subjective stress responses were visually analyzed using histograms, and line graphs to compare differences between groups. For the assessment of subjective stress between-group differences (i.e., between ASD and non-ASD) within each phase (i.e., Baseline, Stress Task, Recovery), the subjective stress VAS score at the start of a phase was averaged together with the VAS score for the end of the phase. This was done to provide a composite mean VAS score for each participant in each phase. The between-groups difference within each phase was assessed using an independent sample *t*-test. The objective stress responses (psychophysiological measure) were measured using the high frequency (normal units) HRV index, which reflected the HRV for each entire phase. HRV between-groups differences (i.e., ASD and non-ASD) within each phase was assessed using an independent samples *t*-test. Furthermore, the correlation between two difference scores (i.e., each participant's average VAS Stress Task score minus their average VAS Baseline score vs. their high frequency [normal units] HRV Index for Stress Task minus their HRV Index for Baseline) was calculated within each group to assess if changes in subjective reports of stress and changes in objective stress, between the Baseline and Stress

Task phases, were related. Findings from the qualitative interview was be used to explain discrepancy or congruence in findings in the research questions.

CHAPTER 4

RESULTS

The purpose of the present study was to examine the subjective (psychological) and objective (psychophysiological) stress responses of autistic young adults and compare them to typically developing young adults. There were 12 in the autistic group and 24 in the non-autistic group. All participants underwent an online stress stimulation and measures of their subjective and objective stress experiences were obtained. This chapter provides the results of descriptive and quantitative inferential analyses examining the research questions and hypotheses. Brief information from the qualitative interview regarding participants' stress experiences related to the online stress stimulation are provided for both exploratory purposes and to assist in explaining the quantitative results.

Participant Characteristics

Details of the participant characteristics are presented in Table 2. Considering all potential participants in both the autistic and in the non-autistic group, a total of 141 individuals requested participation in the study, and were contacted for the screening via email, phone call, and/or Zoom. Of the 141, 59 agreed to be screened, six of which were screened out, and the rest were asked to participate. Three participants in the autistic group dropped out before beginning the stress stimulation. This resulted in 46 participants undergoing the stress stimulation. Among the 46 participants, 14 participants were in the autistic group and 32 were in the non-autistic group. Of those in the autistic group, one autistic participant requested not to complete the entire online stress stimulation midway through the Stress Task due to severe stress. Another autistic participant went through the entire online stress stimulation. However, upon retrieval of the heart rate data from the device, the data was corrupted. Data from these participants were excluded in

Table 2.

Case Counts and Frequencies for Categorial Demographic Characteristics of Young Adults in College with and without ASD

Demographic Characteristics	ASD (n = 12)		Non-ASD (n = 24)	
	n	%	*n*	%
Gender				
Female	4	33	14	58
Male	4	33	10	42
Trans	2	17	--	--
Non-binary	2	17	--	--
Race				
White	11	92	18	75
Black	1	8	1	4
Asian	--	--	4	17
Native American/Alaska Native	--	--	1	4
Ethnicity				
Hispanic/Latinx	1	8	1	8
Academic Status				
Freshman	2	17	2	8
Sophomore	4	33	15	63
Junior	2	17	7	29
Senior	3	25	--	--
Prefer not to answer	1	8	--	--
Professionals who diagnosed				
Clinical Psychologist	9	75	--	--
Psychiatrist	2	17	--	--
Other or don’t recall	1	8	--	--

Table 2. (cont'd)

Demographic Characteristics	ASD (n = 12)		Non-ASD (n = 24)	
	n	%	n	%
Comorbidity				
Attention-deficit Hyperactivity Disorder	6	--	--	--
Generalized Anxiety Disorder	7	--	--	--
Major Depressive Disorder	5	--	--	--
Obsessive Compulsive Disorder	1	--	--	--
Post-traumatic Stress Disorder	2	--	--	--

Note. Each participant reported one or more co-occurring diagnoses.

the study. Among the 32 participants in the non-autistic group, the data from two participants were corrupted as well and six had diagnostic conditions (e.g., ADD, ADHD, MDD) that precluded the data gathered in the analysis. In the end, a total of 36 participants qualified for the study with 12 autistic participants were in the ASD group and 24 typically developing participants were in the non-autistic group.

Participants' age, gender, race, and ethnicity were obtained. In terms of age in the ASD group, 42% of participants were 19 years old (n = 5), 17% of participants were 21 years old (n = 2), 17% of participants were 22 years old (n = 2) , 8% of participants were 18 years old (n = 1), 8% of participants were 20 years old (n = 1), and 8% of participants were 23 years old (n = 1). Regarding age in the non-ASD group, 71% of participants were 20 years old (n = 17), 17% of participants were 21 years old (n = 4), 8% of participants were 22 years old (n = 2), and 4% of participants were 19 years old (n = 1). In terms of gender in the ASD group, 33% were females (n = 4), 33% were males (n = 4), 17% were trans (n = 2), and 17% were non-binary (n = 2). In the non-ASD group, 58% were females (n = 14) and 42% were males (n =10). In terms of race in

the ASD group, 92% reported White (*n* = 11) and 8% reported Black (*n* = 1). In the non-ASD group, 75% reported White (*n* = 18), 17% reported Asian (*n* = 4), 4% reported American Indian or Alaska Native (*n* = 1), and 4% reported Black (*n* = 1). One person reported Hispanic/Latinx in the ASD group and in the non-ASD group.

Academic status and work information were also obtained. In terms of academic status in the ASD group, 33% were sophomores (*n* = 4), 25% were seniors (*n* = 3), 17% were freshmen (*n* = 2), 17% were juniors (*n* = 2), and 8% preferred not to answer (*n* = 1). In terms of academic status in the non-ASD group, 63% were juniors (*n* = 15), 29% were seniors (*n* = 7), and 8% were sophomores (*n* = 2). In terms of work hours in the ASD group, 33% reported not working (*n* = 4), 33% reported working 1-10 hours per week (*n* = 4), 25% reported working 12-20 hours per week (*n* = 3), and 8% reported working 40 hours per week (*n* = 1). In terms of work hours in the non-ASD group, 38% reported not working (*n* = 9), 21% reported working 21-30 hours per week (*n* = 5), 17% of participants reported working 11-20 hours per week (*n* = 4), 17% reported working 31-40 hours per week (*n* = 4), and 8% reported 1-10 hours per week (*n* = 2).

Levels of exercise activity per week are also reported. Since physical activity affects HRV, participants' levels of exercise activities were also obtained. In terms of the level of exercise in the ASD group, 33% reported no exercise (*n* = 4), 33% reported 1-5 hours of exercise per week (*n* = 4), 25% reported 6-10 hours of exercise per week (*n* = 3), and 8% reported 11-20 hours of exercise per week (*n* = 1). In terms of the level of exercise in the non-ASD group, 45% reported 1-5 hours of exercise per week (*n* = 11), 33% reported 6-10 hours of exercise per week (*n* = 8), 13% reported no exercise (*n* = 3), and 8% reported 11-15 hours of exercise per week (*n* = 2).

Levels of involvement in extracurricular activities per week are also reported. In terms of extracurricular activities per week in the ASD group, 50% reported 1-5 hours of involvement in extracurricular activities per week (n = 6), 17% reported no involvement in extracurricular activities (n = 2), 17% reported 6-10 hours of involvement in extracurricular activities per week (n = 2), and 17% reported 11-15 hours of involvement in extracurricular activities per week (n = 2). In terms of extracurricular activities per week in the non-ASD group, 46% reported no involvement in extracurricular activities (n = 11), 42% reported no involvement in extracurricular activities (n = 5), and 33% reported no involvement in extracurricular activities (n = 8).

Participants self-reported use of prescription medications. Since medications can affect HRV, use of medications among participants was gathered. Use of medications among the non-ASD group precluded prospective participants from participating. However, use of medications in the ASD group was documented and reported. The medications used by participants were selective serotonin reuptake inhibitors (n = 6), amphetamine dextroamphetamine (n = 2), aripiprazole (n = 2), methylphenidate hydrochloride (n = 2), tretinoin (n = 1), lisdexamfetamine dimesylate (n = 1), alprazolam (n = 1), guanfacine (n = 1), risperidone (n = 1), benzodiazepines (n = 1), hydrocodone-acetaminophen (n = 1), methylphenidate (n = 1), lamotrigine (n = 1), atenolol (n = 1), clonazepam (n = 1), and bupropion hydrochloride (n = 1). Four female participants reported using birth control medications. These are reported since previous literature suggested the influence of the female menstrual cycle to influence cardiac autonomic regulation (Bai et al., 2009; Sato et al., 1995; Tenan et al., 2014) though one study found that the use of birth control medications does not affect HRV (Teixeira et al., 2015).

Autism diagnosis was determined using self-report. All autistic participants were reportedly diagnosed by either a psychologist or a psychiatrist. In terms of comorbidity diagnoses in the ASD group, two participants were diagnosed with attention-deficit hyperactivity disorder, generalized anxiety disorder, and major depressive disorder; two participants were diagnosed with attention-deficit hyperactivity disorder and generalized anxiety disorder; four participants were diagnosed with generalized anxiety disorder and major depressive disorder; three participants were diagnosed with attention-deficit hyperactivity disorder alone; and two participants were also diagnosed with post-traumatic stress disorder. None of the participants were actively seeking psychotherapy treatment for any of their diagnoses at the time of participation in the study.

Descriptive Data

Subjective stress was measured by VAS which were obtained at six time points (see Figure 1) during the online stress stimulation. To characterize the subjective stress responses during Baseline, Stress Task, and Recovery, VAS measures at time points 1 and 2 (Baseline) were averaged, time points 3 and 4 (Stress Task) were averaged, and time points 5 and 6 (Recovery) were averaged. This was done so that each participant had an average VAS value for each phase. Physiological stress response was assessed by measuring the heart rate for each second during the online stress stimulation. To characterize the objective stress response during Baseline, Stress Task, and Recovery, the obtained heart rates were divided into Baseline (10 minutes), Stress Task (6 minutes), and Recovery (10 minutes) and each heart rate file was analyzed in Kubios HRV software to obtain the high frequency [HF] (normal units) HRV index for phase (i.e., Baseline, Stress Task, and Recovery).

Subjective and objective stress variables were analyzed visually using histograms and line graphs to observe between-group differences. These are described below.

Histograms of the VAS scores and HF HRV index for Baseline, Stress Task, and Recovery are presented in Figures 2 and 3. Since two VAS scores were obtained (one at the beginning and one at the end) for each phase, the average of these values were computed to represent the VAS score for a particular phase (i.e., Baseline, Stress Task, Recovery). Generally, the histograms reveal non-normal distributions.

Line graphs of the mean VAS scores and the mean HF HRV index for Baseline, Stress Task, and Recovery are presented in Figures 4 and 5. Overall, a similar pattern of increase and decrease in VAS scores across phases was observed in both groups and a differential pattern was observed in the HF HRV index in both groups.

Scatter plots of the computed differences between the average VAS Stress Task score minus the average VAS Baseline score and the high frequency (normal units) HRV Index for Stress Task minus the high frequency (normal units) HRV Index for Baseline for each group are presented in Figures 6 and 7. Overall, a small-to-negligible correlation was observed within each group.

Research Questions and Hypotheses

RQ 1. Does the subjective stress response of autistic individuals differ from the subjective stress response of those without autism within each of the three phases (i.e., Baseline, Stress Task, Recovery)? (For this research question, each participant will have their VAS for each phase represented by the average of the VAS scores from the beginning and end of the phase [e.g., average of Baseline T1 and T2, average of Stress Task T3 and T4, and average Recovery T5 and

T6]. The group mean VAS average scores will then be compared across groups within each phase.)

H.1.a. The mean Baseline VAS scores for autistic individuals will be significantly lower when compared to the mean Baseline VAS scores of individuals without autism.

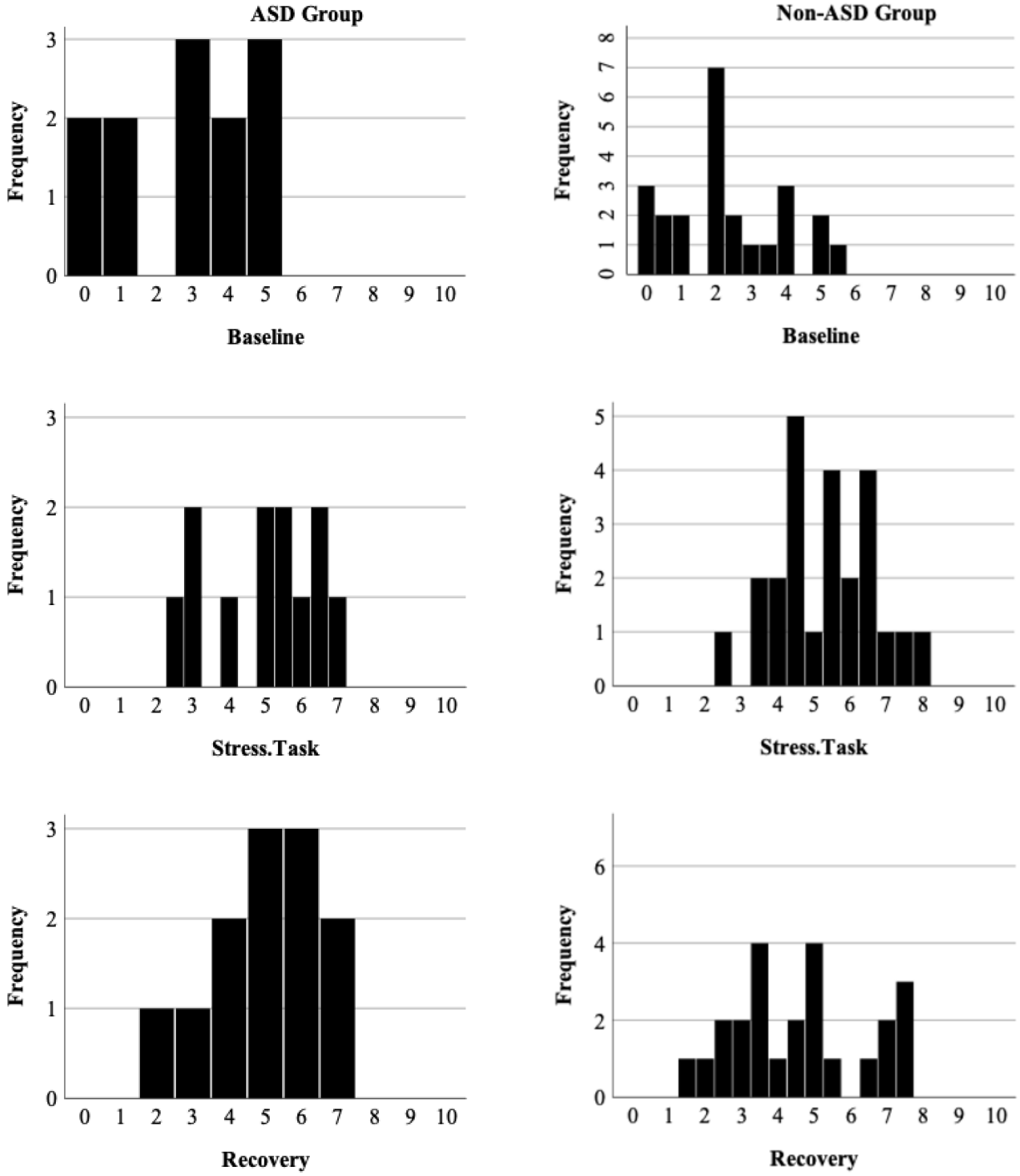
H.1.b. The mean Stress Task VAS scores for autistic individuals will be significantly lower when compared to the mean Stress Task VAS scores of individuals without autism.

H.1.c. The mean Recovery VAS scores for autistic individuals will be significantly lower when compared to mean Recovery VAS scores for individuals without autism.

To answer RQ 1, descriptive statistics were computed and are presented in Table 3. Since there were two VAS measures for Baseline (beginning and end), the average VAS score was computed for each phase (i.e., Baseline, Stress Task, Recovery). All participants were asked the question "How would you rate your stress level at this time? Please choose just one number from 0, no stress, to 10, extremely stressed" before and after the Baseline, Stress Task, and Recovery phases. The computed means, standard deviations, range independent samples *t*-tests, and Mann Whitney *U* tests were calculated for the three phases (i.e., Baseline, Stress Task, Recovery) for both ASD and non-ASD groups. **Considering *RQ 1***, overall, the observed means for the VAS measure across the two groups were similar within each phase and VAS means for both groups showed similar patterns across phases (see Figure 4). Considering ***H.1.a.,*** during Baseline, the ASD group showed a higher observed mean VAS measure ($M = 2.63$, $SD = 1.87$) than the non-ASD group ($M = 2.33$, $SD = 1.64$). However, the results of both parametric and non-parametric statistical tests (i.e., independent samples *t*-test and Mann Whitney *U* test) for Baseline were ($t[34] = -.48$, $p = .63$ and $U[N_{ASD} = 12, N_{Non\text{-}ASD} = 24] = 126.50$, $z = -.59$, $p = .55$) non-significant; therefore, this hypothesis was not supported. Considering ***H.1.b.,*** during the Stress

Figure 2.

Histograms of the Mean Visual Analog Scale Measure in Each Group by Phase



Note. The computed VAS scores were the average of the two VAS score (at the beginning and at the end) for each phase (i.e., Baseline, Stress Task, Recovery).

Figure 4.

Visual Depiction of the Mean Visual Analog Scale Measure Responses by Group Across Phases

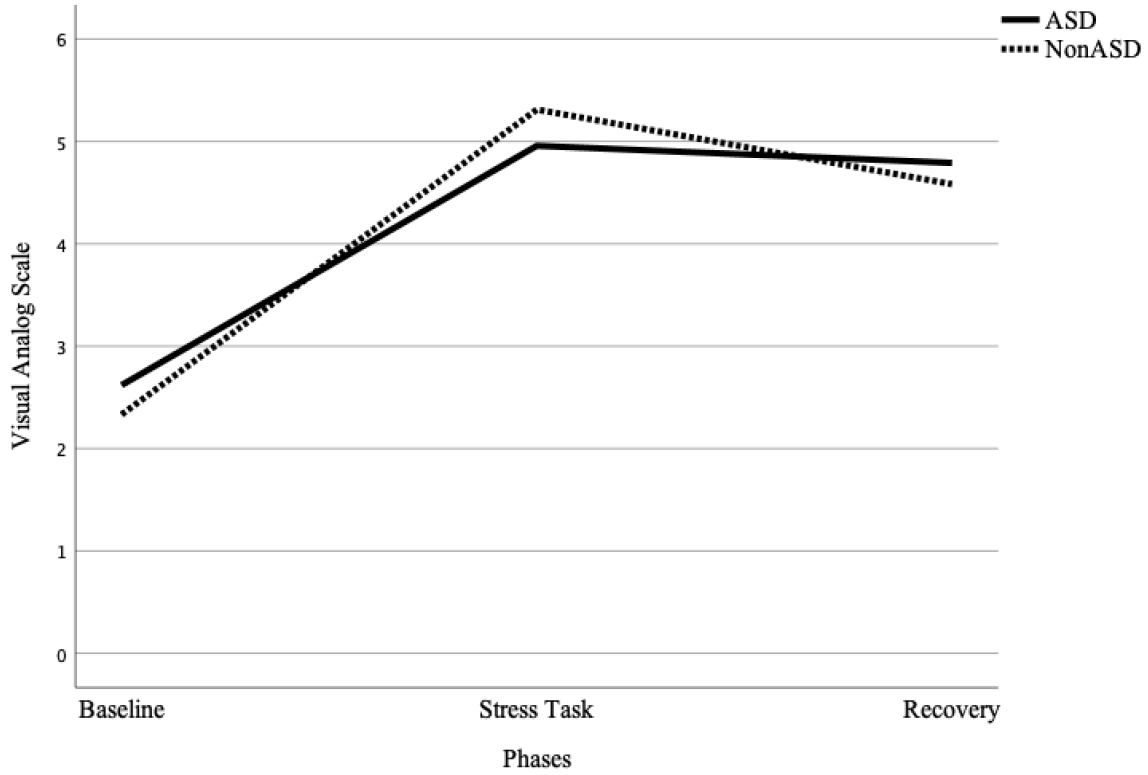


Table 3.

Descriptive Summary of the Visual Analog Scale Measure

	Visual Analog Scale							
	ASD			Non-ASD				
	M	*SD*	Range	*M*	*SD*	Range	*t*-test	*p*-value
Baseline	2.63	1.87	0.00 – 5.00	2.33	1.64	0.00 – 5.50	-.48	.63
Stress Task	4.96	1.51	2.50 – 7.00	5.31	1.37	2.50 – 8.00	.71	.48
Recovery	4.80	1.50	2.00 – 7.00	4.58	7.50	1.50 – 7.50	-.34	.74

Note. Non-parametric Mann Whitney *U* test results are reported in the text but are not included in the table. Statistical conclusions were the same for both parametric and non-parametric tests.

Task, the ASD group showed a lower observed mean VAS measure (M = 4.96, SD = 1.51) than the non-ASD group (M = 5.31, SD = 1.37). However, parametric and non-parametric tests for the Stress Task (t[34] = .71, p = .48 and U[N_{ASD} = 12, $N_{Non\text{-}ASD}$ = 24] = 129.00, z = -.51, p = .61) were non-significant; therefore, this hypothesis was not supported. Considering ***H.1.c.,*** during Recovery, the ASD group showed a higher observed mean VAS measure (M = 4.80 SD = 1.50) than the non-ASD group (M = 4.58, SD = 7.50). However, again, parametric and non-parametric tests of the between-groups difference within the Recovery phase (t[34] = -.34, p = .74 and U[N_{ASD} = 12, $N_{Non\text{-}ASD}$ = 24] = 132.00, z = -.40, p = .69) were non-significant; therefore, this hypothesis was not supported.

RQ 2. Do the objective stress responses of autistic individuals differ from the objective stress responses of those without autism during each of the three phases (i.e., Baseline, Stress Task, Recovery)? (The HRV index [referred to as objective stress response above] is represented by a single overall score for each phase.)

> ***H.2.a.*** The high frequency (normal units) HRV index from autistic individuals will be significantly lower when compared to individuals without autism during the Baseline.
>
> ***H.2.b.*** The high frequency (normal units) HRV index from autistic individuals will be significantly lower when compared to individuals without autism during the Stress Task.
>
> ***H.2.c.*** The high frequency (normal units) HRV index from autistic individuals will be significantly lower when compared to individuals without autism during the Recovery.

To answer RQ 2, descriptive statistics were computed and are presented in Table 4. The means, standard deviations, range, independent sample t-tests, and Mann Whitney U tests were calculated for each of the three phases (i.e., Baseline, Stress Task, Recovery) to assess the

difference between the ASD and non-ASD groups. **Considering *RQ 2***, overall, the observed means for the HF HRV index across the two groups were similar within each phase and HF HRV means for both groups showed similar patterns across phases (see Figure 5). Considering ***H.2.a.,*** during Baseline, the ASD group showed a higher observed mean HF HRV index measure (M = 38.09, SD = 6.57) than the non-ASD group (M = 35.58, SD = 8.05). However, the results of both parametric and non-parametric statistical tests (i.e., independent samples t-test and Mann Whitney U test) for Baseline were (t[34] = -.93, p = .36 and $U[N_{ASD} = 12, N_{Non\text{-}ASD} = 24]$ = 118.00, z = -.87, p = .38) non-significant; therefore, this hypothesis was not supported. Considering ***H.2.b.,*** during the Stress Task, the ASD group showed a lower observed mean HF HRV index measure (M = 33.65, SD = 12.36) than the non-ASD group (M = 34.46, SD = 8.72). However, parametric and non-parametric tests for the Stress Task were (t[34] = .23, p = .82 $U[N_{ASD} = 12, N_{Non\text{-}ASD} = 24]$ = 139.00, z = -.17, p = .87) non-significant; therefore, this hypothesis was not supported. Considering ***H.2.c.,*** during Recovery, the ASD group showed a higher observed mean HF HRV index measure (M = 37.34, SD = 5.50) than the non-ASD group (M = 35.55, SD = 6.23). However, again, parametric and non-parametric tests of the between-groups difference within the Recovery phase (t[34] = -.88, p = .39 $U[N_{ASD} = 12, N_{Non\text{-}ASD} = 24]$ = 113.00, z = -1.04, p = .30) were non-significant; therefore, this hypothesis was not supported.

Effect sizes were computed for VAS measures and HF HRV index, and these are presented in Table 5. For the VAS measure, standardized mean difference effect sizes of .2, .5, and .8 were considered small, medium, and large, respectively (Cohen, 1988). Obtained effect sizes estimates ranged from negligible (i.e., 0.04) to small (i.e., 0.17 – 0.24) for VAS measures during Baseline, Stress Task, and Recovery. According to Quintana (2017), recommended effect size d standards for HF HRV studies are small = 0.26, medium = 0.51, and large = 0.88.

Figure 3.

Histograms of the High Frequency HRV Index Measure in Each Group by Phase

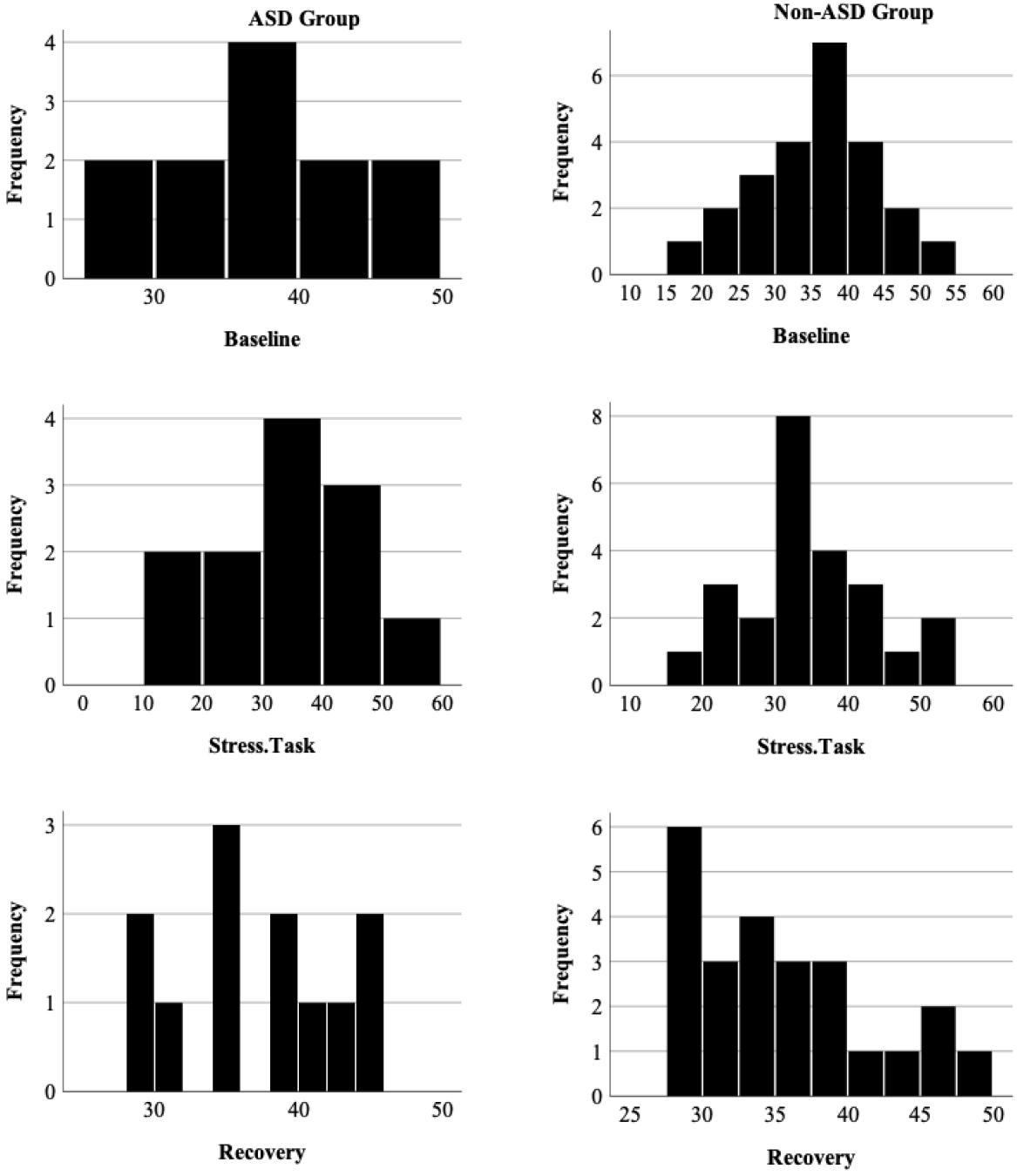


Figure 5.

Visual Depiction of the Mean HF HRV Index Measure Responses by Group Across Phases

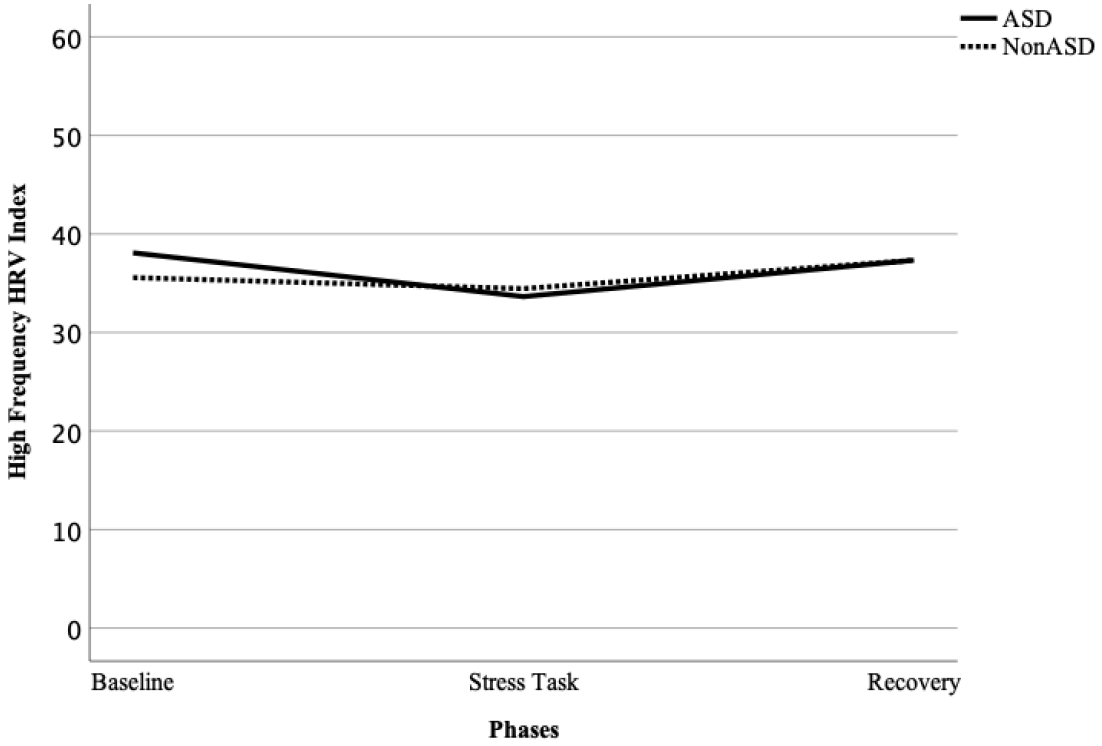


Table 4.

Descriptive Summary of the High Frequency HRV Index Measure

	High Frequency HRV Index Measure (nu)							
	ASD			Non-ASD				
	M	*SD*	Range	*M*	*SD*	Range	*t*-test	*p*-value
Baseline	38.09	6.57	27.97 – 49.50	35.58	8.05	18.23 – 50.08	-.93	.36
Stress Task	33.65	12.36	13.69 – 55.59	34.46	8.72	19.19 – 54.01	.23	.82
Recovery	37.34	5.50	29.78 – 45.57	35.55	6.23	27.75 – 43.39	-.88	.39

Note. Non-parametric Mann Whitney *U* test results are reported in the text but are not included in the table. Statistical conclusions were the same for both parametric and non-parametric tests.

Table 5.

Cohen's d Effect Size Estimates

	Cohen's *d*		
	Baseline	Stress Task	Recovery
Visual Analog Scale	0.17	0.24	0.04
High Frequency HRV Index	0.34	0.08	0.30

Obtained effect size estimates ranged from negligible (i.e., 0.08) to small (i.e., 0.30 – 0.34) for HF HRV index during Baseline, Stress Task, and Recovery.

RQ 3. What is the relationship between the subjective stress responses (VAS) Baseline-to-Stress Task phase difference and the objective stress response (HRV) Baseline-to-Stress Task phase difference within each group? (For this research question, each participant's Baseline score will be subtracted from their Stress Task score. This was done for ease of interpretation [i.e., positive value indicates higher than Baseline, while negative value indicates lower than Baseline]. For the VAS, this will involve the phase average score for each participant [i.e., average Stress Task AS – average Baseline VAS]. For the HRV, this will involve the single HRV Index for the phase for each participant [i.e., Stress Task HRV Index – Baseline HRV Index].)

> ***H.3.a.*** Autistic individuals will show a negligible-to-small and non-significant correlation between subjective (mean Stress Task – mean Baseline Phase) difference scores and objective (Stress Task – Baseline Phase) difference scores.
>
> ***H.3.b.*** Typically developing individuals will show a medium-to-large, significant correlation between subjective (mean Stress Task – mean Baseline Phase) difference scores and objective (Stress Task – Baseline Phase) difference scores.

To answer RQ 3, first, the VAS average for Stress Task minus the VAS average for Baseline was computed. Second, the HF HRV Index for Stress Task minus the HF HRV Index for Baseline was computed. The Pearson correlation between these two values was then calculated within the ASD group and the Non-ASD group. The scatter plots for these correlations are presented in Figures 6 and 7. **Considering *RQ 3***, observed correlations in the two groups ranged from small (r = -.10) to negligible (r = .02). Considering ***H.3.a.***, the result shows a small and non-significant correlation between subjective difference and objective difference stress responses in the ASD group, $r(10) = -.10$, $p = .76$; therefore, this hypothesis was supported. Considering ***H.3.b.***, the result showed a negligible and non-significant correlation between subjective difference and objective difference stress responses in the non-ASD group, $r(22) = .02$, $p = .95$; therefore, this hypothesis was not supported.

It should be noted for the ASD group, that the scatter plot (see Figure 6) suggested a potential outlier case in the lower left quadrant. When this data point was removed, the correlation increased to $r(9) = -.48$, $p = .135$ (non-significant). However, when the next most influential data point was removed, the correlation decreased to $r(8) = -.184$, $p = .611$ (non-significant). Whether any influential cases were removed or left in, the results for the correlation were non-significant and consistent with the hypothesized prediction.

RQ 4. How do individuals with and without autism describe their experience of stressful situations? (*Exploratory*)

To further understand discrepancies and congruences on stress experiences between the groups, the researcher used interview data obtained from all participants after the completion of the online stress stimulation. The researcher obtained data from participants' answers to three relevant qualitative interview questions. The first question "How was your overall experience of

Figure 6.

Scatter Plot for the Correlation Between High Frequency HRV Index Measure and Visual Analog Scale Measure for ASD Group

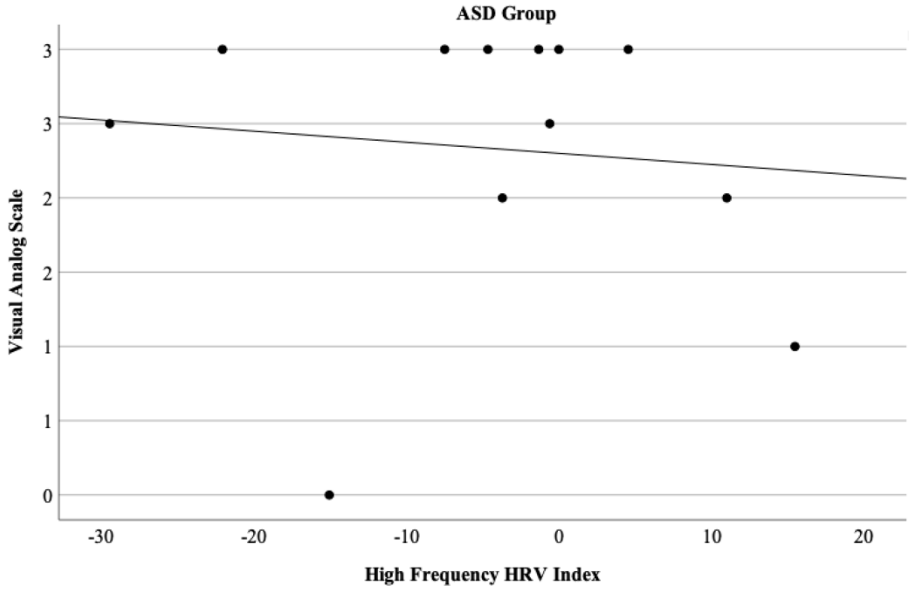
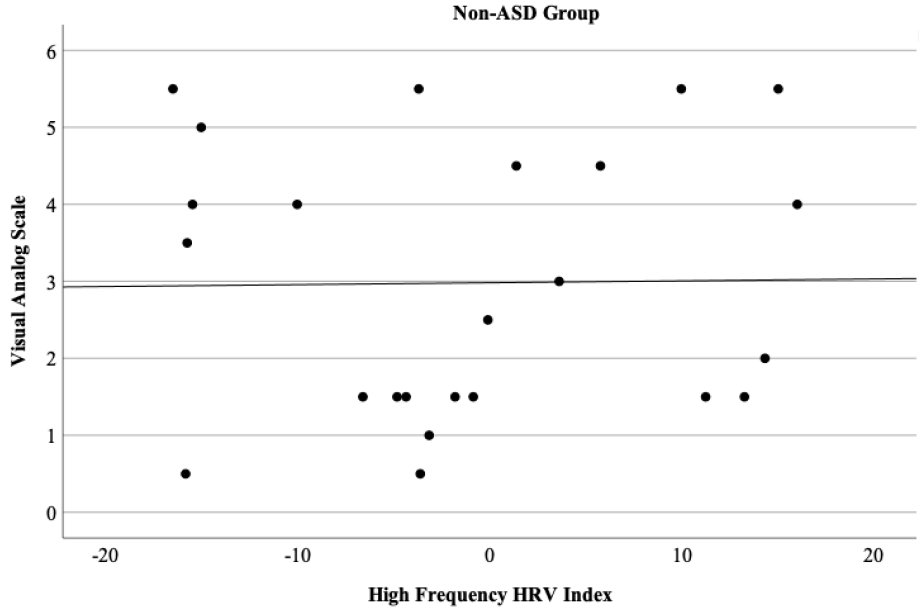


Figure 7.

Scatter Plot for the Correlation Between High Frequency HRV Index Measure and Visual Analog Scale Measure for Non-ASD Group



this activity?" was asked initially to get a general sense of how the participants reacted to the online stress stimulation and to get their overall perspective of their experience. All participants' answer to this question was unanimous, that the online stress stimulation was stressful, surprising, shocking, and unexpected. Generally, participants explained that talking about themselves was not something they would typically deem as a stressful experience even though all of them felt an increase in their perceived stress level. In addition, they explained that their feeling of stress was due to the length of time they had to talk about themselves, the two research facilitators' demeanors and non-verbal cues, and the fact that they were told their non-verbal cues were being evaluated. Despite these, both ASD and non-ASD groups used coping strategies to help with when feeling overwhelmed from the stressful stimuli.

The second question was "What is the first thing you do when you feel overwhelmed with emotions?" This question was asked since it would not be feasible to ask how participants coped during the online stress stimulation because they were paid to complete the study. Therefore, they may not have considered opting out during participation. In addition, participants were encouraged to speak as much as they could for five minutes, leaving them no opportunity to use coping skills such as controlled breathing, meditation, or mentally tuning out during the study. Despite all participants not being able to opt out or use these coping skills during the stress stimulation, these general stress coping mechanism and subjective psychological perspective provides unique insight into how participants would behave in response to stress and whether they were able to pay attention to how their body responds to stress. Autistic young adults generally had coping mechanisms and skills they could use to offset and mitigate day-to-day stressful situations. Particularly, many autistic participants would step away from the stressful situation (avoidance) whether physically or mentally, depending on the context and the situation

if they could. The activities they engaged in to cope include sleeping, being distracted, talking to other people about their feelings, reading, dancing, journaling, playing computer games, watching movies, listening to music, and getting on social media. To help calm down and change overwhelming stressful feelings, they used tools such as a weighted blanket while laying down on the bed in a quiet room or a timer to help objectively evaluate stressful situations to let time pass before re-engaging with the stressful situation. It is worth noting that five of the 12 autistic participants had worked closely with therapists and psychologists for years who taught them skills such as Dialectical Behavior Therapy skills and other stress management skills such as the ability to "break [things] down into smaller chunks" to see the stressor as a challenge and manage emotions better. Though these participants would step away from the source of an overwhelming stressful stimulus, generally, they had learned from previous experience or by using an actual or a mental timer to come back to the source of the stressful stimulus to address it. Eight out of the 12 autistic participants felt a change in their emotion and stress level as time passed and as they utilized their coping mechanisms. Therefore, these pieces of information demonstrated that autistic participants in this study showed their capability to cope with stress responses.

Typically developing participants also had coping mechanisms and skills they could use to offset and mitigate day-to-day stressful situations. The main coping mechanisms used by members of the non-ASD group were avoidance, breaking things down into smaller chunks by mentally compartmentalizing events and seeing them as a challenge or writing things down and talking to a friend or a family member for advice or distraction from the overwhelming stimulus. In addition, many participants in this group gravitated to watching movies, playing phone games, reading, playing video and computer games, and going on social media to distract themselves

from overwhelming stressful stimuli. Other participants also reported participation in physical activities such as running and sports while others would make time for sleeping and focus on self-care activities. Three participants reported they would focus on their breathing the moment they felt overwhelmed, two participants reported they would normally cry right away when feeling overwhelmed, and one reported working with a psychologist or therapist to help with stress management. Fourteen out of the 22 participants felt a change in their emotion and stress level as time passed and as they utilized their coping mechanisms.

The third question was "How do you know your body is reacting to stress?" This question was asked to get information on participants' awareness of their body's reactions to stress. In addition, participants self-reported bodily sensations provide insight on how they understand that their body is responding to a stressful situation. Autistic young adults, generally, would feel their heart rate increase; would feel their heart beat stronger; would feel their face become red, warm, or flushed; and would feel a tightening of their chest. Other sensations reported by this group include sweating, heaving headaches or acid reflux, hyperventilation, and a lowered immune system. One participant noted that in private settings, her hands would flap unintentionally but in public settings she would exert a lot of effort to prevent this reaction to avoid ridicule. Similar to coping with stress, answers to this question supported that autistic participants were capable of being in tune with their bodily responses to stress.

Participants in the non-ASD group reported they would feel their heart rate increase; would feel their heart beat stronger; would feel warmth on their face and ears or sometimes an overall warmth throughout the body; would feel tension and tightening on their jaw, hands, shoulders, back, and chest; would feel sweaty; and would feel nauseous. In addition, some

participants reported having more gray hair or sometimes brittle hair or nails, migraines, and an overall feeling of the body shutting down and not having energy to do anything.

In summary, the findings from the current study did not support the set hypotheses. For RQ 1, it was hypothesized that the VAS score in the ASD group would be significantly lower compared to the non-ASD group during each phase of the stress stimulation. The results were statistically non-significant. Therefore, the hypotheses were not supported. For RQ 2, it was hypothesized that the HF HRV index in the ASD group would be significantly lower compared to the non-ASD group during each phase of the stress stimulation. Similarly, the results were statistically non-significant. Therefore, the hypotheses were not supported. For RQ 3, it was hypothesized that there would be a small correlation between the subjective and objective stress responses in the ASD group and a large correlation between the subjective and objective stress responses in the non-ASD group. The results were statistically non-significant. Therefore, these hypotheses were not supported. The statistically non-significant findings could be attributed to the low sample size. Nevertheless, RQ 4 provides some leeway to explain how participants coped with stress in general when feeling overwhelmed, as well as how their body responds to stress. Findings from RQ 4 might provide additional insight on the psychological and psychophysiological stress responses of participants. The next chapter will provide further discussion on these results, particularly in emphasizing the importance of the integration of subjective appraisal in understanding these stress experiences.

Supplementary Information on Other HRV Indices

In addition to high frequency HRV as a measure of heart rate variability, there are other HRV indices that are commonly reported. For the current study, only the high frequency HRV was used to set the hypothesis in order to preserve statistical power. However, additional HRV

indices are presented, and the group differences were calculated (see Tables 6 to 11). Since respiratory sinus arrhythmia has been associated in ASD symptomatology (Neuhaus et al., 2014), the following tables depict additional HRV data, respiration rates, and heart rates obtained in the sample. In general, these indices showed the same trends as the HF HRV when comparing between the ASD and the non-ASD groups, with no statistical significance. A more detailed explanation of the HRV indices is provided in Chapter 5.

Table 6.

Within-Group Descriptive Statistics and Between-Group Comparisons for the Low Frequency HRV Index Measure

	Low Frequency HRV Index Measure (nu)							
	ASD			Non-ASD				
	M	*SD*	Range	*M*	*SD*	Range	*t*-test	*p*-value
Baseline	61.90	6.58	50.49 – 72.02	64.43	8.05	49.91 – 81.76	.94	.55
Stress Task	66.34	12.37	44.38 – 86.30	65.53	8.72	45.98 – 80.81	-.23	.14
Recovery	61.90	5.11	54.41 – 70.21	64.44	6.24	51.61 – 72.22	1.22	.48

Table 7.

Within-Group Descriptive Statistics and Between-Group Comparisons for the RMSSD HRV Index Measure

	RMSSD HRV Index Measure (ms)							
	ASD			Non-ASD				
	M	*SD*	Range	*M*	*SD*	Range	*t*-test	*p*-value
Baseline	373.51	37.05	292.60 – 423.70	360.64	51.04	279.3 – 423.6	-.78	.03
Stress Task	365.46	30.41	300.40 – 462.80	374.60	42.70	286.00 – 440.60	.60	.78
Recovery	386.33	30.41	335.6 – 437.20	380.35	26.51	306.5 – 413.60	-.61	.27

Table 8.

Within-Group Descriptive Statistics and Between-Group Comparisons for the NN50 HRV Index Measure

	NN50 HRV Index Measure (ms)							
	ASD			Non-ASD				
	M	*SD*	Range	*M*	*SD*	Range	*t*-test	*p*-value
Baseline	191.75	43.71	123.00 – 254.00	190.67	48.36	106.00 – 276.00	-.65	.79
Stress Task	101.00	34.40	56.00 – 182.00	116.50	34.34	45.00 – 174.00	1.28	.93
Recovery	194.00	45.39	130.00 – 281.00	197.87	52.17	87.00 – 275.00	.22	.38

Table 9.

Within-Group Descriptive Statistics and Between-Group Comparisons for the SDNN HRV Index Measure

	SDNN HRV Index Measure (ms)							
	ASD			Non-ASD				
	M	*SD*	Range	*M*	*SD*	Range	*t*-test	*p*-value
Baseline	284.83	21.43	239.1 – 307.80	281.24	32.72	206.50 – 321.10	-.34	.07
Stress Task	275.95	30.08	234.9 – 340.00	287.49	32.23	226.60 – 333.70	1.03	.52
Recovery	289.36	17.12	250.90 – 316.30	284.50	21.91	217.9 – 312.1	-.67	.40

Table 10.

Within-Group Descriptive Statistics and Between-Group Comparisons for the Mean Respiration

	Respiration Measure (Hz)							
	ASD			Non-ASD				
	M	*SD*	Range	*M*	*SD*	Range	*t*-test	*p*-value
Baseline	.17	.03	.11 - .23	.17	.04	.10 - .26	.61	.49
Stress Task	.18	.05	.11 - .29	.17	.04	.11 - .25	-.53	.89
Recovery	.16	.03	.11 - .21	.18	.04	.10 - .25	1.47	.23

Table 11.

Within-Group Descriptive Statistics and Between-Group Comparisons for the Mean Heart Rates

	Heart Rates							
	ASD			Non-ASD				
	M	*SD*	Range	*M*	*SD*	Range	*t*-test	*p*-value
Baseline	86.91	9.76	70.42 – 99.72	87.16	19.64	62.36 – 158.75	.04	.19
Stress Task	87.05	8.94	69.40 – 101.63	91.54	21.50	69.42 – 165.34	.69	.11
Recovery	83.92	7.38	93.13 – 83.92	83.96	22.11	61.73 – 170.97	.01	.11

CHAPTER 5

DISCUSSION

Overview

The purpose of the study is to examine the subjective (psychological) and objective (psychophysiological) stress responses of autistic young adults with a group of non-autistic young adults as a comparison group. Subjective stress responses were measured by a Visual Analog Scale (VAS) and objective stress responses were measured by High Frequency Heart Rate Variability (HF HRV) Index. For the autistic group, objective stress response findings reveal higher observed HF HRV index measures during Baseline and Recovery and lower HF HRV index measure during the Stress Task. The findings from Baseline, Stress Task, and Recovery were non-significant between the ASD and non-ASD groups. Subjective stress response findings from the current study reveal higher observed mean VAS measure during Baseline and Recovery and lower mean VAS measure during the Stress Task, though the findings were also not significant. When comparing subjective and objective stress responses, findings reveal negligible and non-significant correlation between subjective and objective stress responses for the autistic group and for the non-autistic group. Studies in the autism literature on analyzing HRV using TSST have mainly focused on children and adolescents (Cheng et al., 2020) and findings from the current study provide insight on the subjective and objective stress experiences of young autistic adults.

Before providing further discussion of the results, the researcher cautions the interpretation of the findings due to the low sample size. In the current study, post hoc power analysis revealed a medium effect size at 27.9% power. However, plausible explanations will be provided to explain patterns of current findings for further inquiry. In addition, to represent the

VAS measure for each phase, time points 1 and 2 (Baseline), time points 3 and 4 (Stress Task), and time points 5 and 6 (Recovery) were averaged. This resulted to each participant obtaining a VAS score for each phase. For the HF HRV Index, the heart rates were divided into Baseline, Stress Task, and Recovery and each file was analyzed separate to obtain the HF (normal units) HRV Index for each phase (i.e., Baseline, Stress Task, and Recovery).

Objective Stress Responses

For objective stress responses, the current study used several indices to quantify HRV that are supported by current literature (Billeci et al., 2018; Cheng et al., 2020; Pace et al., 2016; Pham et al., 2021; Thapa et al., 2019). However, to preserve the power, the researcher only set the hypothesis for one HRV index (i.e., high frequency), which are one of the most commonly used as supported by the literature (Mathewson et al., 2011; Matsushima et al., 2016; Neuhaus et al., 2014; Pham et al., 2021; Schaaf et al., 2015). In the latter part of the discussion, the researcher will provide literature on findings on other indices beyond the high frequency index.

To summarize, first, the findings in the current study regarding HF HRV index are not supported in terms of the hypotheses of the mean difference between the ASD and the non-ASD group for Baseline, Stress Task, and Recovery. This non-significance could be attributed to the small sample size which has not allowed adequate power to detect any statistical differences.

In the current study, the statistically non-significant findings between the ASD and non-ASD groups may be attributed to the Stress Task protocol's potential inability to elicit the level of stress as in other studies. Specifically, participants were asked to talk about themselves similar to a job scenario. They may have had opportunities to practice this task outside the current hypothetical stress stimulation. Furthermore, the stress stimulation used in the current study was adapted from the online version of the TSST which was a systematic protocol found to be able to

detect changes in cortisol (Gunnar et al., 2021). Although cortisol and HRV are considered valid measures of psychophysiological stress responses, it is plausible that the level of sensitivity picked up by the HF HRV index measure is different. In other words, even though both cortisol levels and HRV index measure psychophysiological stress responses, the TSST protocol may not have been sensitive enough to detect psychophysiological stress response differences between ASD and non-ASD groups using HRV index.

Beyond the statistical hypothesis of the mean difference, the researcher explored the data at the descriptive level. When looking at the descriptive scores (means of each group) of the ASD and control groups, the HF HRV index measure during Baseline and Recovery had a higher observed means in the ASD group, which was an unexpected finding, while lower mean HF HRV index during the Stress Task was found in the ASD group, which was expected.

Mean Differences

Baseline and recovery. When looking at the observed means during Baseline and Recovery, results were contradictory to the literature. Specifically, the current study reveals that observed means of the HF HRV index was higher during Baseline and Recovery which contradicts the findings that autistic individuals had statistically lower HF HRV than controls during resting (i.e., Baseline and Recovery) conditions (Bujnakova et al., 2016; Mathewson et al., 2011; Matsushima et al., 2016; Thapa et al., 2019). A lower HF HRV means that participants still felt stressed during Recovery from the Stress Task. Even though these findings may be unexpected, another finding from a sample of young autistic children reported a high HF HRV index when compared to controls during resting conditions (Pace et al., 2016). Viable explanation of this finding is discussed later in this chapter.

Stress task. During the Stress Task, the observed HF HRV mean was lower in the ASD group revealed a lower HF HRV index in the ASD group which confirms findings in the literature. HRV studies in young autistic adults report statistically lower HRV during stressful situations (Dijkhuis et al., 2019; Kuiper et al., 2017). As shown in the literature, autistic individuals have lower HRV due to the psychophysiology principle of Polyvagal Theory. This theory explains the vagus nerve's influence over a person's social engagement and the non-conscious risk assessment or appraisal of a stimulus (neuroception, Slonim, 2014). The vagus nerve helps modulate the heart (HRV) during stressful situations. Furthermore, the polyvagal theory emphasizes the role of HRV in social engagement (Porges, 1995a) and adaptive social functioning (Edmiston et al., 2016).

Influence of Comorbidity

Participants in the current sample reported comorbid conditions that may have affected the HF HRV findings. Recently, scholars who reviewed the results of HRV studies and its relation to psychopathology reported that lower HRV is associated with negative outcomes (Pham et al., 2021). Findings in the literature reveal individuals with Generalized Anxiety Disorder (Chalmers et al., 2014; Tulen et al., 1996), Post-traumatic Stress Disorder (Lakusic et al., 2007), and those with Major Depressive Disorder (Kemp et al., 2010, p. 2010; Stein et al., 2000; Tulen et al., 1996) tended to have lower HRV. And unfortunately, comorbid conditions reveal an even lower HRV such as those with anxiety and depression (Kemp et al., 2012). Among autistic individuals, a 40% prevalence of anxiety has been found in this population (van Steensel et al., 2011). Findings indicate an association between anxiety and HRV which suggests decreased executive functioning and lower HRV (Guy et al., 2014). Depression is also prevalent in this population (Hollocks et al., 2019) and those with depression and autism have been found

to employ lesser reappraisal emotion regulation which leads to lower HRV compared to controls (Cai et al., 2019). Furthermore, a recent study explored the impact of an auditory stimulation and found autistic individuals with Attention-deficit Hyperactivity Disorder had both sympathetic and parasympathetic regulation activation (Bellato et al., 2021). This highlights potential relationship between arousal and symptomatology which has been implicated in HRV (Pham et al., 2021). Another recent study investigated the influence of ADHD on ASD and scholars found that ADHD mediated the slow response exhibited by autistic participants with ADHD during visual stimulation task which suggests ADHD's potential influence in response to a stimulus (Bellato et al., 2022).

Subjective Stress Responses

The VAS measure is documented in the literature as a valid measure to detect changes in stress perception among young adult and adult clinical populations (Casadaban et al., 2021; Herr et al., 2004); however, the use of this measure in the autism population is yet to be fully explored. Similar to the HF HRV measures, the non-significant findings based on the inferential statistics must be interpreted with caution because the sample size was small.

Stress task. As the inferential statistics using *t*-tests did not show significant differences between the ASD and non-ASD group, the researcher explored further by comparing the observed means of the VAS scores for each group. When looking at these observed means of the VAS measure between ASD and non-ASD groups for Baseline, Stress Task, and Recovery, the following patterns were identified. There was a lower observed mean VAS measure during the Stress Task in the ASD group as compared to the non-ASD group, meaning that autistic individuals reported lower perceived stress as compared to those in the non-ASD group during the Stress Task. This result was expected. In healthy controls, increase stress perception

following the TSST was found (Apazoglou et al., 2017; Childs et al., 2006; Kelly et al., 2008; Soravia et al., 2009) and likewise in clinical populations such as those with obesity (Rosenberg et al., 2013) and those with motor functional neurological disorders (Apazoglou et al., 2017). For autistic participants, the lower perceived stress during the Stress Task could be due to exaggerated and overestimation of abilities (Furlano et al., 2015). The job scenario was hypothetical and that participants were aware that there would be no negative consequences after completing the Stress Task. Therefore, autistic participants may have perceived the entire situation as something that should not generate a high amount of stress.

Baseline and recovery. In the ASD group, the observed mean of the VAS rating was higher as compared with the non-ASD group was higher during Baseline and Recovery when participants were not subjected to a stressful stimulus. This unexpected finding may be attributed to gender differences within the ASD group. Another study that explored gender differences among participants following the TSST found that female perceived higher stress than male (Mohammadi et al., 2019). More importantly, another study confirmed gender differences young adult males and females in perceived stress (Kudielka et al., 2004). In our ASD group, there was an equal number of female and male participants (n = 4, 50%), which was higher than what the prevalence showed in terms of male and female ratio of being diagnosed on the autism spectrum. However, the autistic sample composition also had individuals who did not fit into the biological definition of male and female. Specifically, two other participants reported in the beginning stages of transitioning to male and two other participants who identify as non-binary were born female. This increased the number of biological female participants to eight (67%). It may be that those transitioning to male and those who identified as non-binary affected traditional

female gender roles in terms of stress perception since gender roles are implicated in stress perception following the TSST (Kelly et al., 2008; Liu & Zhang, 2020).

Another potential explanation to the high observed VAS mean during Baseline and Recovery could pertain to sensory processing sensitivity prevalent in the autism population. The literature reports 90% of autistic individuals were diagnosed with sensory-perceptual abnormality, particularly auditory hypersensitivity (Gomes et al., 2008). A recent study reported sensory over-responsivity to be 60% prevalent in the autism population (Carson et al., 2022). Furthermore, a recent meta-analysis reported 38-45% prevalence of decreased sound tolerance (the ability to tolerate regular everyday sounds) and up to 70% of autistic individuals have reported experiencing it at one point in their lives (Williams et al., 2021). However, in the autism population, this sensitivity to certain sounds could impair social communication skills (Demopoulos & Lewine, 2016; Khalfa et al., 2004; Rosenhall et al., 1999). Although autistic participants in this study did not report an official diagnosis of sensory processing disorder, it may be that autistic participants may experience sensory processing issues that affected their stress response due to the music. Particularly, one participant reported feeling uneasy specifically because of the relaxing music during Baseline and Recovery and another reported not liking the relaxing music because that type of music was not something the participant would use when trying to calm down.

The high observed VAS means during Baseline and Recovery may also be attributed to anticipatory stress during these phases. All participants in the study were informed that the study was a stress stimulation; therefore, they expected to be stressed. Furthermore, they were instructed of the sequence of the study phases (i.e., Baseline, Stress Task, Recovery, Debriefing, and Interview). Since participants knew that right after Baseline, they would be sent to Room 1

where the Stress Task would take place, the high rating of VAS measure suggests that the anticipation of being sent to experience the Stress Task may have influenced the responses. Anticipatory stress has been reported as an adaptive response that allows psychological and psychophysiological responses to occur to help deal with the upcoming stressor (Schulkin, 2011; Schulkin et al., 1994). The literature suggests that anticipation toward an upcoming stressor can lead to better regulation of mental and physical states (De Raedt & Hooley, 2016). In the case of the study sample, the potential influence of anticipatory is expected since the sample population is college students who tend to experience different types of stress regarding deadlines surrounding school, employment, or professional engagements.

Subjective Perception of Stress Informs Objective Stress Responses

The current study used the Transactional Model of Stress and Coping (Lazarus & Folkman, 1984) to support the complex mechanism of stress and coping in affecting a person's adjustment. However, simply using an objective measure (HF HRV Index) may not capture the personal subjective experience of how the stress affects the individual. Although soliciting a subjective measure (VAS) enhances the understanding of whether a stressor has affected the individual, yet it does not provide further understanding on the mechanism on how unique individual experiences shape stress responses. This theory provides additional insight to other constructs such as appraisal that are relevant to the understanding of the stress phenomenon and process that cannot be explained otherwise.

The Transactional Model of Stress and Coping model posits the transactional nature of coping during stressful situations between the person's appraisal of the situation and the environment and that person's capacities, goals, beliefs relative to the stressful situation (Noret et al., 2018). Consequently, appraisal of the situation becomes critical when determining stress

perception because it helps the person manage and/or control the stressor (Graham, 2015; Raskauskas & Huynh, 2015). This model also highlights the dynamic (or transactional) nature of appraisal because appraisal requires insight regarding what is taking place and the person's attributes and characteristics. The lack of insight during stressful experiences has been reported on autistic individuals (Furlano et al., 2015; Hoza et al., 2012; Johnson et al., 2009; Lerner et al., 2012; Locke & Mitchell, 2016; McQuade et al., 2011; Vuori et al., 2017). Therefore, the use of objective measures such as HRV may allow autistic individuals to pay attention to the psychophysiological responses to stress to raise awareness of their stress responses. At the same time, the use of subjective measure and qualitative interviews cover the appraisal component of the model, thereby allowing the researcher to understand the mechanism behind their stress responses which could be different in both ASD and non-ASD groups. Therefore, combining both subjective and objective stress responses will provide a more thorough understanding of the stress experiences of participants in this study.

Comparison of Quantitative Subjective and Objective Responses

Studies examining VAS and HRV have revolved around other conditions such as chronic pain (Chang et al., 2012; Danilin et al., 2022; Martínez-Lavín et al., 1998). In this study, VAS was used to measure perceived stress as done in other studies (Hellhammer & Schubert, 2012; Strahler et al., 2010). The literature shows discrepant (e.g., exaggeration, overestimation) reporting of stress experiences in the autistic population (Hoza et al., 2012; Johnson et al., 2009; Lerner et al., 2012; Locke & Mitchell, 2016; McQuade et al., 2011; Schriber et al., 2014) which explains the small correlation observed in the ASD group.

In this study, no significant correlations were found between the subjective stress responses and objective stress responses in both ASD and non-ASD groups. This suggests there

was no relationship between how the participants perceived the stressful task and how their body responded to the stressful task. In the ASD group, this finding is consistent with the other studies that report lack of insight and discrepant reporting of stressful experiences in this population (Hoza et al., 2012; Johnson et al., 2009; Lerner et al., 2012; Locke & Mitchell, 2016; McQuade et al., 2011) but the low sample size may affect the results of the study. In the non-ASD group, the non-significant findings can be attributed to the low sample size which greatly affects statistical power when conducting the analyses.

The small correlations found in the current study may be attributed to the characteristics of the sample. Specifically, the sample population of young adults in college was accustomed to or have had similar experiences in the past (i.e., applying for a job or conducting a job interview online) that were similar to the Stress Task scenario. Because of previous experiences, the scenario used in the current study was probably a familiar experience for participants. As a result, the HPA system did not trigger as typically would be expected in stressful situations. The HPA system is a neuroendocrine response to stress to enable the body to release cortisol and allows for increased HRV via the vagus nerve (Cool & Zappetti, 2019; Hollocks et al., 2014; Porges, 1995b).

In addition, the online nature of the Stress Task may have diminished the social evaluative component of the stress stimulation because the facilitators were behind the computer screen and not evaluating them in person. Furthermore, participants were informed at the beginning of the stress stimulation they could opt out of participating at any point during the study. This may have allowed for potentially diminished stress perception using the VAS measure; participants were reminded that the online stress stimulation was not real and therefore could not negatively harm them.

Further examination of the trend line of the correlational data provides some explanation about the patterns. The autism literature reports low subjective stress perception (Hoza et al., 2012; Johnson et al., 2009; Lerner et al., 2012; Locke & Mitchell, 2016; McQuade et al., 2011) and low psychophysiological stress responses (Cheng et al., 2020), therefore we can expect a positive association between subjective stress perception and psychophysiological stress response. However, in the current study, the trend line shows a negative and inverse relationship between VAS measures and HF HRV index. This means that as subjective stress perception was high, the body's objective psychophysiological stress response was low (low HF HRV). In other words, the participants perceived a stressful stimulus as stressful, and the body's psychophysiological response to the stressful stimuli (HRV) went down. This may suggest that for our autistic participants, their body was not able to cope well in relation to and regardless of the perceived high stressful situation. However, their bodily response to a low HRV (i.e., not coping with the Stress Task) was consistent with their perception that the task was indeed stressful. Therefore, our participants were able to perceive accurately what their body's reaction was.

In the non-ASD group, the researcher speculated a positive relationship between subjective stress perception (high VAS) and objective psychophysiological stress response (high HF HRV) because the body responds to stressful stimuli in accordance with perceived stress coming from the environment (Porges, 1995a). In the current study, the trend line shows a positive relationship between VAS measures and HF HRV index. The finding is consistent with another study showing positive correlation between psychological stress responses from VAS measure and psychophysiological stress responses from saliva cortisol in healthy adults (Childs et al., 2006; Hellhammer & Schubert, 2012; Kelly et al., 2008). This means that their high stress

perception was accurately reflected in accordance with their psychophysiological stress response. In addition, this shows that their body was able to cope well in relation to the perceived stressful situation. Despite the expected findings in the study, there were unexpected findings which warranted further examination of qualitative interview data to understand the mechanism on how unique individual coping strategies can help influence stress perception, which is addressed in the following section.

Use of Interview Data to Understand Perception of Stress

Because appraisal is a significant component of perception, the researcher utilized participant's interview data to supplement current study findings. Participants were interviewed and some of the questions that were asked were "How was your overall experience of this activity?", "What is the first thing you do when you feel overwhelmed with emotions?", and "How do you know that your body is reacting to stress?"

In the ASD group, participants used avoidance and other coping strategies in response to overwhelming stressful situations, however they were not able to do so during the Stress Task. Generally, autistic participants reported using avoidance to physically distance themselves from the stressful event or mentally tuning out of the stressful situation. Avoidance is defined as a response to a stimulus that is perceived as a threat to escape or reduce harm that can potentially be inflicted by the stimulus (Carver & Connor-Smith, 2010). This strategy was reported to be used because it allows autistic individuals extra time to veer away from the stressful situation so that the level of arousal and emotional toll does not become unmanageable (Rieffe et al., 2014). Another strategy reported by autistic participants is distraction. This strategy includes talking to other people, reading, dancing, journaling, playing computer games, watching movies, listening to music, and getting on social media. These distracting strategies have been reported as an

effective mechanism to emotion regulation during stressful situations (Cai et al., 2018). Given the nature of the study, participants were unlikely able to avoid nor able to distract themselves from the stressful stimulus. Even though participants were informed at the beginning of the stimulation that they could opt out of participation in the study, participants were unable to use coping strategies that allowed them to still complete the Stress Task. Though if the Stress Task was unbearably stressful to cause harm, a protocol was in place to discontinue the stress stimulation. Unfortunately, avoidance and distraction would not have permitted them to complete the stimulation and the other coping strategies they have identified in the interview may also not have been conducive for completion of the stimulation. Consequently, their stress perception went up during the Stress Task which was unexpected.

The interview data on participants' physical body reactions to stress also shed some light on their level of self-awareness to stress. Physical and bodily manifestations to stress such as increased heart rate, increased respiration, chest pain, nausea, and lowered immune system (Cool & Zappetti, 2019; Klein & Corwin, 2002; Schulz et al., 2020). The autism literature reports lack of insight in reporting stress experiences in the autism population (Hoza et al., 2012; Johnson et al., 2009; Lerner et al., 2012; Locke & Mitchell, 2016; McQuade et al., 2011). This means autistic individuals are not able to know when their body is reacting to a stressful stimulus. Contrary to findings in the literature, however, findings from the current study reveal autistic participants experience increased heart rate, stronger heartbeat, flushed and warm face, tightening of the chest, sweating, headache, and lowered immune system. This means they can identify physical manifestations of stress. These findings complement the quantitative results indicating an increased stress perception from Baseline to the Stress Task among autistic

participants and further validates autistic young adults in the sample had the insight to report stress experiences.

Strengths

The current study used an objective measure of stress and a subjective measure of stress, coupled with an interview to evaluate the stress response of 12 autistic young adults and 24 non-autistic young adults with a standardized online social stress stimulation protocol. This study has several strengths. First, even though the use of objective measures such as HRV in conjunction with subjective stress perception such as the visual analog scale is not new in the literature (Bourdillon et al., 2020; Laborde et al., 2015; Martínez-Lavín et al., 1998), this strategy is particularly salient in the autistic population because autistic individuals often show the lack of ability to perceive abstract phenomena (Hoza et al., 2012; Johnson et al., 2009; Lerner et al., 2012; Locke & Mitchell, 2016; McQuade et al., 2011). In this study, the researcher focused on the perception of stress, which was shown to be difficult for autistic individuals. Therefore, their bodily sensations may not effectively translate to a signal or an awareness of the need to react to stressful situations (Edmiston et al., 2016; Fuld, 2018; Kuiper et al., 2017). Furthermore, when reporting on stress situations, the literature reports discrepancies (Johnson et al., 2009; Lerner et al., 2012; Vuori et al., 2017) in relation to how their body would respond (Sivaratnam et al., 2015; Taylor & Corbett, 2014). Because of the difficulty in understanding the body's response to stress, autistic individuals often lack insight of their own abilities, resulting to unintentional exaggeration of their experiences (Vuori et al., 2017) and overestimation of their capacities (Furlano et al., 2015) in response to a stressful stimulus. Therefore, using an objective measure, such as a variant of the heart rate, would likely raise awareness and educate individuals about their body's response to stress. At the same time, the use of a subjective measure, such as a

visual analog scale, would allow the individuals to communicate whether they perceived the stressful stimulus as stressful. This measure also accounts for potential individual differences in stress perception. Furthermore, the use of an interview has allowed the exploration of whether the stimulus was stressful and why it was stressful. Second, the current study used theory to conceptualize the stress phenomenon experience. Using theory to guide rehabilitation research (Bright et al., 2021; Raeburn et al., 2015) grounds the analysis and provides a clear insight to critically analyze the stress phenomenon. The current study used the Transactional Model of Stress and Coping (Lazarus & Folkman, 1984) to guide the subjective stress experience which allowed incorporation of appraisal of subjective stress experiences through the VAS measure and qualitative interview. Furthermore, the current study also utilized the Polyvagal Theory (Porges, 1995a, 2009) to understand the objective stress experience which enabled further understanding of the role of HRV in adaptive social functioning (Edmiston et al., 2016). Third, the current study used a systematic way to induce stress on participants. The use of the Trier Social Stress Test (TSST) is considered the gold standard in studying and inducing stress and perception (Shields & Slavich, 2017). The recent adaptation of the TSST using online protocol reveals that it is capable of inducing psychophysiological stress response using cortisol (Gunnar et al., 2021). In addition, the current study protocol used another psychophysiological stress response which HRV. Using a systematic stress induction protocol enabled participants to experience the stressor as similarly as possible to allow for better comparison of subjective and objective stress responses. Furthermore, it adhered to the HRV recommendations from the Task Force such as ensuring that HRV recordings are at least 5 minutes long, ruling out participants who are currently taking cardiovascular medications, using normal units to evaluate HF HRV, and ensuring that data collection time is consistent throughout all the participants (in the current

study, data collection took place between 1 p. m. and 6:30 p. m.; Malik, 1996). Fourth, even though only exploratory, the current study incorporated qualitative interview data to provide supplemental insight on the stress experience of participants. Using qualitative data to explain subjective and objective stress data is novel. Incorporating qualitative data in the study provided additional insight on the cognitive appraisal of participants. Even though cognitive appraisal can be measured quantitatively as threat, challenge, controllability, harm, or loss (Carpenter, 2016), the use of qualitative data to explore cognitive appraisal allows further explanation beyond the categorization of appraisal of threat, challenge, or control.

Limitations

Despite the strengths identified above, the current study is not without limitations. First, the overall sample size is small. In the current study, post hot power analysis reveals a medium effect size at 27.9% power. Overall, studies in the HRV literature reported a medium effect size with 60% power (Cheng et al., 2020; Quintana, 2017). Therefore, replication of the study will produce further evidence to support or refute our findings. Second, the current study only reported the high frequency HRV index (Mathewson et al., 2011; Neuhaus et al., 2016; Schaaf et al., 2015). Other HRV indices such as the Root Mean Square of Successive Differences between normal heartbeats (RMSSD), the Standard Deviations of all the NN intervals (SDNN), and low frequency are common indices reported in the autism literature (Billeci et al., 2018; Bricout et al., 2018; Frasch et al., 2020; Kuiper et al., 2017; Mertens et al., 2017; Pulopulos, Hidalgo, et al., 2018; Smeekens et al., 2015). Since previous literature has reported that higher HRV does not necessarily mean better functioning (Stein et al., 2005), the comparison between other HRV indices might provide a better picture on the stress phenomenon because each HRV index measures a component of the psychophysiological stress response. As mentioned previously,

high frequency reflects the parasympathetic system's vagus nerve activity (Malik, 1996) which helps with coping and appraisal (Jamieson et al., 2013). Other HRV indices include RMSSD which reflects the HF heart rate oscillations (Pham et al., 2021; Shaffer & Ginsberg, 2017), SDNN which reflects parasympathetic activity short-term recordings but, in 24-hour or more recordings, correlates more with low frequency HRV (Shaffer & Ginsberg, 2017), and low frequency which reflects sympathetic and parasympathetic activity (Billman, 2013). Furthermore, it is possible to find statistically significant results in certain HRV indices but not the others (Billeci et al., 2018; Bujnakova et al., 2016). Third, even though the current study adhered to the HRV recommendations from the Task Force (Malik, 1996), there has not been a consensus on the preprocessing of HRV data (Peltola, 2012). Preprocessing pertains to the manual or automatic detection of ectopic or false heart beats and then replacement of these beats. The current study used Kubios HRV software which automatically detected ectopic beats and replaced them with interpolated RR values. Without an automatic and systematized detection and interpolation of ectopic beats, HRV analyses are bound to human error from manual ectopic beat corrections. The traditional manual editing method suggested by the Task Force could be outdated due to the computational power of newer HRV devices (Nunan et al., 2010) such as the device used in this study. The UMI Care device used in this study used PPG technology to detect heart rates per second which were used to detect the heart rate spectra at different frequencies (Elgendi et al., 2016; Fleming & Tarassenko, 2007; Jong et al., 2017). Fourth, it is possible that the online stress stimulation was not sensitive to detect changes in HRV. There is one study which validated the use of an online version of the TSST and was sensitive to detect psychophysiological stress response such as cortisol (Gunnar et al., 2021). However, the online version of the TSST may not be able to detect other psychophysiological stress response such as

HRV that was used in this study. Anecdotal reports from participants in the current study revealed that they felt stressed during the Stress Task. However, they also reported their stress would have been higher if the stress stimulation task was conducted in-person. This may suggest that the online stress stimulation may not have been as stressful as if it were done in-person. Fifth, the current study did not address the influence of comorbidity conditions within the sample. Since participants in the ASD group reported having more than one co-occurring diagnoses and HRV has been implicated in clinical populations such as those with Generalized Anxiety Disorder, Post-traumatic Stress Disorder, Major Depressive Disorder (Pham et al., 2021), Attention-deficit Hyperactivity Disorder (Robe et al., 2019), and Obsessive Compulsive Disorder (Olbrich et al., 2022), we were not able to tease out the potential effects of ASD diagnosis with HRV. And sixth, the sample composition in the current study relied on self-reported diagnosis of ASD though it is possible that participants may have had falsely reported diagnosis of ASD.

Implications

Findings from the current study reveal that autistic participants had lower observed subjective stress responses and lower objective stress responses when compared to controls during the Stress Task. In addition, small correlations were observed between subjective and objective stress responses in both groups. Because of the small sample size in the current study, these implications should be taken with caution. Implications in clinical practice, rehabilitation counselor education, and research will be discussed.

Clinical Implications

Findings from the current study has implications in clinical practice in the allied health field including general counseling. First, this study found that autistic and non-autistic

participants' subjective rating of a stressful experience was comparable, that both groups generally perceived a stressful experience similarly. This means young adults are susceptible to stress regardless of having autism or not. Therefore, young adults without autism could benefit from stress management and/or emotion regulation training.

Second, more importantly, specifically targeting stress management and skills training to autistic young adults. Autistic individuals are highly susceptible to stress and emotion dysregulation if not equipped with strategies to manage their stress. Findings from this study conveyed autistic individuals can raise their awareness of their stress responses. Also, information from the autistic participants that some had learned stress management skills before which likely led to their ability to manage their stress level during the stress stimulation. Therefore, teaching autistic individuals the necessary stress management skills early is imperative for better mental health outcomes as they face life stressors. As reported in the current study, young autistic adults can be taught to increase their level of awareness and detection of stressful situations and can be taught to mitigate the effects of those stressors. Studies have shown that these skills could be taught as individual formats (Ke et al., 2018), group formats for adults (e.g., Lee, 2021), as well for young children and adolescents (e.g., White et al., 2021). This illustrates the importance of providing early stress management intervention in this population.

Third, as indicated in the literature, though not fully reported in this study, findings from the qualitative interview data reveal that participants benefited from working with counseling therapists to help with emotion regulation and stress management. Even though research on treatment focusing on emotion regulation among autistic individuals is scant, a report summarizing the cognitive behavior therapy and mindfulness-based interventions benefit autistic

individuals (Cachia et al., 2016; Perihan et al., 2020). Furthermore, a meta-analytic study has reported improvement in emotion regulation, emotion recognition skills, and social communication skills following technology-based therapeutic interventions for autistic children, adolescents, and young adults (Karami et al., 2021). The current study has found autistic participants who have benefited from these training early on were able to identify and manage the effects of stressful experiences as they become young adults. This finding calls for early intervention and prevention for autistic individuals so they will become more prepared to handle stressors associated with their life pursuits.

Fourth, the use of a heart rate tracker to objectively detect stressful experiences can help raise awareness of the body's stress response. Some autistic participants in the study reported they would use a concrete and tangible device such as a timer to help with getting back to addressing a stressful experience after being away from it for some time. Having a device such as a heart rate tracker to provide a concrete signal of the onset of a stressful experience can help with preventing overwhelming stressful situations and becoming unmanageable. Furthermore, a recent article focusing on the use of technology in providing emotion regulation intervention to autistic individuals have found the use of personalized technological support to help with managing autistic attributes and traits is beneficial (Gillies-Walker et al., 2022). Other scholars have also recommended using concrete objects such as iPods, cellphones, or robots in intervention programs for autistic individuals (Achmadi et al., 2012; Syriopoulou-Delli & Gkiolnta, 2022; Yee, 2012).

Education Implications

The current study findings add further to the rehabilitation counseling education body of knowledge. Rehabilitation counseling is a profession that understands the influence of the body

physiology and function in the person's experience of disability (Bolton et al., 2000). This phenomenon is called functional limitations and it has long been recognized as an important knowledge that prospective rehabilitation counselors (Leahy et al., 2003, 2013, 2018). Findings in the current study provide insight on how the use of psychophysiological data such as HRV can supplement understanding of the psychological stress experienced by autistic individuals. Rehabilitation counselor educators can then use this knowledge to enhance their understanding of their client's experiences to stressful situations.

Another education implication emphasizes the need for counselor educators to focus training future counselors and rehabilitation counselors on cognitive reappraisal techniques to help autistic clients with their personal and other life goals. Particularly, since autistic clients experience stress in social settings, counselor educators can emphasize training future counselors about specific appraisal strategies such as cognitive reframing, reflecting, paraphrasing, and use of open-ended questions to enhance cognitive appraisal skills of their autistic clients who are feeling stressed in social situations. Counselor educators can also train future rehabilitation counselors to help clients as they access and get involved in various social and community events. In addition, counselor educators can also train rehabilitation counselors to provide emotion regulation skills training to autistic clients to help autistic clients reappraise overwhelming stressful situations.

Research Implications

The current study provides important research implications for rehabilitation counseling researchers. First, combining psychophysiological data with psychological data has provided a unique perspective in the perceived stress experience of autistic participants. Since the literature indicates discrepant (e.g., exaggeration, overestimation) reporting of stress experiences in the

autistic population, using psychophysiological data to inform the psychological stress perception experienced by autistic participants has shed new insight on the stress phenomenon experienced in this population. Typically, the literature reports either psychophysiological or psychological experiences of stress in this population. Combining these data adds to the general body of knowledge regarding stress experiences in the autistic population and it promotes a more holistic perspective on the stress phenomenon among members of this population.

Second, though only exploratory, the current study has found autistic participants typically chose avoidance as their primary coping strategy and often used tangible and concrete objects such as a timer to help manage stressful experiences. Use of a timer matches well in this population as autistic individuals tend to be concrete in their thinking. Further, the timer provides a tangible and concrete strategy because autistic individuals can distract (avoid) themselves from a stressful situation and then use a timer to momentarily come back to the situation when overwhelming feelings of stress have subsided. Rehabilitation counselor educators can further explore the use of these and other devices by this population in stress management and emotion regulation.

Recommendations for Future Study

The current study provided insight on the stress experience of autistic individuals. However, its limitations precluded it from conducting rigorous analysis, therefore the researcher has identified recommendations for future studies. First, obtaining a sufficient sample size should be a priority. As previously discussed, HRV studies typically report a medium effect size with 60% power and that the current study was only able to yield 27.9% power. In the future, it will be important to recruit adequate sample size. Increasing sample size will not only improve statistical power but will also allow for other more robust statistical analyses such as ANOVA or

Repeated Measures ANOVA to be conducted. More robust statistical analyses and increasing statistical power will definitely strengthen the findings and contribute more to aggregate statistical studies such as meta-analyses in the future.

Second, matching participants with and without ASD will help address potential confounding variables within the study. Specifically, matching helps reduce the bias from treatment effects resulting to better estimation of effects (Rubin & Thomas, 1996). In addition, matching participants with ASD with those without may be a cost-effective and time-effective strategy because it allows for targeted recruitment of control group participants (Stuart & Lalongo, 2010).

Third, improving screening of autism by incorporating other measures to verify autism diagnosis. The current study used self-report to indicate autism diagnosis. In the future, it will be important to confirm autism diagnosis by physicians or psychologists. Another strategy will be to use the Autism Diagnostic Observation Schedule-2 (ADOS-2; McCrimmon & Rostad, 2014) and/or the Autism Diagnostic Interview-Revised (ADI-R; Lord et al., 1994) to confirm autism diagnosis. Accurate grouping of autistic participants and control will help strengthen findings regarding the population.

Fourth, recruiting participants from a more diverse group including females who have not had counseling or therapy intervention on stress management. The sampled autistic group in the current study were females who have received psychotherapy to manage stress. This may have impacted the results because our data shows that many of our sampled autistic participants had the skills to mitigate stressful situations. Therefore, their body may have already been accustomed to adjusting to stressful situations. Recruiting participants who have not had any psychotherapy to manage stress will enable future research findings to tease out psychological

effects and potential psychophysiological effects confounding factor of psychotherapy or stress management training that may have allowed autistic individuals to effectively manage stress.

Fifth, it will also be important to evaluate the impact of conducting TSST online versus in person. Conducting the stress stimulation online may have reduced the stress that could have potentially been experienced by autistic participants if this were conducted in person. It could be that the online feature buffered the effects of stress among autistic participants because, even though the Stress Task was a social situation, there was no direct human interaction within the same spatial space. In fact, during the qualitative interview, some participants reported their feelings of stress would be more if the stress stimulation was conducted in person.

Sixth, adding a secondary psychophysiological measure to supplement the HRV finding. Other studies have used skin conductance (Mertens et al., 2017), cortisol (Pulopulos et al., 2018), heart period (Sheinkopf et al., 2013), and temperature (Tang et al., 2021) with HRV to evaluate psychophysiological stress responses. An additional psychophysiological measure will provide a more thorough understanding of the body's psychophysiological stress response or provide a supplementary validation to the subjective perception of a stressful stimulus.

Seventh, it is important to consider changing the Stress Task scenario and make it more sensitive to psychophysiological stress changes in this population. Though the online TSST for children was sensitive to detect changes in the body (Gunnar et al., 2021), this test may not have been sensitive enough to detect changes using HF HRV. Many participants from both groups reported in the qualitative interview recently experiencing a job interview scenario within the past several months and have felt that they will yet experience similar situations in the future. This familiarity with the job scenario, though deemed stressful, may account for the findings. In the future, to help tease out differing experiences among groups, it might be helpful to create a

social scenario such as a conversation about a communal event and allow for more of an organic regular day-to-day conversation as opposed to a one-directional speech that is commonly used in TSST. In addition, since this study only focused on the Stress Task Phase, the other phases (i.e., Baseline and Recovery) should also be analyzed to understand changes between resting and social situations.

Eighth, reporting of HRV indices has not been consistent, future studies may benefit from consistent reporting of HRV indices. Scholars have proposed the *Guidelines for Reporting Articles on Psychiatry and Heart rate variability* (GRAPH) which is a checklist of items as guidelines in reporting studies that used HRV index (Quintana et al., 2016). The current study has incorporated almost all the items in this checklist; however, a report of potential sources of ectopic beats from participants' posture was not included in this report. Due to self-stimulating behavior that typically occurs among autistic individuals, some participants' HRV may have been impacted. In the future, it will be important to advise participants to limit movement to a seated position, with legs and hips at 90° and to monitor, record, and report participant movement (potential source of ectopic beats) during the stress stimulation.

Ninth, future studies can investigate the influence of comorbidity conditions in the ASD population. Unfortunately, the current study only documented the presence of these comorbid conditions and evaluating for the effects of comorbid conditions is beyond the scope of the current study. Meta-analyses and systematic reviews have reported comorbid conditions to be prevalent in autistic children (Hossain et al., 2020), young adults (Hudson et al., 2019) and adults (Hollocks et al., 2019). Addressing the influence of other comorbid conditions can shed more light on how ASD diagnosis affects HRV.

Conclusion

Stress is a universal phenomenon experienced regularly by everybody. It is experienced psychologically through subjective perceptions and psychophysiologically through the autonomic nervous system (objective). In clinical populations such as autism, stress has had a negative impact which has affected autistic populations experience of social situations. Unfortunately, studies on subjective stress responses in the autistic population can be challenging given that self-reporting on stress experiences can be abstract and require insight. This study used objective measures of stress to validate the subjective experience of stress by autistic individuals. Findings reveal small correlation between subjective and objective stress responses which corresponds to the self-reporting challenges experienced by autistic individuals; study findings also reveal non-statistical findings. The current study provides insight on the use of objective psychophysiological data to validate subjective psychological stress perception among autistic individuals as well as using qualitative data to obtain cognitive appraisal information to support subjective and objective data findings.

APPENDICES

MICHIGAN STATE
UNIVERSITY

Initial Study APPROVAL
Revised Common Rule

June 30, 2021

To: Ka Lai Gloria Lee

Re: **MSU Study ID:** STUDY00006138
IRB: Biomedical and Health Institutional Review Board
Principal Investigator: Ka Lai Gloria Lee
Category: Expedited 3, 6, 7
Submission: Initial Study STUDY00006138
Submission Approval Date: 6/29/2021
Effective Date: 6/29/2021
Study Expiration Date:

Title: Objective and Subjective Stress Responses of Young Adults with Autism Spectrum Disorder

This submission has been approved by the Michigan State University (MSU) Biomedical and Health Institutional Review Board. The submission was reviewed by the Institutional Review Board (IRB) through the Non-Committee Review procedure. The IRB has found that this study protects the rights and welfare of human subjects and meets the requirements of MSU's Federal Wide Assurance (FWA00004556) and the federal regulations for the protection of human subjects in research (e.g., 2018 45 CFR 46, 21 CFR 50, 56, other applicable regulations).

Office of Regulatory Affairs
Human Research Protection Program

4000 Collins Road
Suite 136
Lansing, MI 48910

517-355-2180
Fax: 517-432-4503
Email: irb@msu.edu
www.hrpp.msu.edu

How to Access Final Documents
To access the study's final materials, including those approved by the IRB such as consent forms, recruitment materials, and the approved protocol, if applicable, please log into the Click™ Research Compliance System, open the study's workspace, and view the "Documents" tab. To obtain consent form(s) stamped with the IRB watermark, select the "Final" PDF version of your consent form(s) as applicable in the "Documents" tab. Please note that the consent form(s) stamped with the IRB watermark must typically be used.

Continuing Review: IRB approval is valid until the expiration date listed above. If the research continues to involve human subjects, you must submit a Continuing Review request at least one month before expiration.

Modifications: Any proposed change or modification with certain limited exceptions discussed below must be reviewed and approved by the IRB prior to implementation of the change. Please submit a Modification request to have the changes reviewed. If changes are made at the time of continuing review, please submit a Modification and Continuing Review request.

New Funding: If new external funding is obtained to support this study, a Modification request must be submitted for IRB review and approval before new funds can be spent on human research activities, as the new funding source may have additional or different requirements.

Immediate Change to Eliminate a Hazard: When an immediate change in a research protocol is necessary to eliminate a hazard to subjects, the proposed change need not be reviewed by the IRB prior to its implementation. In such situations, however, investigators must report the change in protocol to the IRB immediately thereafter.

Reportable Events: Certain events require reporting to the IRB. These include:

- Potential unanticipated problems that may involve risks to subjects or others
- Potential noncompliance
- Subject complaints
- Protocol deviations or violations
- Unapproved change in protocol to eliminate a hazard to subjects
- Premature suspension or termination of research
- Audit or inspection by a federal or state agency
- New potential conflict of interest of a study team member
- Written reports of study monitors
- Emergency use of investigational drugs or devices
- Any activities or circumstances that affect the rights and welfare of research subjects
- Any information that could increase the risk to subjects

Please report new information through the study's workspace and contact the IRB office with any urgent events. Please visit the Human Research Protection Program (HRPP) website to obtain more information, including reporting timelines.

Personnel Changes: Key study personnel must be listed on the MSU IRB application for expedited and full board studies and any changes to key study personnel must to be submitted as modifications. Although only key study personnel need to be listed on a non-exempt application, all other individuals engaged in human subject research activities must receive and maintain current human subject training, must disclose conflict of interest, and are subject to MSU HRPP requirements. It is the responsibility of the Principal Investigator (PI) to maintain oversight over all study personnel and to assure and to maintain appropriate tracking that these requirements are met (e.g. documentation of training completion, conflict of interest). When non-MSU personnel are engaged in human research, there are additional requirements. See HRPP Manual Section 4-10, Designation as Key Project Personnel on Non-Exempt IRB Projects for more information.

Prisoner Research: If a human subject involved in ongoing research becomes a prisoner during the course of the study and the relevant research proposal was not reviewed and approved by the IRB in accordance with the requirements for

research involving prisoners under subpart C of 45 CFR part 46, the investigator must promptly notify the IRB.

Site Visits: The MSU HRPP Compliance office conducts post approval site visits for certain IRB approved studies. If the study is selected for a site visit, you will be contacted by the HRPP Compliance office to schedule the site visit.

For Studies that Involve Consent, Parental Permission, or Assent Form(s):

Use of IRB Approved Form: Investigators must use the form(s) approved by the IRB and must typically use the form with the IRB watermark.

Copy Provided to Subjects: A copy of the form(s) must be provided to the individual signing the form. In some instances, that individual must be provided with a copy of the signed form (e.g. studies following ICH-GCP E6 requirements). Assent forms should be provided as required by the IRB.

Record Retention: All records relating to the research must be appropriately managed and retained. This includes records under the investigator's control, such as the informed consent document. Investigators must retain copies of signed forms or oral consent records (e.g., logs). Investigators must retain all pages of the form, not just the signature page. Investigators may not attempt to de-identify the form; it must be retained with all original information. The PI must maintain these records for a minimum of three years after the IRB has closed the research and a longer retention period may be required by law, contract, funding agency, university requirement or other requirements for certain studies, such as those that are sponsored or FDA regulated research. See HRPP Manual Section 4-7-A, Recordkeeping for Investigators, for more information.

Closure: If the research activities no longer involve human subjects, please submit a Continuing Review request, through which study closure may be requested. Closure indicates that research activities with human subjects are no longer ongoing, have stopped, and are complete. Human research activities are complete when investigators are no longer obtaining information or biospecimens about a living person through interaction or intervention with the individual, obtaining identifiable private information or identifiable biospecimens about a living person, and/or using, studying, analyzing, or generating identifiable private information or identifiable biospecimens about a living person.

For More Information: See the HRPP Manual (available at hrpp.msu.edu).

Contact Information: If we can be of further assistance or if you have questions, please contact us at 517-355-2180 or via email at IRB@msu.edu. Please visit hrpp.msu.edu to access the HRPP Manual, templates, etc.

Expedited Category. Please see the appropriate research category below for the full regulatory text.

Expedited 1. Clinical studies of drugs and medical devices only when condition (a) or (b) is met.
(a) Research on drugs for which an investigational new drug application (21 CFR Part 312) is not required. (Note: Research on marketed drugs that significantly increases the risks or decreases the acceptability of the risks associated with the use of the product is not eligible for expedited review.)
(b) Research on medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling.

Expedited 2. Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture as follows:
(a) from healthy, nonpregnant adults who weigh at least 110 pounds. For these subjects, the amounts drawn may not exceed 550 ml in an 8 week period and collection may not occur more frequently than 2 times per week; or
(b) from other adults and children, considering the age, weight, and health of the subjects, the collection procedure, the amount of blood to be collected, and the frequency with which it will be collected. For these subjects, the amount drawn may not exceed the lesser of 50 ml or 3 ml per kg in an 8 week period and collection may not occur more frequently than 2 times per week.

Expedited 3. Prospective collection of biological specimens for research purposes by noninvasive means.
Examples: (a) hair and nail clippings in a nondisfiguring manner; (b) deciduous teeth at time of exfoliation or if routine patient care indicates a need for extraction; (c) permanent teeth if routine patient care indicates a need for extraction; (d) excreta and external secretions (including sweat); (e) uncannulated saliva collected either in an unstimulated fashion or stimulated by chewing gumbase or wax or by applying a dilute citric solution to the tongue; (f) placenta removed at delivery; (g) amniotic fluid obtained at the time of rupture of the membrane prior to or during labor; (h) supra- and subgingival dental plaque and calculus, provided the collection procedure is not more invasive than routine prophylactic scaling of the teeth and the process is accomplished in accordance with accepted prophylactic techniques; (i) mucosal and skin cells collected by buccal scraping or swab, skin swab, or mouth washings; (j) sputum collected after saline mist nebulization.

Expedited 4. Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves. Where medical devices are employed, they must be cleared/approved for marketing. (Studies intended to evaluate the safety and effectiveness of the medical device are not generally eligible for expedited review, including studies of cleared medical devices for new indications.)
Examples: (a) physical sensors that are applied either to the surface of the body or at a distance and do not involve input of significant amounts of energy into the subject or an invasion of the subject's privacy; (b) weighing or testing sensory acuity; (c) magnetic resonance imaging; (d) electrocardiography, electroencephalography, thermography, detection of naturally occurring radioactivity, electroretinography, ultrasound, diagnostic infrared imaging, doppler

blood flow, and echocardiography; (e) moderate exercise, muscular strength testing, body composition assessment, and flexibility testing where appropriate given the age, weight, and health of the individual.

Expedited 5. Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis). (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(4). This listing refers only to research that is not exempt.)

Expedited 6. Collection of data from voice, video, digital, or image recordings made for research purposes.

Expedited 7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)

Expedited 8. Continuing review of research previously approved by the convened IRB as follows:
(a) where (i) the research is permanently closed to the enrollment of new subjects; (ii) all subjects have completed all research-related interventions; and (iii) the research remains active only for long-term follow-up of subjects; or
(b) where no subjects have been enrolled and no additional risks have been identified; or
(c) where the remaining research activities are limited to data analysis.

Expedited 9. Continuing review of research, not conducted under an investigational new drug application or investigational device exemption where categories two (2) through eight (8) do not apply but the IRB has determined and documented at a convened meeting that the research involves no greater than minimal risk and no additional risks have been identified.

APPENDIX B: Recruitment Email

Subject line: Online Stress Stimulation Study

Hello,

My name is Jarhed Peña and I am conducting a research study at Michigan State University. Thank you for expressing interest in participating.

I am conducting an online stress stimulation study of college students 18-26 years old and am wondering if you would like to participate.

The purpose of the study is to examine the objective and subjective stress of young adults in college with and without autism spectrum disorder in an online stress stimulation environment via Zoom. This study involves 2 sessions on Zoom.

During the first Zoom meeting, we will go over how to set up the Zoom meeting and how to use the heart rate device. We will also go over how you can receive and mail or return the device back to me and send you the survey questions link via email. This meeting will last about 30 minutes. **You would receive a $20 Amazon Gift Card via email for participating in this portion.**

During the second Zoom meeting, we will conduct the stress stimulation study **and** interview about your experience during the stress stimulation. This meeting will last 30 to 90 minutes. **You would receive a $40 Amazon Gift Card for the stress stimulation and a $20 Amazon Gift card for the interview. You may receive a sum total of $80 Amazon Gift Card for participating in the entire study.**

At the end of the study, you will receive the gift cards and a copy of the personality profile report from the questionnaire you have filled up.

If you are interested in participating in this study or would like to learn more, please respond to this email, or call or send an SMS to me at (562) 281-7155 so we can discuss the logistics.

Thank you,

Jarhed Peña, MRC, LLPC, CRC

STRESS EXPERIENCES OF YOUNG ADULTS WITH AUTISM

Young adults in college experience stress. We are conducting an online stress stimulation study about your heart rate and your perception of a stressful experience.

Duration: 30 - 90 minutes

To sign up for the screening, scan this code on your phone, or go to:https://tinyurl.com/StressStudySignUp

We are looking for young adults, 18-26, with autism in college

Earn up to $80 Amazon Gift Card PLUS **Receive** your own Personality Profile

Photo by Atul Choudhary from Pexels

FOR MORE INFO, CONTACT:

Jarhed Peña, MRC, LLPC, CRC
penajarh@msu.edu
(562) 281-7155

Gloria K. Lee, PhD, CRC
leekalai@msu.edu
(517) 432-3623

APPENDIX D: Screening Protocol

Thank you for your interest in participating in the Stress Response Study. I would like to ask you a few questions in order to determine if you will be eligible for the study. Before I begin the screening, I would like to tell you a little bit about it. This study will stimulate a stress experience and we will measure your heart rate and perception of stress during this experience. You will wear one of our heart rate devices that will be strapped on to your upper arm. The entire stress stimulation lasts 30 minutes. Afterwards, you will be given the opportunity to participate in an interview about this stress experience to gain insight about your experience.

This screening will take about two minutes and I will ask you questions about your health. You will have to answer all the screening questions so we can determine if you are eligible. Your participation in the screening is voluntary and your answers will be kept confidential. Regardless of the screening results, your answers to the screening questions will not be retained.

Would you like to continue with the screening?

- *[If yes, thank the person and proceed to ask the screening questions.]*
- [*If no, thank the person.*]

Q1: What is your age?

[Looking for 18-26 years old.]

Q2: What medical and/or psychological or psychiatric diagnoses do you have?

[Looking for Autistic Disorder, Asperger's Disorder, PDD-NOS, Rett's Disorder, Childhood Disintegrative Disorder, Autism Spectrum Disorder, Autism (special education classification). These diagnoses include the potential participant from the study.]

[Looking for those without diagnosis of Intellectual Disability. If potential participant has this diagnosis, the participant will be excluded from participating and regardless of having any of the above autism diagnoses.]

[If potential participant has psychological or psychiatric diagnoses, this is just noted, and participant can still participate in the study. The co-PI will then assess the severity of this by asking whether participant is currently taking medications and/or receiving psychotherapy*. If the participant is both taking medications and receiving psychotherapy, the participant may indicate having severe psychological or psychiatric diagnosis, and the participant will be excluded from the study. Otherwise, the participant will be requested to participate in the study upon meeting the rest of the screening questions.]*

[If potential participant has any of the above autism diagnoses <u>and</u> is deemed by the co-PI to have a severe psychological or psychiatric diagnosis, the participant will be excluded from participating in the study.]

Q3: Do you have a stable internet connection that allows you to participate in an online 2-hour video session?

[Looking for a Yes.]

Q4: Do you have a quiet and private place where you can be alone in for 2 hours?

[Looking for a Yes.]

Q5: Do you have access to a computer screen that is 13” or larger?

[Looking for a Yes.]

Q6: Do you take any medications? (e.g., stimulants, antipsychotics, SSRIs, etc.)

[Looking for a No. But if the answer is Yes, ask, "What medications are you taking?"]

[To be eligible, participants cannot be taking cardiovascular or antipsychotic medications.]

Q7: Are you allergic to Velcro?

[Looking for a No.]

Q8: Do you have a phone with a front-facing camera feature?

[Looking for a Yes.]

Q9: Are you experiencing any symptoms of COVID-19, such as fever or chills, cough, shortness of breath or difficulty breathing, fatigue, muscle or body aches, headache, new loss of taste or smell, sore throat, congestion or runny nose, nausea or vomiting, or diarrhea?

[Looking for a No.]

Thank you for answering the screening questions.

- *[If eligible, indicate the person is eligible, thank the person, and set up 2 dates to meet (in-person and/or via Zoom) to move forward with the study.]*
- *[If not eligible, indicate the person is not eligible and thank the person.]*

Do you have any questions about the screening or the research? If you have questions or concerns about this study, please contact Dr. Gloria Lee at lekalai@msu.edu, (517) 432-3623 or Jarhed Peña at penajarh@msu.edu, (562) 281-7155.

Thank you again for your willingness to answer our questions.

APPENDIX E: Consent Form

Objective and Subjective Stress Responses of Young Adults
with Autism Spectrum Disorder

Jarhed Peña, MRC, LLPC, CRC
penajarh@msu.edu
(562) 281-7155.
Gloria K. Lee, PhD, CRC
leekalai@msu.edu
(517) 432-3623
Erickson Hall room 459, 620 Farm Lane, East Lansing, MI 48824,
Department of Counseling, Educational Psychology, and Special Education
Michigan State University

BRIEF SUMMARY

This study examines the stress responses of young adults in college settings. Participation in this study is completely voluntary. Participants' physiological and psychological stress responses will be observed during a stress stimulation via Zoom with the help of two research facilitators. A heart rate device will be attached to the participants during the study and the study sequence consists of: Baseline (10 minutes), Stress Stimulation (6 minutes), Recovery (10 minutes), and Debriefing (5 minutes) totaling 31 minutes. Afterwards, participants will be asked to participate in a 45-minute interview to talk about their experience and how they generally cope with stress. Participants may gain additional insight about how they react to stressful situations and may feel uncomfortable during the stress stimulation. Despite this, the study poses no more than minimal risk and participants can elect to stop participation at any point during the study without question.

PURPOSE OF RESEARCH

You are being asked to participate in a research study about the bodily response and perception of a stress experience among young adults in college. In this study, we are hoping to gain more insight on the appraisal and bodily response of young adults with autism spectrum disorder. Your participation in this study will take around 30 minutes to 90 minutes, depending upon your participation in the interview.

WHAT YOU WILL BE ASKED TO DO

Upon eligibility to participate, you will be asked to set up two Zoom meetings with the researcher. The first is intended to discuss logistics such as how to receive the heart rate device and setting up the stress stimulation via Zoom. The second is intended for the stress stimulation. During the stress stimulation, you will put on our heart rate device on your upper arm. The stress stimulation is 30 minutes long and its sequence is as follows:

1. Baseline – remain seated while listening to relaxing music (10 minutes),
2. Stress stimulation (6 minutes),
3. Recovery – remain seated and listen to the same relaxing music (10 minutes),

4. Debriefing – answer any questions with the researcher (5 minutes), and
5. Interview – optional, interview about your experience and how you generally handle stressful situations (45 minutes).

POTENTIAL BENEFITS

Participating in this study may give you additional insight about yourself such as how you perceive and appraise stressful situations in your life. It will also give you the opportunity to learn more about yourself such as personal characteristics you may not yet know of.

POTENTIAL RISKS

This study poses reasonably foreseeable risks. Below are possible risks that may arise:

1) Increased heart rate. Some people may feel nervous or anxious conversing with others. We encourage you to do your best to interact with everybody.

2) Uncomfortable feeling. Some people may feel uncomfortable talking with other people through Zoom. We encourage you to do your best to look in the camera and it's okay if you don't.

3) Germs and Viruses. To greatly minimize exposure to germs and/or viruses, our heart rate devices will be sanitized and cleaned before use. In addition, sanitary wipes are also provided to you for use after using the device.

4) Fatigue. The survey battery may take up to 120 minutes to complete. You can take a break and come back at any time to complete the rest of the questionnaire. Also, after the 31-minute stress stimulation, you will be asked to participate in an interview about your experience. To help with this, participants will be given the option to have a 5-minute break after the stress stimulation before proceeding with the interview.

5) Feeling uncomfortable answering some questions. Some survey questions may feel too personal to some people because they may ask about your personality, habits, and/or physical health. We encourage you to answer the questions completely and to the best of your ability because the complete information will allow us to analyze the data.

6) Confidentiality and privacy. Your comments will remain confidential, and your privacy will be protected. We are trained to adhere to ethical practices to address confidentiality and privacy issues.

PRIVACY AND CONFIDENTIALITY

All data collected in this study will be kept confidential. Your personal information (i.e., name, email, and address) will be collected but not linked with the study data and only be used to mail or coordinate receipt of our heart rate devices to you. Your name will be assigned a unique numerical identifier and this and your personal information identifier will be recorded separately from the data collected during the study. Completed psychological questions will be administered using MSU's Qualtrics System and PAR Inc.'s encrypted online system; IP addresses are not collected. Your audio and video will also be recorded via Zoom to evaluate your non-verbal communication during the stress stimulation and to generate transcripts of the interview. Transcription of your audio will be done by the lead researcher of the study. All these data will be downloaded and stored within MSU's encrypted OneDrive cloud-based system and within a password-protected computer for the duration of the study. No other personal information will be stored in Qualtrics; only gender and age will be stored in PAR Inc. to help with norm scoring, no other personal information identifier is stored in PAR Inc. Any other names or personal information collected during the study will be replaced with pseudonyms. Only the researchers listed in this form, students assigned in this project, and MSU HRPP will also have access to the data collected in this study. At the end of the study, stored participant information identifiers (i.e., first and last names, addresses, and email addresses) will be removed from all stored datasets. The remaining data (i.e., heart rates, surveys, transcriptions and videos) collected during the study will be

stored in a password-protected computer and may be used for future research studies or distributed to another investigator for future research studies without additional informed consent from the participant or the legally authorized representative.

In cases in which there would be information related to child abuse, elder abuse, or any life-threatening situation, it is our responsibility to report such incident. Your confidentiality will be protected to the maximum extent allowable by law.

YOUR RIGHTS TO PARTICIPATE, SAY NO, OR WITHDRAW

Your participation is completely voluntary. You may opt out of the study at any time without question or penalty. You may choose not to submit the survey questions after answering all of them. You may also choose not to answer specific questions. There are no consequences for withdrawal, refusal to participate, or incomplete submission or participation in this study. However, we would like to encourage you to answer all of the questions to the best of your ability so that we can obtain as much information as we can to analyze the data. Despite this, we recognize that there may be questions that you may feel uncomfortable to answer. In such situations, we encourage you to answer the questions to the best of your ability.

COSTS AND COMPENSATION FOR BEING IN THE STUDY

Participation in this study is at no cost to you. However, you will be given multiple incentives to participate throughout the entire study. These are as follows: Day 1 ($20 Amazon Gift Card), Day 2 ($40 Amazon Gift Card), and Interview ($20 Amazon Gift Card). You may receive as much as a $80 worth of Amazon Gift Cards by fully participating in this study. You may opt out to participate without question at any point during the study and you will receive compensation, as previously outlined, for the portions that you complete or try to complete. You will also receive the full report of your personality profile. However, you will not be provided interpretation of this report by a licensed psychologist, nor will you have the opportunity to ask questions and/or offered mental health services as a result of this report.

CONTACT INFORMATION

If you have concerns or questions about this study or would like to report an injury as a result of this study, please contact the researchers, Dr. Gloria K. Lee, Erickson Hall room 459, 620 Farm Lane, East Lansing, MI 48824, leekalai@msu.edu, (517) 432-3623 or Jarhed Peña, penajarh@msu.edu, (562) 281-7155.

If you have questions or concerns about your role and right as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 4000 Collins Rd, Suite 136, Lansing, MI 48910. Thank you very much.

Your signature below documents your permission to take part in this study.

_____

Participant's Printed Name Signature Date

_____

Researcher's Printed Name Signature Date

You will be sent a copy of this consent document for your records via your email.

APPENDIX F: Participant Instructions

Sending and Receiving the Heart Rate Device

The process in this section is listed below.

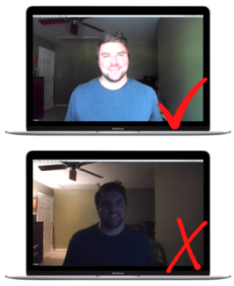
1. Obtain participants' mailing address. Inform participants that the device will be sanitized, placed in a bubble mailing envelope, and then tracked during shipment.
2. Inform participants that the device is estimated to be received within the next 7 business days and that we are tracking the device in the mail.
3. After the study, participants can use the pre-filled bubble mailer to mail the device back.
4. (In person.) Instead of having the device mailed to participants, they will be offered the option to meet with the researcher in person instead to obtain the device. This will still follow COVID-19 protocol of wearing a face mask and social distancing. After the study, participants can then meet with the researcher once again to return the device. If the device is given in person, the lead researcher will conduct ***Day 1: Preparation*** protocol.
5. Below is a list of what is given to participants in the mail:
    a. UMI Care Device (heart rate tracker)
    b. 4 sanitizing wipes
    c. Pre-stamped and pre-filled bubble mailer to be used to return the heart rate device

Day 1: Preparation

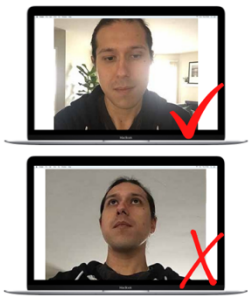
Zoom Set Up. Instructions on how to set up the Zoom meeting are below.

1. Go to the link: [Zoom link], use the Password: [Zoom Password] to enter the meeting. Each link and password will be different for each participant and this information is emailed to each participant.

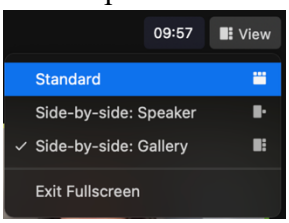
2. Provide the following Zoom guidelines to participants.
3. Find a quiet and private place that you can be alone in for about 2 hours.
4. Ensure that your major source of light is in front of you. Light sources can come from a table lamp, overhead light, window, or even your computer. See picture on the right for reference.



5. Ensure that the volume on your computer is comfortable for you.
6. Ensure that you know how to access and read contents in the Chat box.
7. Ensure that the Zoom window is in Fullscreen.
8. Adjust the camera angle so that camera shows your eye level. You may need to place objects such as books under your computer to ensure that the camera is at eye level. See picture on the right for reference.



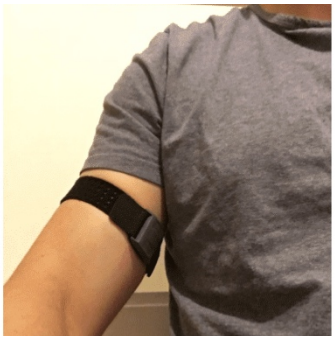
9. Ensure that the Zoom video layout is on Speaker View. You can change the video layout by selecting the options on the top right corner of your Zoom window. See picture on the right for reference. Afterwards, ask participants to take a selfie using their phone camera showing the computer screen in the selfie then show this to the researcher. The researcher ensures that participants adhered to the Zoom set up for the study.



Using Heart Rate Device. Instructions on how to use the heart rate device are below.

1. Unbox the device.

2. Use the sanitizing wipes provided to you to clean the heart rate device including the straps.
3. Loosen the Velcro strap on both sides and put it on either the right or left arm, whichever is most comfortable, above the elbow. Make sure that the device is in contact with the skin. See picture on the right for reference.



4. Strap the Velcro straps in place so that the device is secure but not too tight that it restricts circulation.
5. After putting on the device, turn it on. To power on, press and hold the power button for 5 seconds. If done successfully, the device light will blink purple; this means it is now recording.
6. To power off, press and hold the power button again for 5 seconds. The device light will blink red 3 times and then turn off.

Before the Stress Stimulation. The researcher will contact participants via phone call, email, and/or SMS as a reminder and remind them of the following:

- Refraining from intense exercise at least 24 hours;
- Not consuming any alcoholic beverages at least 24 hours;
- Not consuming any caffeinated beverages at least 2 hours;
- Finding a quiet place for 2 hours; and

Upon logging into the Zoom meeting, the researcher is responsible to ensure that participants have adhered to the Zoom set up and know how to use the heart rate device.

APPENDIX G: Online Stress Stimulation Protocol

The entire stress stimulation will be conducted via Zoom. A breakout room (Room A) will be created beforehand which will be used for the Stress Stimulation. Participants will be informed that their nonverbal cues will be evaluated by the facilitators during the stimulation. There will be a total of 3 persons during the Zoom meeting: the researcher of the study and 2 other individuals that will function as facilitators.

The facilitator #1 is responsible to provide the instructions to participants verbally during the study. This facilitator is charged with ensuring that the pace of the instructions is similar as much as possible across participants.

The facilitator #2 is responsible for keeping track of participants' signs of extreme stress such as sweating, redness on the cheeks, teary eyes, fidgeting, and tone of voice. Upon witnessing any of these signs of extreme stress, the facilitator #2 will briefly check in with participants and give them an option to continue the study or stop the study. If participants choose to continue with the study, they will be asked by the facilitator #2 to proceed with the study with whatever remaining time they have left. If participants choose to discontinue with the study, the facilitator #2 will send them back to the Main Room. Below is the script for this situation.

> *"Wait please. It appears that you are feeling uneasy. Would you like us to stop, or would you like to keep going?"*

The following is a list of facilitator's demeanor and action list.

- Maintain direct eye contact with participants by looking at the camera instead of the screen;

- Speak clearly and decisively;
- Not provide encouragement and minimize expressions;
- End sentences with period rather than in question tone; and
- Show that you are making notes during the stress stimulation.

The lead researcher is responsible for ensuring that participants adhere to the study protocol. The lead researcher ensures that participants have properly set up the Zoom meeting and have turned on the heart rate device. Furthermore, this person helps with the Baseline, Recovery, Debriefing, and interview of participants.

Lead Researcher Checklist before beginning the Baseline.

- Obtain participants' current location.
- Request participants to empty their bladder.
- Check the light source, volume, chat box, and camera angle.
- Ensure that participants are using full screen.
- Ensure participants are on Speaker View (right-click the top-right, check with a selfie)
- Request participants to put heart rate device on their upper or lower arm

Baseline. The lead researcher will instruct participants to wait for 10 minutes in the Main Room while listening to a relaxing music (played by the lead researcher). In the meantime, the two facilitators will be waiting in Room 1 for the stress stimulation. At the end of Baseline, the lead researcher sends participants to Room 1. The script for this part is as follows:

"We will now begin. Please know that you can opt out of participating at any point during this study. We will start with the Baseline. For the Baseline, we ask you to wait here in the Main Room for 10 minutes while listening to the music that you will play. I will let you know

when to press play. I will also turn my video off but please keep your video on. Please know that I'm still here but just have my video turned off. So, if you need me, please let me know verbally or in the chat. Please remain seated and stay on Zoom during the Baseline."

"Before we begin, how would you rate your stress level at this time? Please choose just one answer from 0, no stress, to 10, extremely stressed." 3

"I will now set timer for 10 minutes and will let you know on the screen when the timer is up. Go ahead, please press play on the video and go back to the Zoom window."

[Lead Researcher: turn on the music]

[Lead Researcher: set timer for 10 minutes]

[Lead Researcher: turn off the researcher video]

[after 10 minutes]

[the timer goes off]

[Lead Researcher: turn off the music]

[Lead Researcher: turn on researcher video]

"The timer is up. Please stop the music and drag the video icon all the way to the left, back to the beginning of the video."

"How would you rate your stress level at this time? Please choose just one answer from 0, no stress, to 10, extremely stressed." 2

"I will now send you to Room 1."

[send participant to Room 1]

[pause video recording]

Stress Stimulation. Facilitator #1 will read the instructions for this task. The instructions are as follows:

[Facilitator #1: Press record as soon as participant comes on.]

[Facilitator #1: Pin participant's video.]

"We will now begin the stress stimulation. For this task, you will be given a scenario, and my colleague and I will evaluate your non-verbal cues. The scenario is: Think of a job that you really want to have. I'll give you a moment to do so. [pause 2 seconds] You have recently applied to this job and other people are also being interviewed for this position. Explain and convince us why you think you are the best candidate for this job. You have 5 minutes, and I will let you know when the timer is up."

"Before we begin, how would you rate your stress level at this time? Please choose just one answer from 0, no stress, to 10, extremely stressed."

"Please answer, why you are the best candidate for this job? Your timer starts … now."

[Facilitator #1: Quickly set and start timer for 5 minutes.]

If participants have a question about the job, say, *"Please interpret it however you like as long as it follows the prompt."*

If participants ask for the scenario, say, *"The scenario is you have recently applied to a job you wanted. You will now explain and convince us why you are the best candidate for this job."*

If participants stop speaking for more than 10 seconds, say, *"Please keep going. How else are you a good candidate for this job?", "What makes you a better fit for this job than other candidates?", or "You still have time, please continue."*

When the timer goes off, say, *"The time is up. How would you rate your stress level at this time? Please choose just one answer from 0, no stress, to 10, extremely stressed."*

"Thank you for your cooperation. I will now send you back to the Main Room."

[Facilitator #1: Send participant to the Main Room]

[Facilitator #1: Stop the recording.]

Recovery. The lead researcher will follow the same procedure as the Baseline. The script for this section is as follows:

[Lead Researcher: pin participant's video]

[Lead Researcher: press record as soon as participant comes on.]

"Before we begin, how would you rate your stress level at this time? Please choose just one answer from 0, no stress, to 10, extremely stressed." 7

"We will follow the same procedure as the baseline. Please wait here in the Main Room for 10 minutes while listening to the same music that you heard during baseline."

"I will now set timer for 10 minutes and will let you know on the screen when the timer is up. Go ahead, please press play."

[Lead Researcher: turn on the music]

[Lead Researcher: set timer for 10 minutes]

[Lead Researcher: turn off the researcher video]

[after 10 minutes]

[the timer goes off]

[Lead Researcher: turn off the music]

[Lead Researcher: turn on researcher video]

"The timer is up. Please pause the music."

"How would you rate your stress level at this time? Please choose just one answer from 0, no stress, to 10, extremely stressed." 5

"Please keep your device turned on and on you. We will now go through the debriefing."

Debriefing. The lead researcher will check in with participants to ensure that participants are doing well after the stress stimulation and help them feel comfortable. Participants will be reminded that their performance is not in any indication of their aptitude or achievement and that the stimulation is merely to elicit their stress response. Participants will be informed that this study does not evaluate for any heart anomalies (tachy-, brady-, and arrhythmia) and they will be reminded that the result of the study, particularly the collected heart rate data is only for research purposes and will not be shared with them or any other healthcare professional. However, they will be encouraged to see their healthcare professional if they feel that they felt too stressed during the study. In addition, the researcher will answer any question from participants. Participants will be instructed how to return the heart rate device (either in person or through the mail). Participants will also be asked to participate in a 45-minute interview about their experience during the stress stimulation. If they choose to participate in the interview, there will be a 5-minute break before the interview.

[Lead Researcher: Pause the recording if the participants agreed to be interviewed. Otherwise, stop the recording.]

Overview of the Stress Stimulation

BASELINE (10 mins)	SENT TO BREAKOUT ROOM	STRESS TASK (5 mins)	SENT BACK TO MAIN ROOM	RECOVERY (10 mins)	DEBRIEFING (5 mins)	INTERVIEW

APPENDIX H: Semi-structured Interview Questions

(1) How was your overall experience of this activity?

   a. Follow-up: What adjectives would you use to describe your experience? How so?

(2) What would make this experience more/less stressful for you?

   a. Follow-up: Did you feel you had a handle over the stress you were feeling?

(3) How relevant do you think this activity was for you?

   a. Follow-up: Do you think the scenario is something you will face in the future? Why or why not?

(4) After hearing the scenario, how did you anticipate you would do?

   a. Follow-up: Would you classify your experience as a threat or a challenge?

(5) How do you generally know and identify your emotions? (e.g., happy, angry, or sad)

   a. Follow-up: How are you aware of your emotions?

(6) How do you generally express your emotions? (e.g., happy, angry, or sad)

   a. Follow-up: How do other people know what you are feeling? (or nervous, excited, may have to provide a clear example)

(7) What is the first thing you do when you feel overwhelmed with emotions?

   a. Follow-up: How do you know if your coping strategies are working?

(8) From your experience, how do you think other people know how you are feeling?

   a. Follow-up: Can you provide specific examples?

(9) How do you know your body is reacting to stress?

   a. Follow-up: Can you provide a detailed explanation on how you think your body reacts to stress?

APPENDIX I: Demographic Questionnaire

1. What is your assigned participant ID? _____
2. What is your age? _____
3. What is your gender identity?
    a. Female
    b. Male
    c. Trans
    d. Prefer not to identify
    e. Other _____
4. What is your race?
    a. American Indian or Alaska Native
    b. Asian
    c. Black
    d. Native Hawaiian or Other Pacific Islander
    e. White
    f. Mixed Race
    g. Prefer not to identify
5. Are you Hispanic or Latinx?
    a. Yes
    b. No
6. What is your current or intended major? _____
7. How many credits are you taking this semester? _____
8. What is your academic status?

a. Freshman

b. Sophomore

c. Junior

d. Senior

e. Prefer not to answer

9. Do you currently work?

a. Yes

b. No

c. Prefer not to answer

10. On average, how many hours per week do you work? _____

11. Do you exercise regularly?

a. Yes

b. No

c. Prefer not to answer

12. On average, how many hours per week do you exercise? _____

13. Do you participate in extra-curricular activities?

a. Yes

b. No

c. Prefer not to answer

14. How many hours per week do you participate in extra-curricular activities? _____

15. Have you been diagnosed with any of these conditions? (Check all that apply to you.)

a. Arrhythmia

b. Cardiomyopathy

c. Congenital Heart Defect

d. Coronary Artery Disease

e. Heart Attack

f. Heart Valve Disease

g. Prefer not to answer

h. Other _____

16. (For female participants only.) Do you currently take oral contraceptives?

a. Yes

b. No

c. Prefer not to answer

17. (For participants with autism only.) What is your primary autism spectrum diagnosis?

a. Autistic Disorder

b. Asperger's Disorder

c. Pervasive Developmental Disorder – Not Otherwise Specified (PDD-NOS)

d. Rett's Disorder

e. Childhood Disintegrative Disorder

f. Autism Spectrum Disorder

g. Autism (special education classification)

18. What age were you when you were given the autism spectrum diagnosis? _____

19. Who provided you with the autism spectrum diagnosis?

a. Clinical psychologist

b. School psychologist

c. Medical doctor

d. Other, please specify. _____

How would you rate your stress level at this time?

Please choose just *one* answer from 0 to 10.

Not at all stressed										Extremely stressed
0	1	2	3	4	5	6	7	8	9	10

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