DIFFERENTIAL EFFECTS OF MINDFULNESS MEDITATION VERSUS A CONTROL CONDITION ON POST-STRESS HEART RATE VARIABILITY IN STUDENTS REPORTING HIGH AND LOW ANXIETY

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Abstract

Anxiety is associated with autonomic nervous system imbalance express with varying levels of heart rate variability (HRV). Mindfulness meditation (MM) is an evidence-based tool for regulating HRV. Previous literature has examined HRV changes in those with maladaptive perfectionism after cognitive stress induction. This study found a significant increase in HRV after stress induction in those that practised MM but not in those with maladaptive perfectionism. The current study examined HRV changes in moderate to high anxiety participants and their low anxiety counterparts. Participants (N=68) were randomly assigned to either a 10-minute recovery condition involving guided mindfulness meditation practice ([MME],[N=35]) or listening to a description of mindfulness meditation ([MMD],[N=33]) following cognitive stress induction. A between-subjects repeated measures multivariate analysis of variance (MANOVA) found no significant difference. HRV, however, effect sizes were in the hypothesized direction and support previous evidence that suggests MM is an effective tool for restoring autonomic nervous system (ANS) function following a stress task. There was also a significant change in respiratory rate over time regardless of condition. Additional research should be completed with moderate to high anxiety individuals to better understand ANS activity and its relationship to the anxiety condition.

Keywords: heart rate variability, mindfulness meditation, stress, anxiety, psychophysiology

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Introduction

In an increasingly fast-paced and interconnected world, mental health of young adults has become a topic of significant concern that warrants a deeper exploration. The transition from adolescence to adulthood is marked by a multitude of stressors, which include transitioning from good levels structural support and internal resources to more independence, as well as changing relationships and often travelling hundreds and even thousands of miles away from home (Scales et al., 2016).

These complexities place young adults at increased risks for experiencing psychological distress and mental health issues (Kessler et al., 2007; Royal College of Psychiatrists, 2011). The prevalence of mental health conditions, notably anxiety, depression, post-traumatic stress disorder, and other forms of psychopathology has been on the rise, sparking alarm within the global healthcare community (Castellini et al., 2021; Newlove-Delgado et al., 2023; Twenge et al., 2010). This upward trend highlights the immediate need to tackle mental health concerns within this age group. Additionally, these trends underscore the importance of further research into the distinctive socio-cultural pressures and mental well-being difficulties encountered by young adults, in addition to development of tailored interventions that are sensitive to distinctive experiences and needs of young adults.

Mental Health Challenges in Young Adults: Current Trends

The mental health landscape of young adults is characterized by intricate complexities that span multiple disorders (Kessler et al., 2007). It is estimated that 1.9 million young adults in the United States face serious mental health conditions (Lipari & Hedden, 2013; US Census Bureau, 2014). Health Canada specifically has reported that anxiety disorders effect one in 10 adults and is becoming increasingly more common in young adults (2009). These statistics underscore the need

for a comprehensive understanding of the varied mental health landscape in this demographic group.

While it is undeniable that individuals across all ages face life's adversities, young adults navigate a unique set of circumstances that render them particularly vulnerable to mental health challenges (Skehan & Davis, 2017). The transition from adolescence to early adulthood marks a pivotal phase in one's life, punctuated by a multitude of transformative changes and challenges. These include: the ongoing development of executive functions, academic pressures, the uncertainties of entering a career path, financial responsibilities, and maintaining social relationships (Beiter et al., 2015; Lerner, 2015; Santisi et al., 2018; Shulman & Connolly, 2013). These multifaceted challenges, during young adulthood, are further intertwined with the ongoing processes of identity formation and self-discovery (Benson & Elder, 2011; Klimstra & van Doeselaar, 2017), placing young adults under increased psychological strain.

These personal challenges may indeed be prolonged or exacerbated when considering challenges of accessing mental health services related to social stigma, service underutilization, service shortages, or lack of health insurance (Biddle et al., 2004). Indeed, research has found young adults to underuse appropriate mental health services (Eisenberg & Chung, 2012; Karlin et al., 2008; Rickwood et al., 2005). For example, only about one-third of young adults with clinical-level mental health issues actually seek help from family or a loved one, leading them to suffer in silence (Vanheusden et al., 2008). This service underutilization is in fact due to multiple reasons, which include scarcity of available therapist hours, related increases in mental health service costs, and prolonged wait times for critical interventions (Bishop et al., 2016; National Council Medical Director Institute, 2017; Satiani et al., 2018).

In addition to factors related to the healthcare system, personal obstacles also play a role in mental health service underutilization in this population. One such obstacle is the lack of

recognition for their mental health problems, with as many as 36% of non-help-seeking young adults denying having mental health issues (Vanheusden et al., 2008). Limited knowledge of the signs of mental health problems contributes to this denial (Jorm et al., 2006; Vanheusden et al., 2008; Wright et al., 2005). Young adults, males in particular, are more likely than females to deny having mental health difficulties, possibly influenced by masculine societal norms that encourage attributes of independence and invulnerability (Möller-Leimkühler, 2002; Vanheusden et al., 2008). Young adults may also view mental health difficulties as temporary, holding the belief that mental health problems will naturally resolve, despite substantial evidence on the persistent nature of mental health challenges in this demographic (Ferdinand & Verhulst, 1994; Vanheusden et al., 2008; Wells et al., 1994).

Anxiety in Young Adults

Anxiety is a natural response to stressors and challenges encountered in daily life (Siddaway et al., 2018). In young adults, anxiety symptomatology can vary widely, ranging from mild physical symptoms such as burning or wobbly legs to intense distress like the fear of dying (Beck et al., 1993) While anxiety disorders, such as generalized anxiety disorder (GAD), often serve as the primary focus of clinical attention, subclinical anxiety can permeate various aspects of young adults' lives (Goodwin et al., 2020; Igbokwe et al., 2020; Iqbal & Ajmal, 2018). Anxiety symptoms, even when they do not meet the diagnostic threshold for clinical diagnosis (subclinical anxiety), can act as significant contributors to the overall mental health picture of young adults. Specifically, subclinical anxiety can negatively affect young adults' academic performance (Lepp et al., 2014; Macher et al., 2012), interpersonal relationships (Evans & Wertheim, 1998; Waring et al., 2023), and quality of life (Hansson, 2002). For example, it may manifest as social anxiety, characterized by an overwhelming fear of social interactions and judgment (American Psychiatric

Association, 2013; Morrison & Heimberg, 2013). Others may grapple with obsessive-compulsive tendencies, involving intrusive thoughts, and compulsive behaviours that stem from anxiety (American Psychiatric Association, 2013; Stein et al., 2019). Trauma, whether recent or past, can give rise to post-traumatic stress symptoms, further exacerbating anxiety symptoms within this population (American Psychiatric Association, 2013; Michopoulos et al., 2017).

Anxiety Disorders in Young Adults

Anxiety disorders constitute a significant and prevalent category of psychopathology in young adults (Basta et al., 2022; Copeland et al., 2014), affecting 5 to 19% of young adults (Hawes et al., 2022). Anxiety disorders extend beyond a single homogeneous diagnosis and encompasses conditions, such as depression, PTSD, and OCD (Copeland et al., 2014) Anxiety disorders collectively exert a profound impact on the psychological well-being of young adults (Siddaway et al., 2018; Tuma & Maser, 1985). Together with substance use disorders, anxiety disorders represent the two most prevalent forms of mental health disorders in young adults (Michael et al., 2007).

As mentioned, clinical anxiety may co-occur with various mental health conditions and individuals diagnosed with clinical depression or substance use disorders often reporting comorbid anxiety (Cummings et al., 2014; Pasche, 2012; Simpson et al., 2021; Tang et al., 2016; Vorspan et al., 2015). Overall, three-quarters of individuals with an anxiety disorder encounter at least one additional mental condition throughout their lives (Michael et al., 2007). This comorbidity sheds light on the shared symptomatology with depression, PTSD, and OCD and highlights their shared pathophysiology. Therefore considering the impact of comorbid anxiety symptoms leads to further challenges in the implementation of mental health interventions. For example, in many cases, interventions that focus solely on achieving an anxiety diagnosis may overlook the distressing and debilitating impact of anxiety symptoms. Integrative therapeutic approaches that acknowledge and

target anxiety within the broader context of mental health may offer more comprehensive support for young adults, for example, Rentala et al., (2019) used a more integrative approach involving meditation and found a statistically different decrease in educational stress ($F = 500.9$, $P < 0.001$, $\eta^2 = 0.90$) depression ($F = 222.73$, $P < 0.001$, $\eta^2 = 0.79$), anxiety ($F = 224.67$, $P < 0.001$, $\eta^2 = 0.80$), and stress ($F = 277.09$, $P < 0.001$, $\eta^2 = 0.82$) over three months follow-up.

Mindfulness Meditation as an Avenue to Promote Mental Health in Young Adults

Mindfulness is as a state of conscious awareness characterized by a deliberate and non-judgmental focus on the present moment (Brown et al., 2016; Creswell, 2017). It entails a focused observation of one's cognitive, emotional, and sensory experiences moment by moment, along with an open and receptive attitude towards them. Mindfulness is practised through mindfulness meditation (MM), in which meditators aim to cultivate mindful awareness by focusing attention on the breath. Early in MM training, focused attention (FA) is taught, and individuals are encouraged to briefly notice thoughts, emotions, and sensations but are encouraged to return attention back to the breath. MM often progresses from FA to what is referred to as open monitoring (OM) where free flowing thoughts and sensations are more closely observed and accepted as naturally occurring phenomenon (Brown et al., 2022). For example, mindfulness of breath meditation involves training with the narrow focus on the breath while maintaining an open and non-judgmental awareness of distractions. The fundamental goal is to develop a heightened capacity for sustained attention and detachment from inner experiences. The practice encourages individuals to view thoughts and emotions as transient phenomena, facilitating detachment from habitual reactivity and fostering equanimity.

MM has its historical roots in Buddhist tradition and philosophy (Brown et al., 2016). The concept, known as "sati" in Pali and "smṛti" in Sanskrit, has been a fundamental element of

Buddhist thought for over 2,000 years. In this tradition, mindfulness is conceived as an important element of the path to freedom from and coping with suffering (Brown et al., 2016). Since the 1970s, owing to increasing rates of mental suffering, MM has gradually entered into the secular discourse, contributing to the contemporary mindfulness-based meditation practice and psychotherapies (Brown et al., 2016).

Concurrently, MM has received increasing research attention recently (Chiesa, 2010; van der Riet et al., 2018) as an important contributor to improved psychological health (Auty et al., 2017; Eberth & Sedlmeier, 2012; van der Riet et al., 2018). The mental health effects of MM represent a compelling therapeutic and research domain within contemporary psychology and psychiatry (Gál et al., 2021; Joyce et al., 2010; Wielgosz et al., 2019). MM has demonstrated efficacy in mitigating symptoms across various anxiety disorders and ameliorating chronic stress (Hoge et al., 2013; Hoge et al., 2018; Liu et al., 2021), including alleviation of stress and anxiety (Bamber & Morpeth, 2019; Wielgosz et al., 2019; Zeidan et al., 2014). Furthermore, MM enhances emotional regulation and well-being (Bostock et al., 2019; Grecucci et al., 2015; Zhang et al., 2019; Zollars et al., 2019). It further fosters emotional intelligence (Charoensukmongkol, 2014). MM has been shown to be useful in mood disorders, such as depression, where it has shown promise in symptom reduction (Hedges' g = 0.63) and mood symptoms (Hedges' g = 0.59) as well as in-patients with anxiety disorders (Hedges' g of 0.97 and 0.95) for improving symptoms, assessed and calculated with 95% confidence intervals for the pre-treatment means on all anxiety and depression measures, which established cutoff scores were available (Hoffman et al., 2010).

Moreover, MM offers a potential intervention for trauma-related conditions, including post-traumatic stress disorder, by promoting a sense of safety and grounding (Lang, 2017; Sun et al., 2021). It also helps facilitate the processing of traumatic memories and reduces post-traumatic stress disorder symptoms (Lang, 2017).

Mindfulness Meditation as a Mental Health Intervention

Mindfulness-based interventions (MBIs) are a significant aspect of the contemporary mental healthcare landscape (Goldberg et al., 2018; Klingbeil et al., 2017; Ma et al., 2022; Spijkerman et al., 2016; Zhang et al., 2021). MBIs encompass a range of structured programs, designed to cultivate MM and related skills in individuals (Hofmann & Gomez, 2017). MBIs include acceptance and commitment therapy, mindfulness-based stress reduction, and mindfulness-based cognitive therapy.

ACT aims to increase psychological flexibility through exercises that focus on six interrelated constructs: acceptance, contact with the present moment, self as context, cognitive diffusion, committed action, and values (Hayes, 2004). MBSR was designed originally in a hospital setting where medical patients were being helped to manage the stress of medical conditions or the suffering from stress-related conditions (Kabat-Zinn, 1982). MBSR provides mindfulness training via three formal mindfulness meditation practices: mindful movement, the body scan, and sitting meditation (Crane et al., 2017). MBCT incorporates components from cognitive therapy and was initially developed as a relapse prevention program for patients with recurrent depression (Segal et al., 2002). MBCT combines elements from cognitive-behavioural therapy and mindfulness-based stress reduction, resulting in an eight-session group program (Sipe & Eisendrath, 2012). This therapy, typically delivered in group settings, equips individuals with the awareness to recognize and interrupt the cycle of depressive cognitions and relapse (Segal et al., 2018).

The integration of mindfulness into cognitive-behavioural therapy has further been explored in addressing anxiety disorders. Mindfulness-based stress reduction integrated with cognitive-behavioural therapy principles has demonstrated effectiveness in reducing anxiety symptoms. A systematic review by Ghahar et al. (2020) found MBCT's to significantly improved

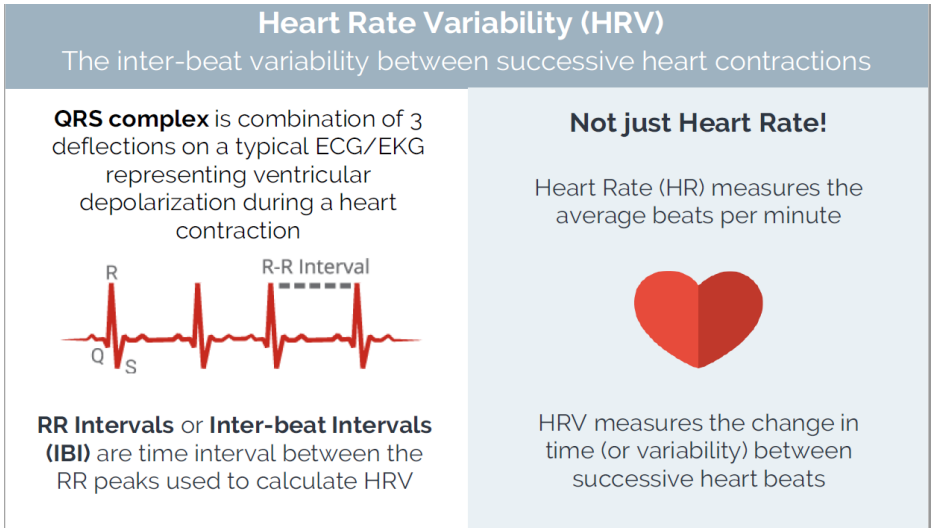
the treatment outcome of GAD in all but one of six studies examined. The mean revised Jadad score of the six studies was 4.3 (range: 3 to 6) and the overall mean effect size was -0.65.

Given availability of remote audio and video platforms, delivery of MBIs have extended beyond traditional in-person settings (Cillessen et al., 2018; Segal et al., 2020), ushering in a new era for online mental health service delivery that can be accessible to wider audiences. In-person MBIs allow for real-time interaction, personalized guidance, and group support, fostering a sense of community among participants. Conversely, online MBIs, while providing flexibility, convenience, and wider dissemination, allow participants to engage in mindfulness practices with or without psychoeducation modules and accommodate diverse schedules and geographic locations. An increasing body of research indicates that therapist-guided, internet-based cognitive-behavioural therapy and, to some extent, digitally delivered mindfulness and acceptance-based interventions, can effectively complement or outperform traditional in-person therapy. When comparing online treatments to more traditional in-person methods, Krik et al. (2022) found a statistically significant difference between groups at post-intervention for depression (Hedges' $g = -0.47$) and anxiety (Hedges' $g = -0.40$). These outcomes favoured online treatment groups.

Heart Rate Variability and Mental Health

Over the past 25 years, heart rate variability (HRV) indices have seen increasing utility as a diagnostic and prognostic marker in the study of physical and psychiatric disorders. HRV is defined as the amount time between successive R-R intervals and is a more accurate measure of the ANS than resting heart rate (HR) alone.

Figure 1. HRV and QRS complex EliteHRV. (2026)



HR and time between successive R-R intervals are both under the influence of the sympathetic (SNS) and parasympathetic nervous systems (PNS). The intrinsic HR, which is generated by the sinoatrial node (SA node), ranges between 100 to 120 beats per minute (BPM). At rest, the intrinsic HR is generally slowed by the parasympathetic (vagus) nerve resulting in a resting HR of between 60 and 90 BPM. Indeed, HR represents the net effect of the parasympathetic nervous system that slows down HR and the sympathetic nervous system that accelerates it. Furthermore, HR is monotonously irregular meaning there is an interbeat variability in time between successive beats. HRV can be assessed in two ways, either in the time domain or in the frequency domain, as a power spectral density (PSD) analysis. In either method, the time intervals between each successive normal R wave are first determined.

Time-domain indices quantify the amount of HRV observed during periods that may range from <1 minute to >24 hours. According to the time-domain measures of HRV, PNS function is best reflected in RMSSD, which is less affected by respiration than is respiratory sinus arrhythmia (RSA; Shafer Ginsburg, 2017). Other time-domain indices include, SDNN, which is thought to be the "gold standard" for stratification of cardiac risk when assessed over a 24 hour period. According

to the frequency-domain analysis, HRV measures of ANS function can be broken down further into high-frequency HRV (HF-HRV), low-frequency HRV (LF-HRV), and very low-frequency HRV (VLF-HRV). HF-HRV is thought to represent parasympathetic activity of the vagus nerve (Task Force, 1996). LF-HRV is believed to be related to sympathetic activity, and the HF/LF ratio has been helpful in identifying the ratio or balance between the SNS and PSNS (Task Force, 1996). HF-HRV is closely related to respiration. RSA represents HR fluctuations that are "in phase" with breathing. In normal RSA, HR increases during inspiration and decreases during expiration. These are indexes of vagal or parasympathetic tone (Roscoe, 1992).

HRV's application to mental health is rooted in the widespread observation of autonomic dysregulation in psychopathologies (Chalmers et al., 2014; Koch et al., 2019; Schneider & Schwerdtfeger, 2020). Specifically, when an organism is challenged by physical and psychological stress, the autonomic system balance between the SNS and PNS are disturbed, which can be reflected in excess SNS response and blunted PNS response (Carol et al., 2017; Philips et al., 2013).

Typically, PNS tone is demonstrated in the capacity of the vagus nerve to reduce HR (Azam et al., 2015). Vagal tone is associated with physiological flexibility and resilience, as well as an appropriate selection of adaptive responses (Porges, 1995). Higher HRV (vagal tone) is an indication of self-regulatory abilities (Segerstrom et al., 2017), while mental and cognitive laboratory stress tasks have been shown to reduce HRV and the modulating effects of the vagus nerve (reduced vagal tone; Taelman et al., 2011). Moreover, when individuals confront stressors that require executive functioning, higher levels of vagal tone are considered adaptive while vagal withdrawals (involving lower levels of parasympathetic tone) are considered maladaptive (Thayer et al., 2012). With this interpretation, however, comes many conflicting findings, especially among psychophysiological studies, as generalized autonomic activity patterns do not encompass a total

range of responses, and there seems to be a unique subset of individuals who have been found to express atypical response patterning to stress (Friedman & Thayer, 1998; Hamilton & Alloy, 2016).

Despite some conflicting findings, the scientific body of evidence exploring HRV in relation to specific mental health populations has been growing, and recent numerous systematic reviews have provided a better guide to understanding the relationship between autonomic function and mental health. Koch et al. (2019) provided an up-to-date analysis of 21 studies including 2,250 unmedicated major depression (MD) patients and 1,982 controls. They found HRV to be significantly lower in MD patients compared to that of controls with a small effect size when looking at the HVR measures in the frequency-domain HF-HRV (Hedges' g = -0.318), time domains, RMSSD (Hedges' g = −0.462), and SDNN (Hedges' g = −0.266). Furthermore, when analyzing published articles on HRV among individuals with PTSD, Schneider and Schwerdtfeger (2020) conducted a random-effects meta-analyses at rest and found a significant group difference in resting HRV, with the PTSD group having lower levels than controls in HF-HRV (Hedges' g = −0.23), RMSSD (Hedges' g = −0.38), and SDNN (Hedges' g = −0.64). Finally**,** a meta-analysis that compared 2,086 patients with an anxiety disorder and 2,294 controls from 36 articles found that individuals with anxiety disorders were characterized by lower resting HF-HRV compared to that of controls with a small effect size (Hedges' g −0.29; Chalmer et al., 2014).

Unfortunately, the relationship between GAD and ASN function has been limitedly explored with HRV. Certain findings suggest that individuals with GAD have a heightened cardiac response to threat and a difficulty restoring to equilibrium during a subsequently presented neutral stimulus—a difficulty that represents a limited range of response compared to controls (Thayer et al., 2000). Along these lines, enhanced prefrontal cortical activity has been observed in association with higher levels of vagal control over the heart (Patron et al., 2018). Since evidence suggests lower resting levels in HRV in individuals diagnosed with GAD, and there are healthy associations

between enhanced prefrontal cortical activity to higher HRV (Patron et al., 2018), it is worthwhile to assess treatments of anxiety, notably in the stress restore process, that aim to enhance prefrontal cortical activity and use HRV as an indicator of therapeutic effect. The results of such assessments may clarify what mechanisms are involved in the ANS.

HRV and Mindfulness Meditation

Mindful attention directed to breathing sensations, as practised during mindfulness of breath meditation, is associated with improvements in cardiac sympathovagal balance, likely related to reducing sympathetic tone and increasing vagal tone (Azam et al., 2015; Telles et al., 2005). Autonomic regulation through increased parasympathetic activation seen through HF-HRV) has been observed in migraine sufferers during 10 minutes of audio-directed MM immediately after experimental stressor exposure (Azam et al., 2016). In individuals with perfectionistic tendencies, an identical meditation audio intervention was further associated with increased HF-HRV in normal controls, but not in individuals identified with perfectionist tendencies (Azam et al., 2015). Similarly, among individuals with elevated GAD symptoms, participants with high trait mindfulness displayed higher RMSSD-HRV at baseline than counterparts with lower mindfulness levels (Mankus et al., 2013). Therefore, on the basis of multiple findings, MM represents a promising modality to adaptively regulate autonomic balance and assist recovery of parasympathetic autonomic function after exposure to experimental stress in individuals with anxiety. In attempts to delineate the psychological mechanisms by which mindfulness meditation may reduce symptomatic anxiety responses, a systematic review compared MBIs to CBT and reported evidence suggesting that MM is superior to CBT in the reduction of symptoms of generic distress but inferior to CBT at reducing fear-related symptoms (Costa et al., 2018). These findings suggest that MM as a stand-alone treatment is unlikely to sufficiently address all the multiple

factors operative in anxiety. Still, there is promise in addressing some important factors that merit the further investigation of MM in relation to anxiety experiences.

Hypotheses

1. All study participants will demonstrate reductions in RR interval, RMSDD, and HF-HRV from baseline rest (BL) phase to the end of stress task (i.e., psychological stress task [PST] phase). A statistically significant main effect of phase would ascertain this hypothesis.
2. At Phases 3 and 4, participants assigned to the MME group will show significantly higher RR interval, RMSDD, and HF-HRV compared to participants assigned to the MMD condition. A statistically significant Condition × Phase interaction would ascertain this hypothesis.
3. At Phases 3 and 4, MME group participants with moderate to high anxiety levels (BAI >21) will show significantly lower RR interval, RMSDD, and HF-HRV compared to MME participants with low anxiety levels (BAI ≤ 21). A statistically significant Group × Phase × Condition interaction would ascertain this hypothesis.

Methods

Participants

This study was conducted at York University. Undergraduate students were recruited through an online undergraduate research participant pool (URPP) that grants course credits for participating in research experiments. While most participants were predictably first-year students, students from other undergraduate years were also included.

Sample Size Estimation

In the Azam et al. (2015) study, a sample size of n = 60 (n = 21 perfectionists and n = 39 controls) was employed to execute a similar lab-based assessment. Analyses of this experiment revealed a significant elevation in HRV during meditation for controls but not for perfectionists. Our study is closely related, and the perfectionists are substituted for moderate to high anxiety individuals, while normal controls are substituted by low anxiety individuals. Given the difficulty of establishing power analyses and sample size estimates for this type of study, we have adopted the Azam et al. (2015) sample size.

Risks and Inclusion-Exclusion Criteria

To be eligible for the study, participants must have been enrolled in an undergraduate program at York University. Prior to the experimental protocol, participants were also screened for cardiac conditions, which would confound the phasic HRV changes observed (Kemp et al., 2012; Miu et al., 2009). Students disclosing any cardiac conditions or meditation experience beyond 10 hours (past or current) were excluded. There was no risk associated with assessment via ECG or respiration measures. Participants were screened with the Beck Anxiety Inventory to determine anxiety status (BAI; Beck et al., 1988). For the purposes of this study, participants were randomized into a low anxiety group if they scored between 0 and 21 and a moderate to

high anxiety group if participants scored from 22 and 63. These groups were constructed based on the original suggested group ranges recommended by Beck et al. (1988) and allowed for effective efficient recruitment / data collection.

Design

This study collected psychometric, demographic, and respiration data, as well as HRV via ECG. After providing informed consent, participants were screened for eligibility and completed the BAI. For the purposes of this study, participants were randomized into a low anxiety group if they scored between 0 and 21 and a moderate to high anxiety group if participants scored from 22 and 63. Following the BAI questionnaires, participants were randomized into one of two separate conditions, an experimental condition that received a guided mindfulness meditation (MME) or a rest group that experienced an audio description of mindfulness (MMD). Prior to beginning the experimental procedure, the participants completed additional psychometric questionnaires.

Questionnaires

Demographic Questionnaire

Participants were asked for demographic information like age, sex, ethnicity/race, and anxiety diagnosis. They were also asked whether they had any additional mental health diagnoses, including but not limited to depressive disorder, bipolar/II disorder I, schizophrenia, substance use disorder, and/or eating disorder. Participants were asked if they had a medical history of cardiovascular disease, heart attack, pulmonary disease, hypertension, diabetes, and thyroid disorders (see Appendix A).

Automatic Thoughts Questionnaire (ATQ)

The ATQ was created by Hollon and Kendall (1980) to assess personal automatic negative statements that often occur in four dimensions: (1) personal maladjustment and desire

for change, (2) negative self-concepts and negative expectations, (3) low self-esteem, and (4) helplessness (see Appendix B). The ATQ consists of 30 items that hold ranked scoring from 30 to 150. Each item is a proposed thought, for example, “I feel like I’m up against the world.” The participants are asked to select the frequency of the thought on a 5-point Likert scale (1 = not at all, 2 = sometimes, 3 = moderately often, 4 = often, 5 = all the time). It has proven to be reliable in distinguishing between depressed and non-depressed groups, with a Cronbach’s alpha of 0.96 (Azam et al., 2015; Hollon & Kendall, 1980).

Beck Anxiety Inventory (BAI)

The BAI was developed by Beck and colleagues (1988) to differentiate between anxiety and depressive symptoms (Beck et al., 1988; see Appendix C). The BAI is considered the gold standard self-report measure of general anxiety symptoms (Baer & Blais, 2010). The BAI is a 21-item self-report measure that assesses anxiety severity in adults, while being able to discriminate from comorbid conditions such as depressive symptoms. It is often used as a weekly measure of anxiety symptoms. The BAI is a self-administered measure that takes between five and 10 minutes to complete, with scores ranging from 0 to 63, and it is rated on a Likert scale ranging from “not at all” to “severely.” (Beck & Manual, 1993) The BAI has received extensive empirical support and expresses internal consistency within psychiatric samples ($\alpha = 0.92$; Beck et al., 1988) and anxiety disorder samples $\alpha = 0.85–0.93$; (BAI; Beck et al., 1998). The original article suggested adequate one-week test–retest reliability ($r = 0.75$), and subsequent research has shown five-week test–retest reliability among individuals diagnosed with panic disorder and agoraphobia ($r = 0.83$; de Beurs et al., 1997).

Patient Health Questionnaire (PHQ-9)

The PHQ-9 was developed to diagnose depression utilizing DSM-IV criteria (Kroenke & Spitzer,2002; see Appendix H).The PHQ-9, a shorter test than other depressive questionnaires, remains highly sensitive at detecting the severity of depression while also being able to discern depression from other disorders (Cronbach's alpha = 0.89). Participants are asked to report the frequency of depressive symptoms over the last two weeks using a four-point scale (0 = not at all, 1 = several days, 2 = more than half the days, 3 = nearly every day). A major depressive disorder is diagnosable if five or more of the criteria have occurred at least "more than half the days" and if one of the symptoms is depressed mood or anhedonia (Kroenke & Spitzer, 2002). The PHQ-9 indicates four levels of depression severity depending on the total score: 0–4 = "none-minimal," 5–9 = "mild," 10–14 = "moderate," 15–19 = "moderately severe," and 20–27 = "severe" (Kroenke & Spitzer, 2002).

Protocol

All the study procedures were approved via the Human Participants Review Subcommittee at the university where the study was conducted, and all participants shared written informed consent upon arriving at the laboratory session and prior to any data collection. Upon arrival at the lab, and after obtaining informed written consent to participate, all participants completed computer-based self-report questionnaires (see Appendix I; this manuscript reports only results from the BAI inventories). The experimental procedure consisted of four phases, in which participants underwent: Phase 1: a five-minute rest, where individuals could sit freely while measurements were taken, Phase 2: a five-minute pattern recognition task as the stressor stimulus, Phase 3: one to five minutes, and Phase 4: six to 10 minutes, in which participants received either MME or MMD. In the MME condition, participants were guided

through audio instructions of mindfulness meditation, and in the MMD condition, participants listened to an audio description of mindfulness. No indication was provided to the participants as to whether they qualified as low anxiety or moderate to high anxiety groups or to the purpose of the stress-induction / post-stress conditions (see Appendix I).

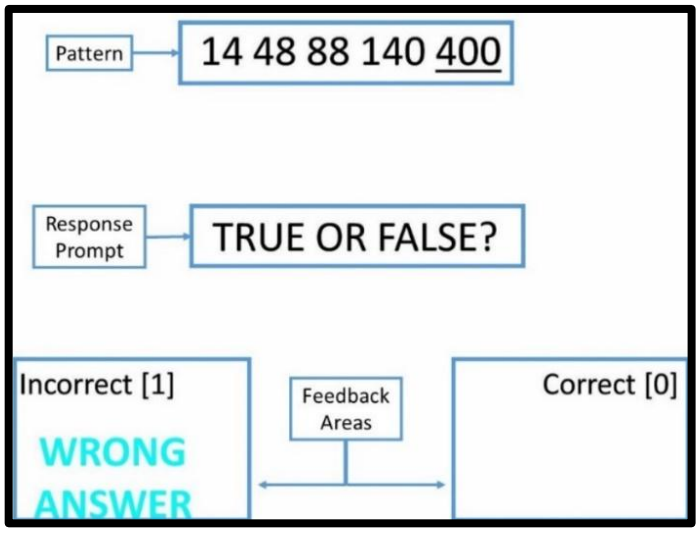
Baseline

During the baseline rest phase, participants were asked to remain seated in a relaxed and upright manner for five minutes while thinking freely with their eyes open. They were instructed to not make any sudden movements, keep their gaze in the same direction, and remain silent. Participants where then attached to an ECG unit and a respiration belt, and a five-minute baseline reading was recorded.

Stress Induction

For stress induction, in a computer-based pattern recognition task (PRT), participants were asked to study four alphanumeric characters presented at the top of the screen for nine seconds and determine the pattern that they follow (Figure 1). After nine seconds, a fifth character was shown and the text "True or False?" appeared in the middle of the screen. Participants were instructed to respond with the following key as quickly as possible: "True" (⇓ key) if they believed the fifth character followed the pattern or "False" (◊ key) if it did not. Immediately after the response, the text "Right Answer" or "Wrong Answer" was presented at the bottom left or bottom right of the screen, respectively for three seconds. Numbers indicating total "Correct [x]" (bottom right) and "Incorrect [y]" (bottom left) answers totalled to the current trial remained on the screen.

Figure 2. Example of Pattern Recognition Task Adapted from Azam et al. (2015)



The alphanumeric characters were designed to appear as if they followed simple or complex patterns; however, none of the problem sets followed a specific pattern (see Azam et al., 2013 for characters used). The "Right Answer" and "Wrong Answer" presentation was configured using a pre-determined random order so that each would be presented 11 times throughout the 22 trials. Participants were told the PST assesses cognitive capacity as a "marker" of intelligence, and the average score of the task is 80 to 85%, with a response time of about a second. The participants were also told their performance must be as close as possible to or equal to all participants (80–85% or above). In realty, the total number of "correct" and "incorrect" trials was fixed. All participants scored 50%. The average time to task completion was five minutes and 15 seconds.

Manipulation Check

After the PST was completed, a manipulation check was performed in which participants were asked three questions (see Appendix E). First, they were asked to rate the difficulty of the PST on a five-point scale (1 = extremely easy, 2 = easy, 3 = average, 4 = difficult, 5 = extremely

difficult). Second, participants were asked to report their stress level while completing the PST on a five-point scale (1 = not stressed at all, 2 = a little stressed, 3 = moderately stressed, 4 = stressed, 5 = extremely stressed). Last, participants were asked to rate their performance on the PST on a five-point scale (1 = poor performance, 2 = below expectations, 3 = met expectations, 4 = above expectations, 5 = exceptional performance).

Listening Intervention

For the post-stress phase, the mindfulness meditation condition (MME), participants were asked to remain seated in a relaxed and upright manner with eyes closed. A 10-minute audio recording was played featuring mindfulness instructions emphasizing attention to breathing sensations and a reorientation to breathing sensations once there was awareness of thoughts, emotions, bodily sensations, and/or external stimuli (Ritvo et al., 2013). The instructions were recorded by a clinical psychologist and experienced MM instructor. In the post-stress rest condition MMD, participants were seated identically as in the MME condition (including eyes closed) and were played an audio description of historical and scientific information on MM by the same instructor for 10 minutes. This recording did not deliver any instruction on how to practice MM; participants were asked to simply rest while the recording played.

Debrief

Following the listening intervention, there was a short debriefing period with each participant. During the debrief, participants were told about the purpose and nature of the study design as well as the deception within the PST and listening interventions. Prior to release of the participants, they were encouraged not to share this information regarding the experiment with other students and then they signed a debriefing form. The examiner was sure to provide each participant with resources and contact information if they experienced distress after the

deception. No participants contacted the principal investigator. For the full study protocol see Appendix I.

HRV Data Collection and Processing

ECG data were recorded using an ADInstruments (ADI) PowerLab 4-channel data acquisition system. LabChart Pro software, developed by ADI, was integrated with the ECG unit, and was used to obtain computer-digitized ECG signals from the PowerLab unit. The standardized sampling rate was 1,000 Hz. ECG data were collected and prepared in accordance with the standards set by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996). Kubios HRV Scientific Version 4.1.0 for Macintosh is integrated with machine learning for automated ECG interpretation, which indicates ectopic and normal beats and is well-validated (https://www.kubios.com/; Laborde et al., 2017).

Data were also visually inspected to ensure each beat-to-beat interval (RR interval) had a clear wavelength (PQRST formation). Algorithms in Kubios were used to detect and inspect potential ectopic beats. The data were inspected to confirm the absence of artifacts and cardiac arrhythmias. Kubios settings were as follows: (1) automatic noise detection: low; and (2) beat correction: threshold very low. Data were analyzed in five-minute epochs, consistent with current recommendations for short-term HRV analysis (Laborde et al., 2017; Pham et al., 2021). Kubios HRV Scientific was used to calculate time and frequency based HRV metrics (Laborde et al., 2017; Li et al., 2019; Pham et al., 2021; Task Force., 1996). Both time-domain and frequency-domain variables were generated with the Kubios HRV Scientific, including average RR interval, the square root of the mean squared differences of successive RR intervals (RMSSD), LF-HRV (0.04 – 0.15 Hz; marker of SNS activity), HF-HRV (0.15 – 0.40 Hz; marker of PSNS activity),

and LF/HF ratio (balance between SNS and PSNS). Frequency-domain results were computed via Fast Fourier transformation (FFT). These metrics were chosen using the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996). Current literature supports this method of HRV analysis (Li et al., 2019; Pham et al., 2021). For time-domain measures, RMSSD is strongly recommended as an estimate of short-term recordings of HRV and was used for analysis (Laborde et al., 2017; Task Force., 1996). RMSSD is strongly correlated with HF-HRV. For the proposes of this study, we used both time-domain and frequency-domain measures for the analysis. Furthermore, the 10-minute post-stress recordings were divided into two 5-minute segments in order to (1) keep the time-length of the ECG recordings used to calculate HRV consistent (i.e., five minutes for baseline, stress induction, and two post-stress phases) and (2) allow for an additional time-point to assess delays in cardiovascular recovery as well as response to MM instruction.

Respiration Data Acquisition and Processing

This procedure is standardized to address the possibility of confounding of respiration in HRV data interpretation. This standardization is according to the recommendations of Allen et al. (2007). Respiration data were collected using a respiratory belt for the duration of the study to account for variations in HRV due to changes in respiration. ECG-derived respiration was acquired using Kubios HRV Scientific, which has been validated (Helfenbein et al., 2014; Lipponen & Tarvainen, 2021; Rogers et al., 2022). RMSSD and HF-HRV are consistent when respiration is controlled (Task Force., 1996).

Statistical Analysis

All statistical analyses were conducted by the IBM Statistical Package for the Social Sciences (SPSS) version 22 (IBM Corp., Armonk, N.Y., USA). All data were examined for departures from

normality, and non-normally distributed variables were transformed to account for this prior to statistical analyses. Numeric variables are presented as means and standard deviations, and categorical variables are presented with frequency and percentage. Potential statistically significant differences between these variables at baseline are examined using independent samples t-test and chi-square test of independence for numeric and categorical variables respectively. A 2 × 2 × 4 mixed (i.e., between and within factors) repeated measures MANOVA was conducted to evaluate changes in study outcomes between study groups, conditions, and over experimental phases. These included two study condition (MME and MMD), two anxiety groups (low anxiety and moderate-high anxiety), and four study phases of baseline, PST, one-to-five-minutes post PST, and six-to-10-minutes post PST. Statistically significant main effects or interactions were then followed up by Bonferroni-adjusted post-hoc pairwise comparisons. Cohen *d* effect sizes were calculated for all between- and within-group comparisons according to procedures described by Lakens et al. (2018). All hypotheses (1–3) in relation to RR interval, log RMSDD, log HF-HRV, and respiration rate were evaluated by conducting a 2 × 2 × 4 repeated measures MANOVA. The MANOVA included the factors were condition (MME versus MMD), phase (BL, PST, Phase 3, and Phase 4), and group (low anxiety versus moderate to high anxiety; see Table 2).

Hypotheses

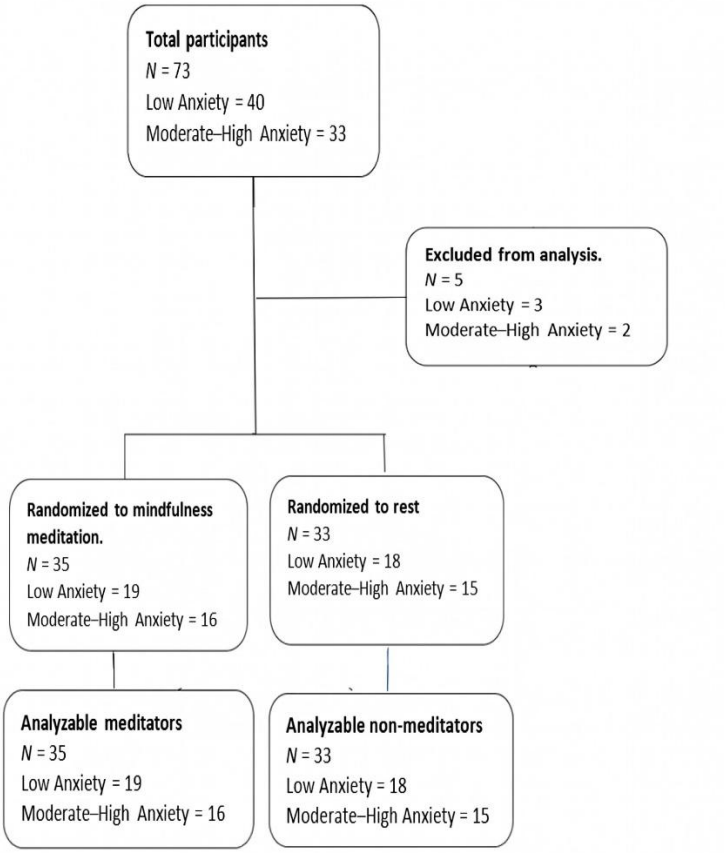
1. All study participants will show reductions in RR interval, RMSDD, and HF-HRV from baseline rest (BL) phase to the end of stress task (i.e., PST phase). A statistically significant main effect of phase would ascertain this hypothesis.
2. At Phases 3 and 4, participants assigned to the MME group will show significantly higher RR interval, RMSDD, and HF-HRV compared to participants assigned to the MMD condition. A statistically significant condition × Phase interaction will indicate support for this hypothesis.
3. At Phases 3 and 4, MME group participants with moderate to high anxiety levels (BAI > 21) will show significantly lower RR interval, RMSDD, and HF-HRV compared to MME participants with low anxiety levels (BAI ≤ 21). A statistically significant Group × Phase × Condition interaction will indicate support for this hypothesis.

Results

Recruitment and Participant Flow

As shown in Figure 1, 73 undergraduate university students (61.6% female) were recruited from the URPP at York University. All participants received course credit for their participation through the URPP. After completion of informed consent, participants were grouped into low anxiety (BAI ≤ 21) and moderate to high anxiety (BAI > 21) groups, according to specified BAI scoring criteria (Beck et al., 1988). Participants were then randomly assigned to either: (a) mindfulness meditation (MME, n = 35), or (b) meditation description (MMD = 33) conditions. Subsequently, both the MME and MMD conditions underwent the four phases of the experimental protocol, namely: the baseline rest (BL), PST, mindfulness meditation or description (1–5 minutes, Phase 3), and mindfulness meditation or description (6–10 minutes, Phase 4). Prior to statistical analyses, five participants (6.8%) were excluded, four due to low ECG signal quality and one due to the participant's familiarity with the unsolvable PRT that was used to induce psychological stress during the stress phase (i.e., Phase 2) of this study. Overall, 68 participants provided complete data for analysis, 35 (51.5%) in MME and 33 (48.5%) in MMD conditions.

Figure 2. Flow of Participants Through the Anxiety Study



Participant Characteristics

Table 1 presents participants' characteristics at baseline for the MME and MMD conditions , stratified by anxiety level. Of the 68 participants included in the analysis (mean age = 24.6, 62.0% female), 35 (54.0%) demonstrated low anxiety (BAI ≤ 21, mean BAI = 10.15) and 31 (45.8%) participants demonstrated moderate to high anxiety (BAI > 21, mean BAI = 30.00). Of the low anxiety participants, 16 (43.3%) were males and 19 were females (56.7%). Among participants with moderate to high anxiety, there were eight (25.8%) males and 23 (74.2%) females.

Table 1. Values of Demographic and Self-Reported Health Information for Anxiety Study Participants

	MME		MMD	
	Low Anxiety (n = 19)	**Moderate-High Anxiety (n = 18)**	**Low Anxiety (n = 16)**	**Moderate-High Anxiety (n = 15)**
Age, *M (SD)*	23.60 (1.7)	23.50 (4.2)	26.17 (7.3)	25.47 (4.4)
Sex, *n (%)*				
Male	10.0 (52.6)	4.0 (25.0)	6.0 (44.4)	4.0 (26.7)
Female	9.0 (47.4)	12.0 (75.0)	10.0 (55.6)	11 (73.3)
BAI,[a] *M (SD)*	10.74 (5.63)	31 (8.85)	9.44 (4.12)	33 (9.35)
PHQ-9,[b] *M (SD)*	8.17 (6.32)	13.73 (7.55)	6.5 (3.45)	16.53 (5.64)
Psychiatric diagnoses, *n (%)*	0. 0 (100.0)	11 (73.3)	1 (5.6)	10 (66.6)
Weekly exercise frequency, *n (%)*				
Rarely	2.0 (10.5)	3.0 (18.8)	5.0 (27.8)	3.0 (20.0)
Sometimes	6.0 (31.6)	5.0 (31.3)	9.0 (50.0)	7.0 (46.7)
Often	11.0 (57.9)	5.0 (31.3)	1.0 (5.6)	4.0 (26.7)
Very often	0.0 (0)	3.0 (18.8)	3.0 (16.7)	1.0 (6.7)
PST stress rating, *n (%)*				
Not or little stressed	7.0 (36.8)	6.0 (37.5)	6.0 (33.3)	3.0 (21.4)
Moderately stressed	7.0 (31.8)	5.0 (31.1)	5.0 (27.8)	5.0 (35.7)
Stressed / extremely stressed	5.0 (26.3)	5.0 (31.1)	7.0 (38.9)	6.0 (42.9)
Respiration rate,[d] *cpm (SD)*	14.69 (3.67)	14.2 (3.91)	15.1 (2.71)	15.6 (3.44)
Resting HR,[e] *bpm (SD)*	74.87 (9.96)	78.03 (9.9)	75.1 (11.4)	80.69 (9.48)
RR interval (ms)	821.70 (117.34)	785.50 (98.82)	819.10 (111.63)	758.51 (106.09)
Log RMSDD (ms)	1.65 (0.20)	1.62 (0.21)	1.67 (0.20)	1.57 (0.20)
Log HF (ms^2)	3.01 (0.47)	3.00 (0.46)	3.04 (0.39)	2.85 (0.52)

Note. MME: guided mindfulness meditation condition; MMD: audio description of mindfulness meditation condition; low anxiety: scores 0–21 on the BAI; moderate-high anxiety: scores > 22;
Note. RR: mean RR interval ; RMSDD: root mean square of successive difference; HF: high-frequency band; PST.
[a] BAI.
[b] Patient Health Questionnaire-9.
[c] Self-rating of stress after stress task.
[d] Respiration rate as inhalation exhalation cycles per minute.
[e] Resting HR as BPM.

RR Interval Change in Response to Stress Induction and Recovery

For RR interval, MANOVA indicated a statistically significant main effect for phase: (Λ = 0.85, F [3,62] = 3.65, p = 0.02). The Phase × Condition (Λ = 0. 98, F [2,62] = 0.419, p = 0.74), Group × Phase (Λ = 0.93, F [3,62] = 1.51, p = 0.22), and the Group × Phase × Condition (Λ = 0.99, F [3,62] = 0.21, p = 0.89) interactions did not show statistical significance. Subsequent evaluation

of the simple main effects for phase indicated a statistically significant reduction in mean RR interval from BL to PST phase (MD = –22.55, SE = 7.78, P = 0.03) and a statistically significant increase in mean RR from PST to Phase 3 (MD = 23.10, SE = 7.56, P = 0.02). Specifically, consistent with Hypothesis 1 (i.e., reduction in RR mean interval from BL to PST), mean RR interval decreased from BL (M = 796.16, SE = 12.82) to PST (M = 773.61, SE = 11.50).

Hypotheses 2 and 3 were not supported, as there was non-statistically significant Condition × Phase (p = 0.22) and Group × Phase × Condition (p = 0.89) interactions. Contrary to our hypotheses, mean RR interval at Phases 3 and 4 did not significantly differ between MME and MMD conditions and between MME (low anxiety) and MME (moderate to high anxiety) groups ..

Log RMSSD and HRV Change in Response to Stress Induction and Recovery

For log RMSSD, MANOVA indicated no statistically significant effects for either phase (Λ = .917, F [3.62] = 1.87, p = 0.145), Group × Phase (Λ = .917, F [3,62] = 1.87, p = 0.144), Condition × Phase (Λ = .985, F [3,62] = .31, p = 0.82), or the Group × Phase × Condition interaction (Λ = .948, F [3,62] = 1.123, p = 0.344). None of Hypothesis 1, 2, or 3 were supported by statistical significance in the RMSSD indices. Contrary to our hypotheses, mean RMSSD did not statistically differ from baseline to stress phase nor did Phases 3 and 4 significantly differ between MME and MMD groups or between MME (low anxiety) and MME (moderate to high anxiety) participants. Despite lack of significance, an examination of Cohen's *d* effect sizes between conditions (MME vs MMD) and within the low anxiety group suggests a magnitude difference at Phase 3 (d = 0.35) and Phase 4 (d = 0.31). This difference was seen is in the hypothesized direction as the within-group effect sizes between the PST phase, to Phase 3 (d = 0.32) and Phase 4 (d = 0.25), among low anxiety participants of the MME condition, were of a moderate effect versus the within-group difference of effect in the low anxiety MMD condition from the PST to Phase 3 (d = 0.05) and

Phase 4 (d = 0.10), which was minimal. Of the moderate to high anxiety individuals, there was a small difference between the MME versus MMD conditions at Phase 3 (d = 0.15) and Phase 4 (d = 0.29). However, these results were minimal and in a contrary direction to our hypothesis, as the within-group effects seen in the moderate to high anxiety individuals during the MME were limited from PST to Phase 3 (d = 0.04) and Phase 4 (d = 0.22), and the individuals of moderate to high anxiety in the MMD phase did see a small improvement in HRV from the PST to Phase 3 (d = 0.25) and Phase 4 (d = 0.08).

Log HF-HRV Change in Response to Stress Induction and Recovery

For log HF-HRV, the MANOVA showed no statistically significant main effects for phase (Λ = .902, F [3,62] = 2.245, p = 0.092), Group × Phase (Λ = .969, F [3,62] = 0.663, p = 0.578), Condition × Phase (Λ = .964, F [3,62] = 0.772, p = 0.514), or Group × Phase × Condition (Λ = .926, F [3,62] = 1.64, p = 0.189) interactions. None of Hypothesis 1, 2, or 3 were supported by statistical significance in the HF-HRV indices. Despite lack of significance, an examination of Cohen's *d* effect sizes suggest that there were differences in the magnitude of effect size between the MME and MMD groups of the low anxiety participants at Phase 3 (d = 0.48) and Phase 4 (d = 0.35).

This result for HF-HRV change, were in the hypothesized direction, as the low anxiety participants in the MME condition displayed a large within-group effect size from PST to Phase 3 (d = 0.52) and Phase 4 (d = 0.50). This can be contrasted with the small within-group effect size seen from the low anxiety MMD group between PST to Phase 3 (d = 0.04) and Phase 4 (d = 0.13). This difference was in the hypothesized direction. A similar, yet less pronounced contrast was present for the moderate to high anxiety participants, as the MME MMD between group effect sizes at Phase 3 (d = 0.21) and Phase 4 (d = 0.05) were small to moderate. This was in the hypothesized direction as the MME within-group effect sizes from the PST to Phase 3 (d = 0.50)

and Phase 4 (d = 0.22) were of a higher magnitude than their moderate to high-anxiety counterparts in the MMD condition, PST to Phase 3 (d = 0.23) and Phase 4 (d = 0.20).

Respiration Rate

For respiration rate, the MANOVA showed statistically significant main effects for phase (Λ = .399, F [3, 62] = 31.07, p < 0.001) and the Condition × Phase (Λ = .841, F [3,62] = 3.91, p = 0.013) interaction. There were no statistically significant interactions for either the Group × Phase (Λ = .981, F [3,62] = 0.43, p = 0.732) or Group × Phase × Condition (Λ = .965, F [3,62] = 0.748, p = 0.528) interactions. Subsequent evaluation of simple main effects for the Condition × Phase interaction indicated no statistically significant differences between MME and MMD at Phases 1 (MD = –.901, SE = 0.84, p = 0.297) and 2 (MD = –3.49, SE = 0.979, p = 0.72). However, there were statistically significant differences between MME and MMD at Phases 3 (MD = –2.06, SE = 0.813, p = 0.014) and 4 (MD = –2.53, SE = 0.858, p = 0.004).

Table 2. Stress Recovery From PST to Phases 3 (1–5 minutes) and 4 (6–10 minutes) as Mean (standard errors)

Indicator (unit)	**Phase**	**Low anxiety**		d (between)	**Moderate-high anxiety**		d (between)	**p**
		MME (n = 19)	**MMD (n = 18)**		**MME (n= 16)**	**MMD (n = 15)**		
RR (ms)	**BL**	821.70(24.15)	819.10(24.81)		785.51(26.32)	758.34(27.18)		
	PST	796.42(21.66)	786.50(22.26)	-	761.08(23.61)	750.46(24.15)	-	0.89
	Phase 3	812.50(22.87)	805.82(23.50)	0.13	798.65(24.92)	769.85(25.74)	0.30	
	Phase 4	812.46(21.5)	800.28(22.08)	0.13	792.43(23.42)	758.91(24.19)	0.35	
	d (PST-Phase 3)	0.16	0.19		0.40	0.21		
	d (PST-Phase 4)	0.16	0.14		0.35	0.10		
Log RMSSD (ms)	**BL**	1.65(0.05)	1.67(0.05)		1.62(0.05)	1.57(0.05)		
	PST	1.64(0.05)	1.62(0.05)	-	1.65(0.06)	1.63(0.06)	-	0.34
	Phase 3	1.69(0.04)	1.63(0.05)	0.35	1.66(0.05)	1.69 (0.05)	0.15	
	Phase 4	1.69(0.04)	1.64(0.04)	0.31	1.70(0.05)	1.65(0.05)	0.29	
	d (PST-Phase 3)	0.32	0.05		0.04	0.25		
	d (PST-Phase 4)	0.25	0.10		0.22	0.08		
Log HF (ms^2)	**BL**	3.01(0.11)	3.04(0.12)		3.00 (0.12)	2.85(0.12)		
	PST	2.89 (0.09)	2.89 (0.10)	-	2.85 (0.10)	2.89 (0.11)	-	0.19
	Phase 3	3.09 (0.09)	2.91 (0.09)	0.48	3.05 (0.09)	2.97 (0.10)	0.21	
	Phase 4	3.08 (0.08)	2.95 (0.09)	0.35	2.93 (0.09)	2.95 (0.10)	0.05	
	d (PST-Phase 3)	0.52	0.04		0.55	0.23		
	d (PST-Phase 4)	0.50	0.13		0.22	0.20		
Respiration rate (cpm)	**BL**	14.69 (3.67)	14.2 (3.91)		15.1 (2.71)	15.6 (3.44)		
	PST	19.86(0.92)	19.46(0.95)	-	18.88(1.01)	18.59(1.04)	-	0.53
	Phase 3	14.34(0.77)	16.96(0.79)	0.82	14.34(0.84)	15.84(0.86)	0.46	
	Phase 4	14.20(0.81)	16.83(0.83)	0.79	13.87(0.88)	16.30(0.91)	0.70	
	d (within)	1.50	0.88		0.87	0.96		
	d (within)	1.48	0.90		0.94	0.85		

Note. MME: guided mindfulness meditation condition; MMD: audio description of mindfulness meditation condition; RR: mean RR interval; RMSDD: root mean square of successive difference; HF: high-frequency band

P value represents three way interaction
[a] BAI
[b] Patient Health Questionnaire
[c] Self-rating of stress after stress task
[d] Respiration rate as inhalation exhalation cycles per minute
[e] Resting HR as BPM

Discussion

This study aimed to evaluate psychophysiological HRV responses within stress induction (PST) and two stress recovery conditions: mindfulness meditation (MME) or a comparison mindfulness description (MMD). Participants were among university students marked with low and moderate to high anxiety via the BAI (Beck et al., 1998). HRV indices evaluated during each study phase were the RR interval, as well as indicators of PNS activity: the RMSSD and the HF-HRV.

The RR interval represents the interbeat intervals between successive heart beats and is the primary quantity which the time-domain HRV indices (here the RMSSD) are driven (Shaffer & Ginsberg, 2017). The RMSSD is determined by calculating each successive time difference between heartbeats in milliseconds (ms). These values are then squared, and the results are averaged before the total is obtained (Shaffer & Ginsberg, 2017). RMSSD is an indicator of the PNS activity and is less under the influence of respiration than the RR interval and other HRV indices (Shaffer & Ginsberg, 2017). HF-HRV is a frequency-domain measure that indexes vagal modulation of HR; however, it is much more under the influence of respiration (Shaffer & Ginsberg, 2017).

While our study did not have adequate statistical power, due to small sample sizes, to detect statistically significant differences between MME and MMD conditions at different phases, our results indicate a *key contrast in the pattern of* Cohen's *d* effect sizes in study outcomes. Our results indicated a significant main effect of phase for the RR interval ($p = 0.02$), which indicated an overall reduction 22.6 ms in mean RR from BL to the end of the PST phase ($p = 0.03$) and an overall increase in mean RR from PST to Phase 3 ($MD = 23.10$, $SE = 7.56$, $p = 0.02$). Therefore, while results support Hypothesis 1 (i.e., stress reactivity), these findings do not support Hypotheses 2 and 3. Results did not show any statistically significant main effects or interactions for RMSDD

and HF-HRV. Despite lack of statistical significance for Hypotheses 2 and 3, MME and MMD condtions overall, and when stratified by anxiety levels, showed different patterns of stress recovery. These results present key indications for differences in stress reactivity and recovery patterns between MME and MMD conditions and participants with different anxiety levels, despite a lack of statistical significance.

For instance, we questioned whether at Phases 3 and 4, participants assigned to the MME condition will show significantly higher RR interval, RMSDD, and HF-HRV compared to participants assigned to the MMD condition. A statistically significant Condition × Phase interaction would have supported this hypothesis. However, despite statistical significance in our results, when considering the difference between MME and MMD conditions at Phases 3 and 4 respectively, Cohen's *d* effect sizes indicate a difference of 0.36 and 0.17 magnitudes between conditions in log HF-HRV in favour of the MME. In addition, when participants were stratified as low and moderate to high anxiety levels, results demonstrated similar differences in effect size magnitude between MME and MMD. Specifically, the effect size difference between MME and MMD conditions at Phases 3 and 4 was larger among participants with low anxiety (d = 0.48 at Phase 3 and d = 0.35 at Phase 4, both in favour of MME) versus participants with moderate to high anxiety (d = 0.21 at Phase 3 in favour of MME, d = 0.15 at Phase 4 in favour of MMD). Similar differences in effect sizes at Phases 3 and 4 between MME and MMD conditions were observed for the RMSSD measure, including larger effect sizes among participants with low anxiety (d = 0.35 and 0.31, at Phases 3 and 4 in favour of MME) versus participants with moderate to high anxiety (d = 0.15 at Phase 3 in favour of MMD and d = 0.29, at Phase 4 in favour of MME).

In relation to within-group effect sizes for MME, specifically from low anxiety participants between PST to Phase 3 and PST to Phase 4, results for log HF-HRV showed moderate increases from PST to Phase 3 (d = 0.52) and from PST to Phase 4 (d = 0.50). Similarly , the MME condition

showed a small pre-post increase in RMSSD from PST to Phase 3 (d = 0.32) and PST to Phase 4 (d = 0.35). Comparatively, the within-group effect sizes for the moderate to high anxiety MME group when assessed with log HF-HRV, showed a moderate pre-post increase from PST to Phase 3 (d = 0.55) and a small increase from PST to Phase 4 (d = 0.22). Finally, the within-group effect sizes for the moderate to high anxiety MMD group within the RMSSD indices showed a small pre-post increase from PST (d = 0.25) to Phase 3 and from PST to Phase 4 (d = 0.08), which was similar to that of the moderate to high anxiety MME condition with increases from PST (d=0.04) to phase 3 and from PST (d=0.22)

The effect size differences observed in this study between MME and MMD, when considered against the broader literature (Azam et al., 2015; Azam et al., 2016; Sarana et al., 2005), provides evidence for MM's greater performance at restoring HRV parameters than simple rest following a laboratory stress task (PST). Mindful attention directed to breathing sensations, as practised during mindfulness of breath, in the audio instructed meditation, has been previously effective at improving cardiac sympathovagal balance (Azam et al., 2015; Telles et al., 2005). It is likely that the mindful attention of breath offers unique physiological mechanisms that will enhance PNS activity and restore sympathovagal balance. First, as we observed in our findings, a naturally slower breathing rate was seen by the MME condition at Phases 3 (MD = –2.06, SE = 0.813, p = 0.014) and 4 (MD = –2.53, SE = 0.858, p = 0.004), and this occurred despite any cueing for paced breathing within the MM instruction. It is important to note that breathing rates remained between the 7 to 24 breaths per minute criteria required for HF- HRV to be a valid measure of autonomic function (Task Force, 1996), so while it is possible that the breathing rates differences were contributing to different results, HF-HRV remains a valid measure. Second, it is possible that the MM instruction was perceived as less cognitively challenging and more relaxing than the description task and therefore allowed for greater reduction in HF-HRV. These findings support

previous research and suggest MM meditation outperforms a rest condition at restoring HF-HRV following a stress task.

Regarding Hypotheses 2 and 3, although we did not find statistical significance, the magnitude difference in effect sizes between the low anxiety and moderate to high anxiety participants suggests that individuals with moderate to high anxiety may not benefit from MM to the same extent as their low anxiety counterparts. This is like the results seen by Azam et al. (2015), when they noted that individuals with lower perfectionism scores showed higher levels of HF-HRV during a post-stress meditation compared to their maladaptively high perfectionist counterparts. Although we cannot know for sure why the moderate to high anxiety participants had much lower effect sizes than their low anxiety counterparts, it's possible the answer exists in the difficulty these individuals are known to have in directing attention. As Foster et al. (2015) showed, trait anxiety is associated with impoverished recruitment of the frontal regions that support proactive control in sustained attention. Additionally, elevated trait anxiety has been linked to the inability to maintain and follow task instruction. When interpreting our findings of effect sizes, in the context of Foster et al. (2015), it seems possible that the moderate to high anxiety group experienced lower effects of MM as a result of the inability to sustain attention. Although there was a lack of significant difference between groups, effect sizes suggest a difference. It is possible that individuals with anxiety may have characteristics (limited attentional resources) that interfere with the full benefits of mindfulness. These findings are consistent with current research (Azam et al., 2015; Burg & Wolf, 2012; Krygier et al., 2013).

Some differences were discovered between the RMSSD time domain and HF-HRV frequency domain, the most notable difference occurring between PST to Phase 3 for the moderate to high anxiety participants in the MME condition. RMSSD displayed minimal effect from PST to Phase 3 where HF-HRV displayed a much larger effect. This difference suggests that the benefits

seen in the MME group at Phase 3 were predominantly related to changes in respiration rather than some other cognitive process.

Limitations

Our study had several limitations. This research was conducted over several graduate semesters, and therefore undergraduate students participated at varied times throughout the semester over varying years. This variation may have resulted in study participants who experienced different levels of chronic stress outside of the experiment that may not have been accurately assessed with the inclusion and exclusion criteria. Additionally, since the anxiety condition is complex and exists in an ongoing interplay between state and trait characteristics, defining such characteristics and exploring their effect on HRV was beyond the scope of this study, it is therefore impossible to precisely tease out the specific group/condition differences. Furthermore, throughout the statistical analysis it was found that the study was slightly underpowered, and there seemed to be many atypical responders. Recent evidence has suggested that both amplified reactivity of the ANS (Chida, et al., 2008) and blunted reactivity of the ANS (Carol et al., 2017; Philips et al., 2013) are associated with negative health effects. Hamilton and Alloy (2016) suggest that a unique subset of individuals have been found to express atypical response patterning to stress, and their review highlighted many complexities of HRV reactivity. While their review focused entirely on individuals with MD and serious depressive symptoms, they discovered a range of HRV responses to stress reactivity. They reported that within 82% of the studies examining reactivity in depression, depressed individuals demonstrated atypical RSA reactivity compared to a healthy control group, and this atypical reactivity was expressed through a blunted stress response that predicted poorer depression recovery. We noted a larger proportion of participants, who were included in our study, to be experiencing an atypical blunted or inverted stress response marked by increase vagal tone or limited vagal withdrawal.

Among the 33 participants in our study that meet the BAI qualifications for moderate to high anxiety, the average PHQ-9 (trusted depression inventory) scores in this group were above 10 indicating a comorbidity of moderate to sever depression (Table 1). Furthermore, 35 individuals, who were placed in the low anxiety group, expressed average PHQ-9 scores above 5 indicating possible mild depression (Table 1). Therefore, while we were able to find evidence of increased HR and SNS activity at the stress phase, it is possible our sample requires a more unique understanding of PNS reactivity and exploration that goes beyond the scope of our analysis.

In attempts to better understand varying levels of reactivity seen in mental health populations such as the one explored in our study, we suggest future research explore atypical stress reactivity more closely as a factor in autonomic flexibility, expressed by a range of responses. Following the interpretation of our result, there is a need for a more nuanced understanding of autonomic function beyond a snapshot directional interpretation.

Conclusions

HRV is a measure of autonomic function, which reflects the "dynamic interaction" between the sympathetic and the parasympathetic arms of the ANS. In the general understanding of ANS balance, environmental stressors elicit SNS activation and vagal withdrawal, which results in increased tone of the sympathetic nervous system. Indeed, increased tone of the SNS will assist the mobilization of cognitive and physiological resources, and this is considered to be an adaptive response to stress (Porges, 1995).

Based on our results, it remains clear that MM is a useful tool for normal low anxiety individuals to restore healthy ANS levels following stress. Although we remain hopeful that mindfulness mediation can be useful for regulating ANS function in moderate to high anxiety individuals, it is unclear from our results the extent that this is true, and the answer for this population likely lies in a unique dose that fits individually specific needs. While evidence continues to grow in support of the use of MBIs for mental health disorders, it will be probable that there is not a one-size-fits-all solution and that varying levels of frequency intensity and duration will need to be explored throughout the therapist–patient treatment regime. Flexibility of online solutions seem to look promising, as internet-based cognitive-behavioural therapy, and digitally delivered mindfulness may actually outperform traditional in-person therapy in mental health populations (Krik et al., 2022). All things considered, these findings continue to support the use of MM to enhance physiological self regulation following stress

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Appendix A

Demographic Questionnaire

1) Participant ID

2) URPP ID

3) What is your sex?
   a) Female
   b) Male

4) Year of Birth (YYYY)

5) What is your current age? (in years)

6) Study Major

7) What is your ethnicity (please select all that apply.)
   [] Aboriginal (Inuit, Metis, North American Indian)
   [] West Asian (e.g., Armenian, Egyptian, Iranian, Iraqi, Lebanese, Moroccan)
   [] Black – African (e.g., African, Somali etc.)
   [] Black – Caribbean (e.g., Haitian, Jamaican etc.)
   [] Indo – Caribbean (e.g., Guyanese, Trinidadian etc.)
   [] White (Caucasian – European/American)
   [] Hispanic
   [] Latin American
   [] Chinese
   [] Japanese
   [] Korean
   [] South Asian (e.g., Indian, Pakistani, Bangladeshi, Sri Lankan etc.)
   [] Southeast Asian (e.g., Filipino, Thai, Cambodian, Malaysian, Indonesian etc.)
   [] Other:

8) Have you ever been clinically diagnosed with a mental disorder?
   [] Depressive Disorder
   [] Anxiety Disorder
   [] Bipolar I/II
   [] Schizophrenia/Schizoaffective
   [] Substance Abuse
   [] Eating Disorder
   [] Not Applicable
   [] Other (Please Specify)

9) Have you ever been diagnosed with any of the following:
   [] Migraine without Aura

[] Migraine with Aura
[] Other headache disorder:
[] None of the above

10) Do you have chronic pain?
    a) Yes
    b) No

11) Do you currently have a migraine?
    a) Yes
    b) No

12) If you do have chronic pain, where is affected? _____

13) Do you have a history of mental illness in your family (i.e., first degree relatives)
    a) Yes
    b) No

14) What medications are you currently taking? (Name, reason, dose, how often, time of medication, any changes) If you are not taking medication, please type N/A for not applicable

15) Have you ever had a heart attack in the past?
    a) Yes
    b) No

16) Do you have a history of any of the following (please select all that apply):
    [] Cardiovascular Disease
    [] Pulmonary Disease
    [] Hypertension
    [] Diabetes
    [] Thyroid Disease
    [] Not Applicable
    [] Other (please specify):

17) Are you a current smoker or have you ever been a smoker (e.g. cigarettes, cigars, hookah/seesha, marijuana)?
    a) Current Smoker
    b) Previous Smoker
    c) Never been a smoker
    d) Other (please specify):

18) How often do you smoke (e.g. cigarettes, cigars, hookah/seesha, marijuana)?
    a) A few times a day
    b) Once a day
    c) A few times a week
    d) Once a week
    e) A few times a month

f) Once a month
g) A few times a year
h) Once a year

19) Do you consume caffeine?
a) Yes
b) No
c) Other (please specify):

20) How often do you consume caffeine?
a) A few times a day
b) Once a day
c) A few times a week
d) Once a week
e) A few times a month
f) Once a month
g) A few times a year
h) Once a year

21) Did you have any caffeine today?
a) Yes
b) No
c) Other (please specify):

22) If so, please specify source, amount, time, etc.)

23) Do you consume alcohol?
a) Yes
b) No
c) Other (please specify):

24) How often do you consume alcohol?
a) A few times a day
b) Once a day
c) A few times a week
d) Once a week
e) A few times a month
f) Once a month
g) A few times a year
h) Once a year
i) Not applicable

25) Are you pregnant? (please select N/A if you are a male)
a) Yes
b) No
c) Potentially
d) Not Applicable

26) Do you ever have an irregular menstrual cycle? (please select N/A if you are a male)
    a) Yes
    b) No
    c) Not Applicable

27) How often do you have irregular menstrual cycles?
    a) Very often
    b) Often
    c) Sometimes
    d) Rarely
    e) Never
    f) Not Applicable

28) During a typical 7-day period (week), how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)
    a) Very often
    b) Often
    c) Sometimes
    d) Rarely
    e) Never

29) Have you exercised today?
    a) Yes
    b) No
30) If you have exercised today, how many minutes? _____

31) Do you require correctable lenses (glasses/contacts)?
    a) Yes
    b) No

32) If yes, what is your prescription? _____

33) Do you have an astigmatism?
    a) Yes
    b) No

34) Are you wearing correctable lenses now?
    a) Yes, I am wearing glasses
    b) No, I am wearing contacts
    c) Other: _____

35) Do you have an ophthalmological condition (not including correctable vision)?
    a) Yes
    b) No
    c) Other: _____

36) What is your eye colour?
    a) Blue
    b) Brown
    c) Green
    d) Hazel
    e) Other: _____

37) Do you engage in meditation?
    a) Yes
    b) No

38) What type of meditation do you perform? (Enter N/A if none)

39) How often do you perform meditation?
    a) Very often
    b) Often
    c) Sometimes
    d) Rarely
    e) Never

40) How long have you been meditating (in months)? (If never enter 0)

41) During a typical 7-day period, how many minutes do you spend performing this, or other types of meditation?

Appendix B

Automatic Thoughts Questionnaire (ATQ)

Listed below are a variety of thoughts that pop into people's heads. Please read each thought and indicate how frequently, if at all, the thought occurred to you over the last week. Please read each item carefully and circle the appropriate answers on the answer sheet in the following fashion (1 = "not at all", 2 = "sometimes", 3 = "moderately often", 4 = "often", and 5 = "all the time"). Then, please indicate how strongly, if at all, you tend to believe that thought, when it occurs. On the right hand side of the page, circle the appropriate answers in the following fashion (1 = "not at all", 2 = "somewhat", 3 = "moderately ", 4 = "very much", and 5 = "totally).

Frequency					Items	Degree of Belief				
1	2	3	4	5	1. I feel like I'm up against the world.	1	2	3	4	5
1	2	3	4	5	2. I'm no good.	1	2	3	4	5
1	2	3	4	5	3. Why can't I ever succeed?	1	2	3	4	5
1	2	3	4	5	4. No one understands me.	1	2	3	4	5
1	2	3	4	5	5. I've let people down.	1	2	3	4	5
1	2	3	4	5	6. I don't think I can go on.	1	2	3	4	5
1	2	3	4	5	7. I wish I were a better person.	1	2	3	4	5
1	2	3	4	5	8. I'm so weak.	1	2	3	4	5
1	2	3	4	5	9. My life's not going the way I want it to.	1	2	3	4	5
1	2	3	4	5	10. I'm so disappointed in myself.	1	2	3	4	5
1	2	3	4	5	11. Nothing feels good anymore.	1	2	3	4	5
1	2	3	4	5	12. I can't stand this anymore.	1	2	3	4	5
1	2	3	4	5	13. I can't get started.	1	2	3	4	5
1	2	3	4	5	14. What's wrong with me?	1	2	3	4	5
1	2	3	4	5	15. I wish I were somewhere else.	1	2	3	4	5
1	2	3	4	5	16. I can't get things together.	1	2	3	4	5
1	2	3	4	5	17. I hate myself.	1	2	3	4	5
1	2	3	4	5	18. I'm worthless.	1	2	3	4	5
1	2	3	4	5	19. Wish I could just disappear.	1	2	3	4	5
1	2	3	4	5	20. What's the matter with me?	1	2	3	4	5
1	2	3	4	5	21. I'm a loser.	1	2	3	4	5
1	2	3	4	5	22. My life is a mess.	1	2	3	4	5
1	2	3	4	5	23. I'm a failure.	1	2	3	4	5
1	2	3	4	5	24. I'll never make it.	1	2	3	4	5
1	2	3	4	5	25. I feel so helpless.	1	2	3	4	5
1	2	3	4	5	26. Something has to change.	1	2	3	4	5
1	2	3	4	5	27. There must be something wrong with me.	1	2	3	4	5
1	2	3	4	5	28. My future is bleak.	1	2	3	4	5
1	2	3	4	5	29. It's just not worth it.	1	2	3	4	5

1	2	3	4	5	30. I can't finish anything.	1	2	3	4	5

Appendix C

Beck Anxiety Inventory (BAI)

Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by that symptom during the past month, including today, by circling the number in the corresponding space in the column next to each symptom.

Items	Not at All	Mildly, but it didn't bother me much	Moderately – it wasn't pleasant at times	Severely – it bothered me a lot
1. Numbness or tingling	□	□	□	□
2. Feeling Hot	□	□	□	□
3. Wobbliness in legs	□	□	□	□
4. Fear of the worst happening	□	□	□	□
5. Dizzy or lightheaded	□	□	□	□
6. Heart pounding/racing	□	□	□	□
7. Unsteady	□	□	□	□
8. Terrified or afraid	□	□	□	□
9. Nervous	□	□	□	□
10. Feeling of choking	□	□	□	□
11. Hands trembling	□	□	□	□
12. Shaky/unsteady	□	□	□	□
13. Fear of losing control	□	□	□	□
14. Difficulty in breathing	□	□	□	□
15. Nervous	□	□	□	□
16. Fear of dying	□	□	□	□
17. Scared	□	□	□	□
18. Indigestion	□	□	□	□
19. Faint/lightheaded	□	□	□	□
20. Face flushed	□	□	□	□
21. Hot/Cold Sweats	□	□	□	□

Appendix D

Patient Health Questionnaire (PHQ-9)

Over the last 2 weeks, how often have you been bothered by any of the following problems?	Not at all	Several Days	More than Half the Days	Nearly every day
1. Little interest or pleasure in doing things	0	1	2	3
2. Feeling down, depressed, or hopeless	0	1	2	3
3. Trouble falling or staying asleep, or sleeping too much	0	1	2	3
4. Feeling tired or having little energy	0	1	2	3
5. Poor appetite or overeating	0	1	2	3
6. Feeling bad about yourself – or that you are a failure or have let yourself or family down	0	1	2	3
7. Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
8. Moving or speaking so slowly that other people could have noticed? Or the opposite 0 being so fidgety or restless that you have moving around a lot more than usual	0	1	2	3
9. Thoughts that you would be better off dead or hurting yourself in some way	0	1	2	3
TOTAL SCORE	___ +	____ +	_____	= ____

If you checked off any problems, how difficult have these problems made it for you to take care of things at home, or get along with other people?

Not difficult at all	Somewhat difficult	Very Difficult	Extremely Difficult
☐	☐	☐	☐

Appendix E

Pattern Solving Task

Characters Used

1. AB AZ AC AX AY
2. F1 D3 C5 E7 B9
3. 90 09 19 96 69
4. AG NA CL OH CO
5. 18 56 72 27 63
6. A1 91 B1 81 C1
7. 26 66 36 96 16
8. SH CH ST TH SC
9. US CA RU UK VU
10. 12 21 32 45 59
11. 44 2 56 8 22 4
12. AT AN AM AD AH
13. 54 78 96 12 62
14. UI UO UA UI UE
15. 3e 4A 1b 6U 7i
16. PI IP OP PE AP
17. 13 26 49 82 116
18. T2 F5 N9 S7 E8
19. OR OP OS OW OX
20. 31 24 53 46 75

21. 4T T6 7T T8 9T

22. MU NU PI XI OM

23. 10 25 50 75 0

24. CT CH CK CL CR

25. 11 3 13 6 15 9

Appendix F

PST Manipulation Check

1) Rate the level of difficulty of the Pattern Solving Task on a scale of 5:

1. Extremely easy
2. Easy
3. Average
4. Difficult
5. Extremely difficult

2) How stressed were you while completing the Pattern Solving Task?

1. Extremely stressed
2. Stressed
3. Moderately stressed
4. A little stressed
5. Not stressed at all

3) Rate your performance on the Pattern Solving Task on a scale of 5:

1. Poor performance
2. Below expectations
3. Met expectations
4. Above expectations
5. Exceptional performance

Appendix G

Mindfulness Meditation Practice (MMP) Transcript

In this mindfulness meditation session, let's arrange our bodies to reflect a sense of straightness so our bodies are erect in the way we've evolved to sit and stand, and so our breathing is completely unimpeded and free of obstructions.

Let’s simultaneously focus on relaxing, so there's no sense of rigidity or stiffness. This is an unusual combination, relaxation and straightness, and it implies that we're going to relax in a highly disciplined way.

As you arrange your head and neck, let's focus your eyes downwards at an angle of about 45°, or if you choose gently, let your eyes close. In either case, let your eyes relax and stabilize your vision. This shifts the ratio of stimulation in the brain and permits you to focus within, especially on your body's sensations amongst the different sensations that one can feel.

Your breathing sensations are clear and prominent. So just feel your breathing. And the simple difference between breathing out and breathing in. For just a while now, emphasize longer, slower, and more complete breaths. Especially focus on breathing out thoroughly. Emptying all the air in your lungs and while you're doing so, feeling all the signals that guide your breathing that urge you again to breathe in again once you get to the end of your exhalation. As you breathe out or exhale, you literally let go of air. This also helps you release body tensions.

Just feel your breath moving outwards as you breathe out. And see if you can feel the outwards breath linked to other flows of sensation in your body. These sensations move from the inner core parts of your body towards the outer parts.

We're literally letting go of air. And at the same time, letting go of energy letting energy leave the body through the exhaling breath. And also through these surfaces of our skin.
For the next few minutes. You don't have to think about any of the complex conflicts that may have been left behind before you came here. We're now deliberately simplifying. And returning to the basics of being aware. And being alive.

Now our thinking process inevitably complicates our life. But instead of conflicting with our thinking process, while we're meditating, simply value and respect each thought you're having. But once you're aware of thinking, simply don't continue the thought beyond that point of first awareness. As soon as you're aware of thinking. Simply switch your attentional focus to breathing sensations.

It's common when you're instructed in anything or especially in this technique, to wonder whether you're doing it in the right way. And to be critical of yourself, if you feel that somehow you're not. It's important to realize that there's really no way of failing at doing this particular technique. You're breathing all the time. So sooner or later you will return from distractions to being aware of breathing sensations.

Second, you're thinking quite frequently. So if you miss being aware of some initial thoughts, you will inevitably have additional thoughts that you can become aware of. As soon as you do become aware of thinking, just switch your attention back to breathing sensations.
What we're aiming for here is for you to not evaluate yourself. To let yourself be and experience yourself without having to either field anevaluation or relate to a self-criticism. Whatever thought comes up, just treat it as another thought. Don't elaborate on it. Don't continue it. Simply once you're aware of the thought, return your attention to breathing.

We purposefully emphasize simplicity. The simplicity of relating to the present moment. And relating to each present moment as it unfolds. There's plenty of time later to confront whatever complexities you have left behind, but here we're cultivating our simple capacity to be in the present moment. We are cultivating in this way a relaxed and peaceful state of mind and body.

The relaxation and the simplicity effect sometimes makes you feel like you have too little energy. So you may be feeling drowsy or sleepily, sleepy or just listless. These are indications that you and your brain need some rest. That's fine. Don't try to interrupt these low energy states. Just be aware of what your experiencing. When you are aware of low energy states relate to the judgment that it is a low energy state as the thought. And relate to it that way. Note it and then return your attention to breathing sensations.

It's also possible that you may feel you have too much energy. And somehow circumstances have unfolded that have. Resulted in a high energy. Well, mindfulness is about releasing energy. Letting go of the excess energy we often have by attending to breathing sensations and to the releasing quality of each exhaling breath.

When you breathe out you're stimulating a nerve called the vagus nerve that naturally relaxes your heart and the rest of your body. So, allow the exhaling breath and the action of the vagus nerve to take place. Don't worry about maintaining energy. Let energy go. Let yourself relax. Relaxation of this kind will eventually release energy. So don't worry about being low on our energy. If you're feeling high energy. Simply experience it as such. Label it or relate to it as a thought, and then switch your attention back to breathing sensations.

So we are getting close to the end of about a 10-minute session. There's lots of ways in which you have been, perhaps introduced to a different way of leading to your mind and to your body. Certainly, one of the important themes is combining relaxation actual releasing of energy and a sense of straightness and deliberateness and discipline. So we're being very much aware of exactly what happens when we relax.

Now allow yourself to stretch and move.

Appendix H

Mindfulness Meditation Description (MMD) Transcript

Mindfulness meditation is a top-down volitional mental activity designed to activate the prefrontal cortex in ways demonstrated to positively modify its physical structure, while improving cortical functioning in terms of working memory and complex problem solving.

From a practical, descriptive perspective, mindfulness evokes enhanced awareness. By using breathing sensations for attentional anchoring. Attention is continually returned to as the pre-selected attentional target of breathing sensations after thoughts, emotions and other sensations are related to as distractions. What happens as a meditation session unfolds is the meditator non-avoidably relates to distractions with awareness of distraction, continually triggering a return of attention to breathing sensations.

Since breathing is an ongoing and involuntary physiological function, little effort is needed to attend to breathing. Therefore, breathing awareness can become very relaxed. Attention to breathing sensations, meanwhile, reminds the meditator to focus on the present moment, instead of letting distractions draw awareness back to the past or forward to the future.

As more and more thoughts are related to as distractions rather than as consequential data. The meditator becomes increasingly less identified with each particular passing thought. He or she relies less on an identity derived from cognitive content. Instead, observing thoughts as impermanent. And as ever, changing data of variable validity. Each thought can be related to in the same way valued equally rather than being seen as especially valuable when representing a good state of mind. Body. Or very lacking in value when representing a bad state of mind and body.

Mindfulness can also be understood in terms of how it differs from the mental processing that's influenced by a depressive mood state. In depression, negative thoughts exert strong emotional impacts and are often processed through a focus on past. That is rumination or future, that is worrying events. With minimal focus on the present in mindfulness, all negative thoughts are considered distractions from the attentional target of the breath and ruminative past, and worrisome future processes are also considered distracted with the preferred attentional anchoring directed to the neutral stimulus of the breath, and each present moment.

Over time, the negative or positive value of each thought becomes deemphasized as each thought becomes less identified with the experience of core being. In contrast to emotional upset, there is a neutral focus that centres on breathing and the relaxation effect of slower and deeper respiration.

Core being experienced becomes increasingly relaxed and simple when contrasted with the painful hyper reactions of a depressive spiral where self-criticisms are dominant along with remembered adversities. The migration under mindfulness practice conditions involves substituting attention to neutral breathing sensations for the barrage of self, pejorative thoughts and or remembered sequences of negative outcomes. Not only is it a relief to experience

neutrality instead of negativity, but the relaxation effect of carefully attended breathing. As a neural inhibiting effect analogous experientially to calming down.

Mindfulness can then also be understood in contrast to escalating anxiety experiences that sometimes are labelled as a panic attack instead of the increasingly shallow breathing that often accompanies increasing anxiety. Heavy there's emphasis on breathing deeply. And releasing tension with each breath. Instead of anxiety related thinking that implicitly explores potential negative outcomes and even worst case scenarios. There's a focus on paying attention to breathing sensations and on returning to breathing after thinking distractions that may or may not be negatively focused.

Given the negative ideation of anxiety, escalating experience, the substitution of neutral breathing sensations is preferable and often experienced as a relief as one calms down with mindfulness practice. The negative cognitions associated with escalating anxiety and or panic become less relevant and therefore are experienced less frequently. The calming down process that substitutes for escalating anxiety is a welcome example of self-control and personal mood mastery. Instead of feeling that one's physiological processes are out of control, or even conspiring to create a miserable psychophysical condition, one can feel a calming process where there is often an increasing clarity of perception and insight. Derived from being able to calmly observe. An overview of personal function. In situation. Observation. Another way of describing mindfulness is in terms of ideas centring around flow, which, experientially speaking, is the discovery of a naturally coherent and energized cluster of activity.

Flow can be experienced while viewing a painting, listening to a pleasing musical selection or watching a sunset or creatively working out a design for a house. Flow is often highly functional and creative, while also experienced as autotelic or enjoyable in itself without any additional gratifying features. Accordingly, real life can become infused with flaw and autotelic activities result. When one can generate the focal attention required to discover whether an experience can be audited. Then one can relax into the flow experience rather than trying to transform it into an extreme version of hyper productivity. Flow involves honouring your natural pace of experience without trying to push yourself to conform to a preconceived idea of what should be happening. Flow is a matter of experiencing what is without trying to change anything in particular. In this way, flow is a very honest experience and presentation of self. Once again, mindfulness meditation is a top-down volitional mental activity which is oriented towards fostering our natural resilience as well as a peaceful state of mind.

Appendix I

Protocol

Protocol - An Exploration of Mindfulness Meditation and Anxiety with the use of Heart Rate Variability

Summary of Protocol

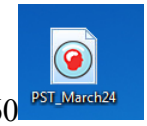
1. **Consent Form & Questionnaires** – 30 minutes
2. **ECG/Respiration Belt Set-Up & Sampling** – 5 minutes
3. **Baseline ECG Respiration**– 5 minutes
4. **Cognitive Task:** Pattern Solving Task (PST)(ECG/Respiration) – 5 minutes
5. **Post-Task Questionnaire** – 1 minute
6. **Listening Intervention:** Mindfulness Description or Mindfulness Meditation (ECG/Respiration) – 10 minutes
7. **Post Listening HRV Measurement –** 2 minutes
8. **Debriefing** – 5 minutes

Preparation before participant arrives:

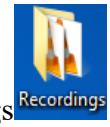
1. Set up ECG:
   - **Turn on the Power Lab unit** from the switch in the back (top left of back) and give it a ~10 minute warm up.
2. Set up Respiration Belt:
   - Make sure the respiration belt is attached to channel two of the Power Lab unit.
3. Set up laptop:
   - Password: ritvolab360
   - Once Power Lab is on, **open Lab Chart**. It will do a 'device scan' and recognize the PowerLab unit provided it is plugged into the laptop via USB. The first menu on the screen will be the 'Welcome Center' and you should be under the tab 'ADI Settings'.



4. Set up questionnaires
   - Open survey monkey links for: Consent Form, Questionnaire on PC
   - Open survey monkey links for: Post-PST and Debriefing Consent
5. Set up cognitive task:



   - Login to computer - username: ritvolab, password: ritvolab360
   - Open the "PST Example" Powerpoint
   - Open "PST_Jan11"
6. Open audio files:



   - Open "Recordings" folder to view the mindfulness recordings

- Have headphones ready for participant

When participant arrives:

1. Go through consent form on computer
2. Enter participant ID and URPP ID in the questionnaires
3. Please turn off your phone or any other distractions.

Setting up the experimental equipment with the participant:

Respiration Belt

1. **Setting up the respiratory belt transducer- better to put on belt FIRST**
   - "Please secure the respiratory belt transducer using the Velcro around their waist below their rib cage, with the black strap facing the front of the diaphragm. Instruct them to keep the sensor with the label upright and position the belt two finger lengths above their belly button.
   - "Please make sure the belt is secure enough so that it moves in and out as they breathe, but that it's not too tight so as to obstruct comfortable breathing."

ECG

1. After the participant has completed the consent form, have them seated, and **explain the experimental protocol:**
   - *"We will be collecting an electrocardiogram (ECG) and respiration data for 5 minutes while you are resting, while you complete a cognitive task (PST) and while you listen to a 10 minute audio. We will also be taking "snapshots" of your HRV throughout the study."*

2. **Prepare the electrodes:**
   - Location: green box beside the desk
   - Attach the leads (red, black, white) on to the metallic node of the electrodes.
   - Remove sticker backing one at a time while explaining where the electrodes belong

3. **Explain where the electrodes go:**
   - *"The ground (black) electrode must be placed on the left ankle (inside facing, tibia)"*
   - *"The negative (white) electrode must be placed on the inside of your right wrist. Please make sure it does not interfere with the flexing motion of the wrist. Bend it forward and then place in the centre of wrist to avoid any interference"*
   - *"The positive (red) electrode must be placed on the inside of your left wrist. Please make sure it does not interfere with the flexing motion of the wrist. Bend it forward and then place in the centre of wrist to avoid any interference"*

4. **Inform participant about the electrodes:**
   - *"Are the stickers secure? Are you comfortable with them on?"*
   - *"Please let me know if the stickers feel as if they're slipping off at any time."*

- Remember to emphasize that when they are sticking the electrodes to their bodies they should rub around the metallic node
- You will need to make three recordings – baseline, PST and listening

Sampling

1. **Open the "Sampling" system file**
   - In the 'Welcome Center' of LabChart, you should see system files labelled "Sampling". When you open "sampling" you should see 'chart view' with three channels on the screen:

2. **Sample their ECG & Respiration briefly on LabChart** (ensure the recording is coming through clearly and with as little noise as possible).
   - **Press the 'Start' button** on your screen to collect a recording (top right). Look at the dots above the spikes in the 'chart view' of Channel 1:
     - There should be prominent 'R' spikes
     - Blue dots: reflect normal beat identification
     - Yellow dots: the beats are being marked 'ectopic' (i.e., a disturbance of the cardiac rhythm)
   - In Channel 2 you should see the respiration signal.
     - *"Please take a deep breath in and out"*
     - You should see the wave ascend with inhalation and descend with exhalation.
     - Don't worry if the wave appears 'jagged' or 'erratic' in the beginning, the belt transducer is most likely calibrating and will gradually smooth out. In the chart view for the respiration signal
     - Ensure you are seeing white dots being placed above each cycle of breathing.
   - **If they are curious, you can show them what it looks like on the laptop. You may also ask them to move and show signal noise. You can use this opportunity to explain this is why you will avoid asking them to move or speak throughout the study.**

Experimentation

Baseline (ECG/Resp) – 5 minutes

1. *"We are ready to begin the baseline ECG and respiration recording. For the next 5 minutes, I need you to remain seated on your chair, and rest with your eyes closed while thinking freely. Please do not make any sudden movements or speak during the 5 minutes."*
2. **Press 'Start' on LabChart** and allow the recording to continue until 5 minutes, it will be automated to stop at 5 minutes
3. Save the LabChart file as VM_101_XX_BL_DATE

Pattern Solving Task (PST) (ECG/Resp)– 5 minutes

1. Open the paradigm file "PST_Jan11" on the desktop computer.
   - The "Pattern Solving Task" paradigm file should be open
2. Open up PowerPoint with PST instructions
   - Read the instructions on the slide and give them the two practice rounds

        - "This task consists of 22 trials which present four alphanumeric characters at the top of the screen. You will have 9 seconds to determine what pattern they follow. After 9 seconds a 5th character is presented, at which point you are asked, as quickly as possible, to respond whether or not it follows the pattern by pressing "True" (T or the left key) or "False" (F or the right key). Feedback will be provided at the bottom right of the screen for "Right Answer" or bottom left of the screen for "Wrong Answer" before the start of the next trial."
        - Go through both examples
    - Read the following instructions to the participant:
        - *"This task will measure your capacity for cognitive processing which is implicated in those with migraines. Cognitive processing is also a marker of intelligence. The average score on this task is 80% with a response time of around 2 seconds. Your performance must be as possible to or equal to the average performance of all subjects. Therefore, please respond as quickly but as accurately as possible*
        - *"I will be measuring your heart rate and breathing. At the end of the task we will do a short questionnaire and then take a snapshot of your pupils. Please do not move or speak during this task. Do you have any questions?"*
    - Do you have any questions?
3. Open the "PST" file in **LabChart** on the laptop. In **Paradigm**, click the green play button . Ask them to adjust themselves in a comfortable position.
    - Enter in participant ID > Press Continue
4. Ask them to read over the instructions one more time, press start in **LabChart**, and observe as they complete the ask.
5. After the experiment, save the data as VM_101_XX_PST_DATE

Complete Post-PST Questionnaire

1. On the laptop, open the Post-PST questionnaire, enter their participant ID
2. Read the questions and click their answers

Listening Intervention: Minfulness Meditation Practice (MMP) or Mindfulness Meditation Description (MMD) (ECG/Resp Belt) – 10 Minutes

1. Open Lab Chart
    - In the 'Welcome Center' open the "Listening" system file.

Mindfulness Meditation Practice:

- *"You will now be listening to a guided mindfulness meditation audio recording. This audio will be about 10 minutes long. This is recorded by my supervisor, a clinical psychologist, so it will be a male voice. You will hear a bell at the beginning of the recording, please wait for the bell to ring again to signal the end of the recording before moving."*
- **Step 1.** Posture and Relaxation: *"Please sit with your back straight up, your muscles should be relaxed, your feet touching the ground and your hands resting on your thighs.*

Please also keep <u>your eyes closed</u> (even though the recording says you do not have to) during the entire listening period"

- **Step 2.** Focusing on your breath: *"Please focus your attention on the sensations as you breathe. Mind wandering is an inevitable, integral and normal part of this task. Whenever you become aware of anything else (e.g., body sensations, sense perceptions, memories, plans, reflections, thoughts, feelings), simply accept that your mind is wandering in a non-judgmental way and refocus on the passage."*
- **Step 3.** Closure: "*At the end of the listening period, remain in silence with your eyes closed for a few moments until you hear the bell. Then when you are ready, please open your eyes. Do you have any questions?"*
- **Step 4.** Give them the headphones (should be plugged into PC via AUX). Choose a random spot in the recording and ask if the volume is okay. If ok, ask them to close their eyes and begin the recording on Labchart and then start audio recording.
- **Save file as:** VM_**101_XX**_MMP_DATE

Mindfulness Meditation Description:

- *"You will now be listening to a description of mindfulness meditation. This audio will be about 10 minutes long. This is recorded by my supervisor, a clinical psychologist, so it will be a male voice. You will hear a bell at the beginning of the recording, please wait for the bell to ring again to signal the end of the recording before moving."*
- **Step 1.** Posture and Relaxation: *"Please sit with your back straight up, your muscles should be relaxed, your feet touching the ground and your hands resting on your thighs. Please also keep <u>your eyes closed</u> during the entire listening period"*
- **Step 2.** Centring on Relaxation: "*Please just try to relax while you are listening to this recording"*
- **Step 3.** Closure: "*At the end of the listening period, remain in silence with your eyes closed for a few moments until you hear the bell. Then when you are ready, please open your eyes. Do you have any questions?"*
- **Step 4.** Give them the headphones (should be plugged into PC via AUX). Choose a random spot in the recording and ask if the volume is okay. If ok, ask them to close their eyes and begin the recording on Labchart and then start audio recording.
- **Save file as:** VM_**101_XX**_MMD_DATE

<u>Debrief – 5 minutes</u>

1. Tell participants they may start to remove the ECG electrodes and the respiration belt
2. Explain deception using the debriefing form
3. Go over the debriefing form consent form on laptop with the participants. Answer any questions they may have. Ask them to sign if they are okay.
4. Thank them for their participation. Grant them their credits.