AN EXPLORATION OF STRESS REACTIVITY AND MINDFULNESS MEDITATION IN INDIVIDUALS WITH MIGRAINE UTILIZING HEART RATE VARIABILITY

Vinashini (Vina) Mohabir

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Abstract (147/150)

Headaches are associated with autonomic nervous system imbalance reflected in heart rate variability (HRV). Mindfulness Meditation (MM) is an evidence-based tool for regulating HRV. Previous literature has examined HRV changes in those with headache disorders after cognitive stress induction. These studies have found there were significant increases in HRV after stress induction in those that practiced MM. The current study examined HRV changes in migraineurs. Participants (N=26) were randomly assigned to a 10-minute recovery condition involving guided MM Practice (N=13) or listening to a description of MM (N=13) following cognitive stress induction. A between-subjects repeated measures MANOVA found a significant difference in HF-HRV over time that varied based on the meditation condition. There was also a significant change in respiratory rate over time regardless of condition. Additional research should be completed with migraineurs to understand ANS activity in migraine and the mechanisms of MM in this population.

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

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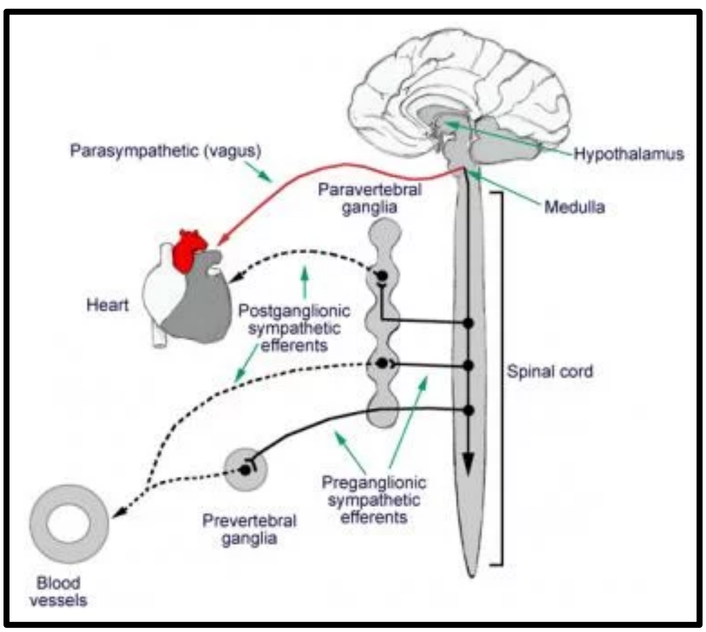
1. Introduction

The autonomic nervous system (ANS) is a critical component of the central nervous system (CNS) and controls involuntary bodily functions implicated in psychological and physiological functioning (Thayer & Brosschot, 2005). Axons within the ANS innervate organs and other tissues directly and indirectly through the release of neurotransmitters such as norepinephrine, adenosine triphosphate, acetylcholine, calcitonin gene-related peptide, and nitric oxide (Scott-Solomon et al., 2021). Heart Rate Variability (HRV) is a biomarker which indirectly assesses ANS activity and sympathovagal balance. HRV measures beat-to-beat variation in heart rate using an electrocardiogram (ECG), reflecting the activity of the two branches of the ANS: the parasympathetic nervous system (PSNS) and the sympathetic nervous system (SNS; Acharya et al., 2006; Allen et al., 2007; Beauchaine & Thayer, 2014; Koenig et al., 2013; Pedrotti et al., 2014). These branches can work together, separately, or in opposition (Sheng & Zhu, 2018). In the context of stressful or threatening experiences, the SNS is responsible for heightening physiological arousal and activating the “fight or flight” survival mechanism. In contrast, the PSNS activates the “rest and digest” mechanism, which relaxes the body and processes to restore homeostasis (Acharya et al., 2006). In healthy individuals, the ANS is flexible, adapting in response to environmental changes. ANS inflexibility is associated with an increased risk of all-cause mortality and a marker of several chronic diseases (Thayer et al., 2012). Psychological or physiological stimuli perceived as threats by an individual can elicit an SNS response, increasing heart rate and blood pressure and dilating pupils (Bradley et al., 2008; de Kloet et al., 2005; Thayer et al., 2012). After a perceived threat is resolved, the PSNS restores homeostasis throughout the body (de Kloet et al., 2005). In chronic stress conditions, the PSNS may encounter difficulties reinstating homeostasis, particularly after prolonged SNS activation, leading to a hyperactive SNS dominating a hypoactive PSNS (Thayer & Brosschot, 2005). In these cases, the ANS is seen as imbalanced. This imbalance increases the risk of both psychological and physical pathology (Thayer & Brosschot, 2005). Constant perception of threat or chronic stress leads to a dysregulated ANS and an overall decline in health (Thayer et al., 2012).

HRV is a reliable measure that illustrates the relationship between psychological and physiological stimuli and the heart (Thayer et al., 2012). HRV is an indirect measure of ANS capacity to change heart rate in response to environmental stimuli (Acharya et al., 2006). The heart is dually innervated by the primary parasympathetic vagus nerve (cranial nerve X) and the primary sympathetic nerves.

Figure 1

Sympathetic and Parasympathetic Innervation of the Heart



Note. Reprinted from Assadi et al., 2016 and colleagues retrieved from Medscape

The vagus nerve originates from the brain stem which controls visceral functions and directly innervates the heart. More specifically, the parasympathetically mediated vagus nerve releases acetylcholine at the sinoatrial node to decrease heart rate. To cause an increase in heart rate, the primary cardiac nerve releases norepinephrine at the sinoatrial node (Pavlov & Tracey, 2012; Porges, 2007; Scott-Solomon et al., 2021; Sheng & Zhu, 2018). Sympathetic effects on the heart are slow relative to parasympathetic changes, typically impacting the heart in one or more seconds. Parasympathetic changes occur much quicker, often within milliseconds, which means the PNS can produce rapid HRV changes (Thayer et al., 2012). These changes are not only linked to the heart as the ANS also regulates the gastrointestinal, respiratory, immune, endocrine, and metabolic systems (Pavlov & Tracey, 2012; Porges, 2007; Scott-Solomon et al., 2021; Sheng & Zhu, 2018). In healthy states, resting cardiac balance is primarily parasympathetically or vagally dominated (Thayer et al., 2012). HRV 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 has a high correlation with parasympathetic activity and the vagus nerve. It is used interchangeably with the term vagally mediated HRV (vmHRV; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). LF-HRV is related to sympathetic activity. The HF/LF ratio has been helpful in identifying the ratio or balance between the SNS and PSNS (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). HF-HRV is also linked with respiration. Respiratory Sinus Arrhythmia (RSA) represents heart rate fluctuations that are ‘in phase’ with breathing. RSA increases heart rate during inspiration and decreases heart rate during expiration. These are indexes of vagal or parasympathetic tone (Roscoe, 1992).

Theoretical Models of Vagally-Mediated HRV

There are three main theoretical models for the mechanism of vmHRV: polyvagal theory, the psychophysiological coherence model, and the neurovisceral integration model. Polyvagal theory is an evolutionary model that connects the vagus nerve, CNS, and the body's physiological and emotional response to changing environmental stimuli. Based on this, Porges and colleagues propose that physiological state is a key component of affect (Porges & Furman, Senta, 2011). In this model, the evaluation of threats in the environment is tied to the individual's current autonomic state. The same environmental stimuli can be interpreted as positive, negative, or neutral depending on the physiological state of the body. Based on this interpretation, Porges proposed this must have different anatomical and physiological characteristics due to the evolution of myelination in the nervous system (Porges & Furman, Senta, 2011). The unmyelinated nervous system was present earlier in evolution when compared to the myelinated system. Unmyelinated and myelinated fibers of the vagus nerve also originate in two different brain areas, which are responsible for regulating physiological phenomena when confronted with stressors or threats (Porges, 1992, 2001, 2007; Porges et al., 1994; Porges & Furman, Senta, 2011). The unmyelinated fibres of the vagus nerve are responsible for regulating the "freeze response," which involves shutting down or avoidance. In contrast, the myelinated system is involved in social behaviour regulation, specifically social engagement. Social engagement promotes self-regulation, including the ability to calm oneself (Porges, 1992, 2001, 2007; Porges et al., 1994; Porges & Furman, Senta, 2011). Porges and colleagues theorized that a higher vagal tone is associated with better social functioning and self-regulation (Shaffer et al., 2014).

Another proposed model of vmHRV is the psychophysiological coherence model developed by Shaffer, McCraty and colleagues (Shaffer et al., 2014). This model utilizes a dynamic systems perspective to explain the relationship between emotion, the heart, and the environment. This theory is based on interactions between the environment, CNS, PNS, heart, and endocrine system (Laborde et al., 2017; Shaffer et al., 2014). Using past experience, the brain builds a database of physiological phenomena impacting neural pathways. Input from the environment can maintain or change these patterns through feedback processes that organize perception, cognition, emotion, and behaviour (Laborde et al., 2017; Shaffer et al., 2014). Consistent inputs from the environment create a reference pattern, the basis of comparison for all incoming stimuli. This theory proposes emotion is generated when there is an incongruency between incoming stimuli and the reference pattern (Laborde et al., 2017; Shaffer et al., 2014). Homeostasis aims to return the body to the reference pattern through internal or external adjustments. If the reference pattern is maladaptive or dysfunctional, the body continues to return to this state despite worsening health (Laborde et al., 2017; Shaffer et al., 2014). The system is dynamic, which means that the reference pattern can be modified through continued encounters with new adaptive patterns to create a new baseline. Shaffer and colleagues propose the heart as a central and significant component of the reference pattern (Laborde et al., 2017; Shaffer et al., 2014). The heart functions as a 'little brain' due to its extensive innervation and afferent networks connecting it with the brain. The heart or 'little brain' functions as a sensory organ that adapts to the external environment within seconds, and an endocrine gland which secretes and creates hormones and neurotransmitters (Laborde et al., 2017; Shaffer et al., 2014). The psychophysiological coherence model links cardiac reference pattern and emotion. This is characterized by increased synchronization between "bodily rhythms", such as heart and respiration rate (Laborde et al., 2017; Shaffer et al., 2014). When coupled with positive emotions, slow-paced breathing produces a coherent harmonic heart rhythm, which increases vagal tone, personal health, social health, and overall health (Laborde et al., 2017; Shaffer et al., 2014).

These theories were missing components to their explanations, which led Thayer and Lane to propose a structural and functional model of emotion and stress regulation that simultaneously addressed the relationship between the heart and vagus nerve (Koenig, 2020; Park & Thayer, 2014; Thayer & Lane, 2000). The Neurovisceral Integration Model (NIM) links the heart and vagus nerve through an interconnected system of neural networks involved in the control of cardiac autonomic activity related to cognitive and emotional self-regulation (Koenig, 2020; Park & Thayer, 2014; Thayer & Lane, 2000). NIM is currently widely accepted as a model to explain the mechanisms and etiology of HRV accounting for the brainstem, frontal lobe, ANS, and vagus nerve. The brain, ANS, and vagus nerve create an integrated system regulated by top-down and bottom-up perception (Koenig, 2020; Park & Thayer, 2014; Thayer & Lane, 2000). Bottom-up perception involves processing sensory information as it happens (e.g. touching something hot and moving before it burns you), while top-down processes involve pre-existing schemas or cognitions. An example of a top-down process is utilizing schemas related to previous socialization (e.g. knowledge of facial expression) and appraising an individual as threatening or friendly (Koenig, 2020; Park & Thayer, 2014; Thayer & Lane, 2000). NIM integrates knowledge of the polyvagal view of HR, where unmyelinated nerves are involved in bottom-up processing and myelinated nerves are involved in top-down processes (Park & Thayer, 2014; Porges, 2001; Thayer & Lane, 2000). This model also accounts for cognitive and affective factors in ANS regulation reflected in measures of vmHRV. During top-down processing of a situation, lower vmHRV is associated with maladaptive cognitive responses, where an individual is hypervigilant, interpreting stimuli as a threat (Koenig, 2020; Park &

Thayer, 2014; Thayer & Lane, 2000). Higher vmHRV is associated with adaptive and regulated top-down and bottom-up processes (Koenig, 2020; Park & Thayer, 2014; Thayer & Lane, 2000).

Figure 2

Visual Representation of Neurovisceral Integration Model

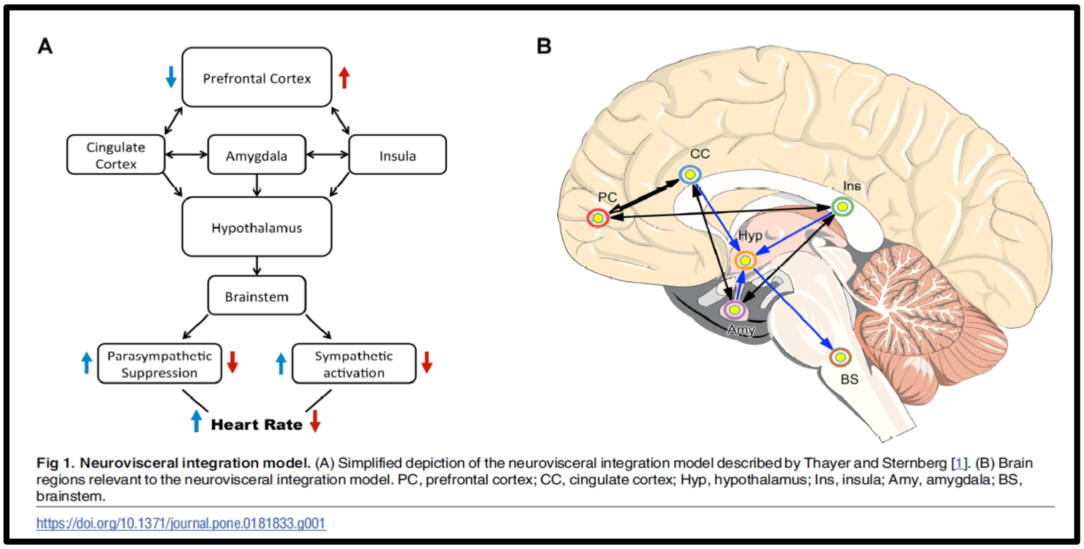


Fig 1. Neurovisceral integration model. (A) Simplified depiction of the neurovisceral integration model described by Thayer and Sternberg [1]. (B) Brain regions relevant to the neurovisceral integration model. PC, prefrontal cortex; CC, cingulate cortex; Hyp, hypothalamus; Ins, insula; Amy, amygdala; BS, brainstem.

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Note. Reprinted from "Combined effect of prefrontal transcranial direct current stimulation and a working memory task on heart rate variability," by Nikolin et al., 2017, PloS ONE, 12(8): e0181833

In stages of high vmHRV, individuals are typically in a state of emotional or cognitive regulation (Park & Thayer, 2014; Thayer, 2015; Thayer & Brosschot, 2005). Thayer and Lane define self-regulation as the "ability to regulate thoughts, emotions, and behaviours, thereby allowing people to choose appropriate responses for different situational demands" (Koenig, 2020; Park & Thayer, 2014; Thayer & Lane, 2000). One of the main elements of NIM is the central autonomic network (CAN), which flexibly responds to environmental demands. The CAN includes the insula, prefrontal cortex, amygdala, hypothalamus, and anterior cingulate cortex, which play a vital role in pain processing, emotion, reward, learning, memory, and social cognition (Xiao & Zhang, 2018). Other brain regions associated with the CAN include the periaqueductal gray matter, parabrachial nucleus, and medulla (Figure 2; Park & Thayer, 2014; Thayer & Brosschot, 2005; Thayer & Lane, 2000).

These brain regions are interconnected. Information flows through the CAN and is processed by neuronal circuits utilizing top-down and bottom-up processing to interpret information (Park & Thayer, 2014; Thayer & Brosschot, 2005; Thayer & Lane, 2000). A key circuit within the CAN is the prefrontal-subcortical inhibitory circuit. The prefrontal cortex plays a role in top-down processing and interprets environmental cues, leading to heightened or inhibited sympathoexcitatory subcortical activity (Park & Thayer, 2014; Thayer & Brosschot, 2005; Thayer & Lane, 2000). When environmental cues are associated with threats or uncertainty, there is no prefrontal subcortical inhibition leading to a threat response by the body. Prefrontal subcortical inhibitory regulation is involved in functions related to the amygdala, such as appetite, prejudice, worry, rumination, and attitude (Park & Thayer, 2014; Thayer & Brosschot, 2005; Thayer & Lane, 2000). Maladaptive regulation of subcortical regions like the amygdala is associated with depression, anxiety, and other psychopathology (Park & Thayer, 2014; Thayer & Brosschot, 2005; Thayer & Lane, 2000). Prefrontal subcortical inhibitory circuits are critical for self-regulation, interacting with vagus nerve functioning. The vagus nerve is linked with these circuits and provides inhibitory neuromodulation to the heart (Park & Thayer, 2014; Thayer & Brosschot, 2005; Thayer & Lane, 2000). vmHRV is an index of ANS activity through this feedback and feedforward process. Higher vmHRV is linked to adaptive functioning of the prefrontal subcortical inhibitory circuit. Those with higher resting vmHRV tend to score higher on cognitive tasks and have more adaptative emotional responses (Park & Thayer, 2014; Thayer & Brosschot, 2005; Thayer & Lane, 2000). Lower resting vmHRV is associated with reduced prefrontal subcortical inhibition, where prefrontal subcortical regions are hyperactive, linked to a multitude of adverse health impacts. Similar to the psychophysiological coherence model, the synchronization of the respiratory and cardiovascular systems is adaptive (Laborde et al., 2017; Shaffer et al., 2014). Methods for evaluating HRV and the brain have considerably evolved since polyvagal theory. The systems view reflects the complexities of the relationship between the ANS, CNS, neuroimmune system, neuroendocrine system, thoughts, emotions, and the environment (Laborde et al., 2017).

The ANS of healthy individuals is flexible and adaptive when confronted with changes in environmental stimuli (Thayer et al., 2012). In states of chronic stress, ANS dysregulation is evident, indicated by SNS overactivity, PSNS underactivity, and consistently low vmHRV (Brosschot et al., 2007). Decreased vmHRV has been linked to cardiovascular disease (Malik, 1998), perfectionism (Azam et al., 2015), depression (Sgoifo et al., 2015), anxiety (Gorman & Sloan, 2000), eating disorders (Murialdo et al., 2007), pain (Koenig et al., 2013, 2015; Koenig, Falvay, et al., 2016; Koenig, Williams, et al., 2016) and headache disorders (Azam et al., 2016; Koenig et al., 2015). Current literature indicates significant and consistent vmHRV reductions in individuals with headache conditions (Azam et al., 2016; Koenig et al., 2015; Perciaccante et al., 2007; Shecter et al., 2002).

Mindfulness Meditation and Headache

HRV is a useful physiological metric of ANS activity and has been utilized to study headache disorders (e.g. migraines, tension-type headaches [TTH]; Koenig, Williams, et al., 2016). Koenig and colleagues published a systematic review and meta-analysis on HRV in people with headaches. This study investigated group differences in time domain measures of HRV utilizing root mean square of successive R-R interval differences (RMSSD), and frequency domain measures of vmHRV. Within the seven studies eligible for inclusion in analysis there were 10 comparisons of those with headaches (HF-HRV N = 67, RMSSD N = 122) to headache-free controls (HF-HRV N = 64, RMSSD N = 125). The meta-analysis indicated a significant main effect of headache disorders on RMSSD (Hedges' g = - 0.63; 95% CI [1.24, – 0.02]) and HF-HRV (Hedges' g = - 0.30; 95% CI [-0.69, 0.10]) when controlling for respiration (Koenig, Williams, et al., 2016). There is decreased vagal activity in individuals with headaches, which is consistent with previous research on migraines and TTH (Azam et al., 2016).

A site for potential therapeutic intervention in individuals with chronic pain and headache disorders is the vagal nerve (Koenig, Williams, et al., 2016). One such intervention that increases sympathovagal balance is mindfulness meditation (MM). MM is a non-invasive treatment which involves focused and non-judgmental awareness of present experiences through sustained attention to breathing sensations (Azam et al., 2015, 2016). Current research suggests MM increases parasympathetic tone, activates the PNS, and restores homeostasis after a stress (Azam et al., 2016). This indicates MM may be beneficial under conditions where sympathovagal balance is shifted towards excess sympathetic activity due to stress or disease processes. Previous studies suggest that those with headache pain who utilized MM experienced significant decreases in pain, new ability to recognize headache symptoms, and increased ability to cope with stressful situations (Kabat-Zinn, 1982, 2003; Kabat-Zinn et al., 1985; Vasquez-Rosati et al., 2017). Azam and colleagues (2016) examined the relationship between HRV and stress recovery facilitated by MM in individuals with primary headache disorders (migraine and/or TTH). This study found mindfulness practice can effectively regulate ANS function and promote recovery after a stressful event for individuals with headache conditions (Azam et al., 2016). The study population consisted of participants with self-reported headache disorders (migraine and/or TTH) and headache-free controls. HRV was measured during baseline, stress-induction, and post-stress recovery. Results indicated significantly higher HF-HRV in both groups during MM compared with baseline, though HRV was significantly higher in the headache group than control. HRV increased significantly during post-stress MM in both groups (Azam et al., 2016). These results suggest those with headache disorders, marked by ANS dysregulation and maladaptive stress response, may be able to use MM to regulate and promote physiological stress recovery (Azam et al., 2016). Additional literature also suggests MM may be an effective treatment for primary headache disorders, as it has been effective in decreasing the frequency of headaches, and decreasing pain from headaches (Cathcart et al., 2014).

Although Azam and colleagues (2016) examined HRV in those with headache disorders in this study, pain was not measured, which is essential since HF-HRV changes are associated with changing levels of pain. It is also unknown whether the study population were experiencing clinically significant levels of headache or migraine as headache conditions were self-reported, and there was no further screening using diagnostic criteria. There is also a need to replicate these methods with a more robust and representative sample that does not exclude conditions comorbid to migraine, as the majority of chronic migraine and episodic migraineurs live with one or more additional health conditions (Burch et al., 2019; Buse et al., 2013; Lipton et al., 2018, 2019; Scher et al., 2005; Wang et al., 2010). There is also further exploration needed to understand stress recovery in those with migraine as there is no literature which distinguishes HF-HRV differences in migraine versus TTH, which have different physiological etiology.

Migraine Etiology

Although current literature has connected ANS dysfunction and migraine, there is currently no consensus on the primary cause of migraines (Pietrobon & Striessnig, 2003).

Activation of the trigeminovascular system (TGVS) is associated with migraine-related pain (Pietrobon & Striessnig, 2003). Pain within the skull is primarily related to trigeminal innervation of meningeal blood vessels. Consequently, the development of migraine is dependent on the stimulation of nociceptive sensory afferent fibers of the trigeminal nerve on meningeal blood vessels (Pietrobon & Striessnig, 2003). Activation of sensory afferent fibers leads to the activation of neurons in the trigeminal nucleus pars caudalis (TNC) and two divisions of the cervical spinal cord (Pietrobon & Striessnig, 2003). The impulses are then transmitted to several thalamic nuclei and the caudal periaqueductal grey region (PAG). The PAG is significantly implicated in migraine and is more generally involved in the transmission of pain (Pietrobon & Striessnig, 2003). TGVS activation also produces vasodilation mainly due to calcitonin gene-related peptide (CGRP) and the activation of the parasympathetic reflex (Pietrobon & Striessnig, 2003). Individuals prone to migraines may produce an excess of CGRP; this pathway has been recently highlighted as relevant to migraines based on pharmacological randomized control trials (RCT) study showing that CGRP release prevents migraine (Edvinsson & Warfvinge, 2019; Loder & Robbins, 2018).

Aura symptoms (e.g. scotoma and scintillations) are related to cortical spreading depression (CSD) in the cortex (Pietrobon & Striessnig, 2003). CSD is a relatively slow wave of sustained neuronal depolarization which generates short-term increases in activity as it progresses through the cortex (Pietrobon & Striessnig, 2003). Initially, the CSD is marked by an increase in regional cerebral blood flow, while the second phase is associated with a decrease (Pietrobon & Striessnig, 2003). Animal models illustrate increased potassium ions, protons, nitric oxide, and other substances during CSD, which may activate or sensitize meningeal trigeminovascular afferents. CSD activates the TGVS, resulting in migraine headaches (Pietrobon & Striessnig, 2003).

Mindfulness and Migraine

Mindfulness has been associated with reductions in depression, anxiety, perceived stress, and general psychological distress (Song & Lindquist, 2015). Individuals with migraines are more likely to experience major depressive disorder, general anxiety disorder, and perfectionism (Breslau et al., 1994, 2003; Breslau & Davis, 1993; Buse et al., 2013; Shecter et al., 2002; Stewart et al., 1992). Perfectionism (Azam et al., 2015), anxiety, and depression (Gorman & Sloan, 2000) are all linked to decreased vmHRV (Graur & Siegle, 2013). Research supports MM as an effective treatment for anxiety disorders, mood disorders, chronic pain, and fibromyalgia (Kabat-Zinn, 1982, 2003; Kabat-Zinn et al., 1985). This indicates MM may benefit individuals with migraines by increasing HF-HRV in addition to reducing anxiety, pain, and depressive symptoms.

Current literature suggests migraineurs are at significantly greater risk of insomnia, psychiatric conditions (depression, anxiety, suicidality), gastrointestinal issues, cardiovascular conditions (stroke, coronary heart disease, hypertension), diabetes, rheumatic conditions (arthritis, psoriasis), asthma, epilepsy, and allergies (Burch et al., 2019; Buse et al., 2013; Lipton et al., 2018, 2019; Scher et al., 2005; Wang et al., 2010). While many studies exclude those with comorbid conditions within HRV research due to phasic changes associated with HRV (Kemp et al., 2012; Miu et al., 2009), there is a need to collect generalizable and clinically relevant results, as many studies contribute to research waste (Chalmers & Glasziou, 2016; Ioannidis, 2014). The present study will include those who meet the diagnostic criteria for only migraine headaches, evaluates pain, and other factors that may impact HF-HRV and ANS recovery after psychological stress induction and response to MM. This study aims to replicate the methodology utilized by Azam and colleagues (2016) in those who only experience migraines headaches.

Rationale and Hypotheses

Migraines significantly impact the economy and the quality of life of migraineurs. According to Statistics Canada, in 2011, 2.7 million Canadians reported they had been diagnosed with migraine headaches (Ramage-Morin & Gilmour, 2014). Migraineurs report migraine pain prevented usual activities such as driving (53%) and sleep (76%). In those with migraines, 50% had to discontinue regular activity (at some point), and 77% indicated a limited ability to function during migraine episodes (Pryse-Phillips et al., 1992). Females are more than three times (3:1) as likely to report migraines than males (Onan et al., 2023; Pryse-Phillips et al., 1992). Since migraines have a detrimental impact on the lives of those affected, there is a need to find new solutions to address migraine pain, pain-related disability, and quality of life (Onan et al., 2023; Pryse-Phillips et al., 1992). MM may be one novel solution. Previous literature has recommend utilizing HF-HRV to further investigate the association of migraine and comorbid conditions (Koenig, Williams, et al., 2016).

This study is novel because it is the first study to examine psychological stress induction in those with migraine to examine stress recovery and compare it to the usage of facilitated stress recovery by MM. This study is also one of the first to study migraine, HRV, and include those with comorbid psychological conditions. In this study, it is hypothesized there will be (1) a significant reduction in HF-HRV during cognitive stress induction, and (2) a physiological recovery evident by an increase in HF-HRV in those who practice MM.

2. Methods

Participants

This study enrolled 26 undergraduate students of all years and various majors at York University. All participants indicated they had been diagnosed with a migraine headache disorder by a healthcare professional. Participants were recruited through an online system of research participation (Undergraduate Research Participant Pool in the Department of Psychology; URPP), which grants university course credit for participation in research. All participants were asked to provide informed written consent at the lab session.

Sample Size Estimation

With the assistance of the Institute for Social Research at York University, sample size was calculated for a 1-way repeated measure analysis of variance (ANOVA). Sample size was calculated using G*Power 3.1.9.2 (Erdfelder et al., 2009). The options in G*Power 3.1.9.2 were as follows: (1) test family – "F-test", (2) statistical test – "ANOVA: Repeated measures, within-between interaction", (3) Type of power analysis – "A priori: Compute required sample size – given α, power, and effect size". An a priori power analysis was completed using a moderate effect size ($f = 0.25$), power ($1 - \beta$ error probability) set at 0.95, and an alpha error probability set at $p < .05$. G*Power 3.1 determined that a minimum sample size of 24 participants (12 per group) would provide ample testing power; therefore, a sample size of $N = 26$ is adequate to detect within-group and between-group differences based on the experimental repeated measures design.

Risks & Inclusion-Exclusion Criteria

To be eligible for the study, participants must have been enrolled in an undergraduate program at York University, between 17 and 29 years old, and met the International

Classification of Headache Disorders 3rd Edition (ICHD-3) criteria for migraine (Headache Classification Committee (IHS), 2018; D. Li et al., 2015; Olesen, 2018). 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 (past or current) were excluded. There was no risk associated with assessment via ECG or respiration measures. Some participants may have felt uncomfortable answering questions about their medical history or performing a cognitively demanding task while attached to various pieces of equipment. If uncomfortable, participants had the option to select "prefer not to answer" on the questionnaires and an option to stop participation at any time without penalty.

Design

This study collected psychometric, demographic, and respiration data, as well as HRV via ECG. After providing informed consent, participants were screened for eligibility. Participants were then asked to complete the study questionnaires. Once the questionnaires were completed, the experimental protocol consisted of three phases which each participant underwent in the same order: (1) Baseline (5-minutes), (2) Stress Induction (10-minutes), and (3) random assignment to either 10-minutes of guided MM practice or 10-minutes of a descriptive lecture about MM.

Questionnaires

Demographic Questionnaire

Participants were asked for demographic information like age, sex, ethnicity/race, and migraine diagnosis. They were also asked whether they had any of the following conditions: depressive disorder, anxiety disorder, bipolar /II disorder I, schizophrenia or schizoaffective, 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. Lastly, participants were asked whether they had a migraine at the time of assessment (Appendix A).

Automatic Thoughts Questionnaire (ATQ)

The ATQ was developed by Hollon & Kendall (1980) to evaluate four dimensions of personal automatic negative statements: (1) personal maladjustment and desire for change, (2) negative self-concepts and negative expectations, (3) low self-esteem and (4) helplessness (Appendix B). The ATQ consists of 30 items, each item being a thought (e.g., "I feel like I'm up against the world"), with scores ranging from 30 to 150. The participants 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 been found to reliably distinguish depressed from non-depressed groups, with a Cronbach's alpha of 0.96 (Azam et al., 2015; Hollon & Kendall, 1980). This scale was included to determine whether physiological metrics (e.g. HRV) are correlated with automatic negative thoughts.

Beck Anxiety Inventory (BAI)

The BAI was developed by Beck and colleagues (1988) to differentiate between anxiety and depressive symptoms (Beck et al., 1988; Appendix C). The BAI is a 21-item self-report questionnaire. It is scored on a 4-point scale (0 = not at all; 1 = mildly but it didn't bother me much; 2 = moderately – it wasn't pleasant at times; 3 = severely – it bothered me a lot). The total score is summed with scores between 0 – 21 categorized as low anxiety, scores between 22 – 35 categorized as moderate anxiety, and scores 36 or above categorized as potentially concerning levels of anxiety (Beck et al., 1988; Fydrich et al., 1992). The BAI is correlated with the revised

Hamilton Anxiety Inventory (r = 0.51) and discriminates between anxiety and depression with a Cronbach's alpha = 0.94 (Fydrich et al., 1992). This scale was included to determine the baseline anxiety level of participants.

Brief Pain Inventory (BPI)

The BPI was developed to measure pain intensity and interference (Cleeland & Ryan, 1994; Appendix D). Participants are first asked to indicate if they experience pain other than "everyday" kinds of pain. They are then presented with a diagram and asked to indicate which areas they feel pain and highlight the area that hurts the most (Cleeland & Ryan, 1994). For questions 3 and 4, participants score their pain at its worst and least in the last 24 hours, from "0 – no pain" to "10 – pain as bad as you can imagine". On the same scale, participants are asked their average and current pain levels (Cleeland & Ryan, 1994). The following two questions (7 and 8) revolve around treatments and medications for pain and relief from pain using those treatments. Question 9 asks participants to rate the level of interference of their pain on mood, general activity, walking, work, interpersonal relationships, sleep, and enjoyment of life, from "0 – does not interfere" to "10 – completely interferes" (Cleeland & Ryan, 1994). The BPI has a Cronbach's alpha of 0.85 for pain intensity items and a Cronbach's alpha = 0.88 for pain interference items in those with chronic non-malignant pain (Tan et al., 2004). This questionnaire was used to assess baseline global pain levels in all participants.

Center for Epidemiologic Studies Depression Scale (CES-D)

The CES-D is a self-report questionnaire designed to study depressive symptoms in the general population (Radloff, 1977; Appendix E). The questionnaire includes 20 questions and focuses on the affective components of depression (Cronbach's alpha = 0.80; Radloff, 1977). Participants are instructed to answer based on how often they have felt the statement in the past week. The responses are scored on a 4-point scale (0 = rarely or none of the time - less than 1 day, 1 = some or a little of the time - 1 – 2 days, 3 = occasionally or a moderate amount of time - 3 – 4 days, 4 = all the time - 5 – 7 days). A score of 16 or above on the CES-D indicates clinical depression (Radloff, 1977). This scale was included to determine the baseline depression levels of participants.

Headache Impact Test (HIT)

The HIT is designed to measure headache impact (Yang et al., 2011; Appendix F). This 6-item self-report questionnaire looks at the impact of headaches on functioning (social, cognitive), psychological distress, and pain. It has been validated for migraine populations (alpha = 0.77; Yang et al., 2011). Participants are asked to respond to questions based on a 5-point scale (6 = never, 8 = rarely, 10 = sometimes, 11 = very often, 13 = always). A score of 49 or less is categorized as “little to no impact”, a score of 50 – 55 is categorized as “some impact”, and scores greater or equal to 60 are classified as “severe impact” (Yang et al., 2011). This scale was included to determine the level of headache-related impact on participants with migraines.

International Classification of Headache Disorders 3rd Edition (ICHD-3)

The ICHD-3 was developed by the International Headache Society (IHS) to standardize the diagnosis of headache disorders for clinical and research purposes (Headache Classification Committee (IHS), 2018; Appendix G). The ICHD-3 was first published for beta testing in 2018 and is a hierarchical classification system. Migraine criteria includes length of headache, pain, location, avoidance of routine physical activity, nausea, photophobia, phonophobia, and at least 5 attacks that fulfill these diagnostic criteria (Headache Classification Committee (IHS), 2018). Migraine with aura includes the presence of reversible aura symptoms and several temporal characteristics (e.g. at least one aura symptom that spreads gradually; IHS, 2018). The ICHD-3 has shown greater sensitivity diagnosing migraine with aura compared to the ICHD-2 (Albers et al., 2014; D. Li et al., 2015). ICHD-3 beta classified 7.8% more headache patients compared to ICHD-2, and both have similar kappa values (Kim et al., 2016). This questionnaire was used to screen participants at the beginning of the study to ensure they met standardized criteria for migraine. If they met the criteria for migraine headaches, they were directed to answer further questions to ascertain whether they experienced aura with their migraines.

Patient Health Questionnaire (PHQ-9)

The PHQ-9 was developed as a diagnostic tool utilizing DSM-IV criteria to diagnose depression (Kroenke & Spitzer, 2002; Appendix H). The PHQ-9 is half the length of other depressive questionnaires while remaining as sensitive (detecting severity of depression) and specific (discerning depression from other disorders) as other measures (Cronbach's alpha = 0.89). Participants are asked to report the frequency of depressive symptoms over the last two weeks using a 4-point scale (0 = not at all, 1 = several days, 2 = more than half the days, 3 = nearly every day). Major depressive disorder is diagnosed if 5 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 4 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). The PHQ-9 has been validated for migraine populations and was utilized to indicate the severity of depressive symptoms (Seo & Park, 2015).

3. Protocol

Baseline

After completing informed consent and study questionnaires (Appendix I), participants were attached to an ECG unit and a respiration belt for 5 minutes. The experimenter instructed the participant to sit in a relaxed upright position while thinking freely with their eyes open, focusing on a fixation cross on a computer screen. Participants were instructed not to make any sudden movements, maintain eye fixation, and stay silent.

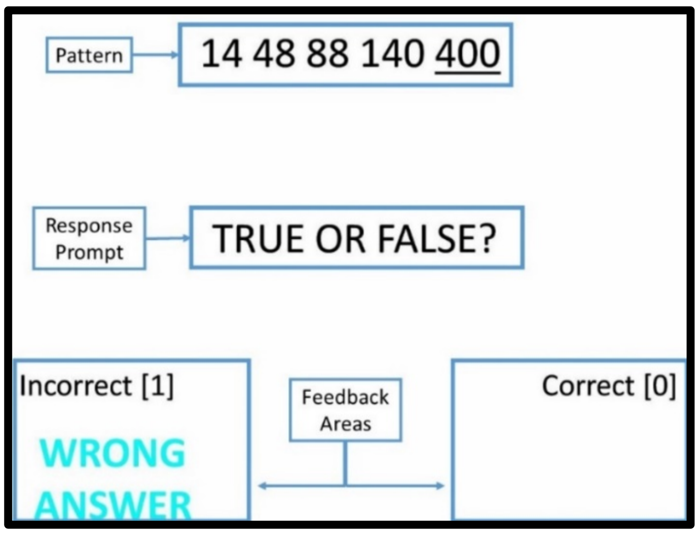
Stress Induction

The stress induction phase involved a modified version of a stress induction task designed by Azam and colleagues called the Pattern Solving Task (PST; 2015). Participants completed the PST for 22 trials while ECG and respiration data were collected.

This task has been used to elicit a cardiovascular stress response in healthy individuals, perfectionists, and those with primary headache disorders (Azam et al., 2015, 2016). It has been proposed that PST elicits sympathetic activation as a response to error detection (Azam et al., 2015, 2016). During the PST, participants were asked to study 4 alphanumeric characters presented at the top of the screen for 10 seconds and determine the pattern (Figure 3). After 10 seconds, a 5th character is presented with the text "True or False?" in the middle of the screen. Participants were instructed to respond as quickly and as accurately as possible with "True" (left arrow key) if they believed the 5th character followed the pattern or "False" (right arrow key) if it did not. Immediately after the response, either "Right Answer" or "Wrong Answer" was presented at the bottom left or bottom right, respectively, of the screen for 3 seconds. The alphanumeric characters are designed to appear to participants as a simple or complex pattern, but none of the problems follow a specific, solvable pattern (Appendix J; Azam et al., 2015; Azam, Katz, et al., 2016). The "Right Answer" and "Wrong Answer" presentations were created in a pre-determined random order. Participants were told the PST assesses cognitive capacity as a "marker" of intelligence, and the average score of the task is 80-85%, 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). The total number of "correct" and "incorrect" trials was fixed. All participants scored 50%.

Figure 3

Example of Pattern Recognition Task Adapted from Azam et al., 2015



Manipulation Check

After the PST was completed, a manipulation check was performed in which participants were asked three questions (Appendix K). 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). Lastly, participants were asked to rate their performance on the PST on a scale five-point scale (1 = poor performance, 2 = below expectations, 3 = met expectations, 4 = above expectations, 5 = exceptional performance).

Listening Intervention

Immediately following the PST, participants were randomized to an experimental condition using a table created with GraphPad (https://www.graphpad.com/quickcalcs/randomize1/; Appendix L). Participants were randomly assigned to either the experimental condition, Mindfulness Meditation Practice (MMP) that was a guided MM audio, or the control condition, Mindfulness Meditation Description (MMD) which was a descriptive lecture on MM. Participants remained attached to the ECG and respiration belt for the duration of both conditions. Each condition was 10 minutes in duration and was played via headphones. The MMP condition was a 10-minute audio recording which featured mindfulness instructions which emphasized bringing attention to breathing sensations. If participants became distracted by thoughts, feelings and/or external stimuli, they were to non-judgementally re-focus on breathing sensations (Azam et al., 2015, 2016; Appendix M). Participants kept their eyes opened and focused on a fixation cross. The instructions were recorded by a clinical psychologist and experienced MM instructor. In the MMD condition, participants were seated identically to the MMP condition (including eyes open). They were played an audio description of historical and scientific information on MM by the same instructor for 10-minutes (Azam et al., 2015, 2016). Participants were asked to rest similar to baseline while the recording was played. The recording did not explicitly include any specific MM instruction (Appendix N). The MMD was designed to be structurally identical to MMP (e.g. same tone of voice, equal duration). Figure 4 illustrates the study design.

Figure 4

Design of Migraine Study

Group		Condition
MMP	MMD	Phase 1: Basline (N = 26)

Ph

<table>
<tr><td rowspan="4">N = 13</td><td rowspan="4">N = 13</td><td colspan="2"></td></tr>
<tr><td colspan="2">Phase 2: Stress (N = 26)
↓</td></tr>
<tr><td colspan="2">Phase 3: Listening Phase (N = 26)
Randomly Assigned to:
↙ ↘</td></tr>
<tr><td>Mindfulness Meditation Practice (N = 13)</td><td>Mindfulness Meditation Description (N = 13)</td></tr>
</table>

Debrief

There was a debrief with each participant at the conclusion of the experimental protocol. Participants were told about the purpose and design of both the PST and listening intervention. Most importantly, they were informed of the deception in the PST (e.g. the score is fixed) and asked not to share this information as other students may partake in the experiment. Participants were asked to sign a debriefing form (Appendix O). They were also provided with resources and contact information if they experienced distress after the deception. No participants contacted the principal investigator. Participants also had the option to give feedback regarding their experience in the study. For the full study protocol see Appendix P.

HRV Data Acquisition & Processing

ECG data were recorded using ADInstruments (ADI) PowerLab 4-channel data acquisition system. LabChart Pro software, developed by ADI, is integrated with the ECG unit, and was used to obtain computer-digitized ECG signal from the PowerLab unit. The standardized sampling rate was 1000 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, (2) beat correction: threshold very low. Data were analyzed in 5-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; K. Li et al., 2019; Pham et al., 2021; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology., 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 (K. 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 of the European Society of Cardiology and the

North American Society of Pacing and Electrophysiology., 1996). RMSSD is strongly correlated with HF-HRV.

Respiration Data Acquisition & Processing

This procedure is standardized to address confounds of respiration in HRV studies according to the recommendations of Allen and colleagues (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 of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology., 1996).

Statistical Analysis

Quantitative statistical analyses were completed with self-report questionnaire data (demographics and psychometrics), ECG data, and respiration data. All statistical testing was completed using Statistical Package for the Social Sciences (SPSS) version 29.0 for Macintosh by IBM with statistical significance set at $p < 0.05$ (IBM Corp, 2024). Questionnaire data were visually examined for outliers and missing data. All data were normal. Independent samples t-tests were used to evaluate differences in numeric variables. Nominal and categorical data were analyzed with Chi-square tests. Psychometric questionnaires were scored (ATQ, BAI, BPI, CES-D, HIT, PHQ-9) and tested utilizing Independent samples t-tests. The PST manipulation check questions were also scored, and between-group differences were tested using an Independent samples t-test.

Respiration data were cleaned and checked for normality before analysis. ECG data were cleaned prior to statistical analysis. All PQRST intervals were examined, and ectopic beats were removed. ECG data were checked for normality. HF-HRV values were log transformed for normality. Both respiration and HF-HRV data were analyzed in 5-minute epochs representing four experimental phases herein referred to as Baseline, Stress, Listening 0-5 mins, and Listening 5-10 mins. A 2(MMD vs MMP) x 4 (Baseline HF-HRV, Stress HF-HRV, Listening 0-5 mins HF-HRV, Listening 5-10 mins HF-HRV) x 4 (Baseline respiration, Stress respiration, Listening 0-5 mins respiration, Listening 5-10 mins respiration) between-subjects repeated measures MANOVA was utilized for HF-HRV and respiration analysis. No conditions of the MANOVA were violated (e.g. sphericity, normality). Post-hoc pairwise comparisons of phase, and the phase by condition interaction were conducted using a Bonferroni correction to adjust for multiple comparisons.

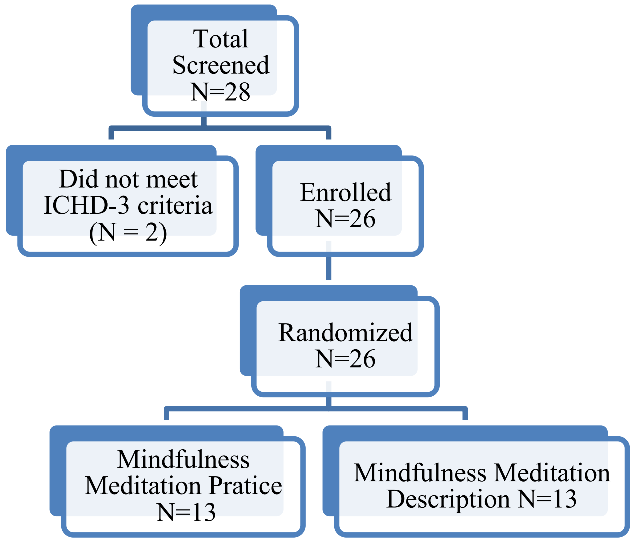
4. Results

Participant Recruitment

28 female participants were recruited for the study (Figure 5). The average age of participants in this study was 19.97 years old (Standard Deviation [SD] = 0.49). Participants were screened for migraine prior to inclusion in the study. N = 2 participants were unable to continue in the study as they did not meet the ICHD-3 criteria for migraine with aura or migraine without aura. 26 participants were included in the final analyses with N=13 in both the MMD and MMP conditions.

Figure 5

Flow of Participants Through the Migraine Study



Demographic and Psychometric Analyses

Descriptive statistics were completed for demographics, comorbidities, and psychometric questionnaires (ATQ, PCI, BAI, CES-D, HIT, PHQ-9). Table 1 presents numeric variables (e.g., age) as means and standard deviations. Categorical and nominal data are presented as frequencies and percentages. Independent samples t-tests were used to evaluate differences in numeric variables. Chi-square tests were used to examine the differences between categorical and nominal data. Participant migraine characteristics are also summarized in this table. There were no significant group differences between those in the MMD compared to the MMP condition (Table 1). The average age in the MMD group was 19.69 years (SD = 1.9) and 20.23 years (SD = 3.1) in the MMP condition. All participants in this study were assigned female at birth (100%). Participants were primarily White (North American, European, 39%) and South Asian (39%).

Results from the ICHD-3 migraine questionnaire are also presented in Table 1. In the study, 20 individuals had diagnosable migraine with aura (76.9%) and 6 individuals had migraine without aura (23.1%). Individuals in the study reported: headaches lasting 4 – 72 hours (MMD = 100%, MMP = 100%), unilateral location (MMD = 46%, MMP = 62%), moderate to severe pain intensity (MMD = 85%, MMP = 100%), pulsating quality (MMD = 100%, MMP = 85%), triggered/aggravated by movement (MMD = 62%, MMP = 31%), nausea and/or vomiting (MMD = 77%, MMP = 70%), photophobia and phonophobia (MMD = 85%, MMP = 85%). For aura symptoms, 77% in the MMD group and 44% in the MMP group experienced visual aura. They also reported sensory aura (MMD = 54%, MMP = 46%), speech/language aura (MMD = 8%, MMP = 31%), motor aura (MMP = 31%), brainstem aura (MMP = 8%), and retinal aura (MMD = 39%, MMP = 62%).

This differed from the migraine diagnosis individuals received from their respective healthcare professionals. According to self-report data, 10 participants were diagnosed with migraine without aura (MMD = 46.2%, MMP = 30.8%) and 15 participants were diagnosed with migraine with aura (MMD = 53.8%, MMP = 69.2%). 27% of participants had a migraine at assessment (MMD = 15.4%, MMP = 38.5%). In the MMD group, 46.2% of migraineurs report using medication and 61.5% report using medication in the MMP group. In this study, individuals experienced chronic health conditions in addition to migraine. Participants in both groups reported chronic pain (MMD = 30.8%, MMP = 53.8%). Participants in the study also reported pulmonary disease (MMD = 7.7%), high blood pressure (MMD = 7.7%), low blood pressure (MMD = 7.7%), diabetes (MMD = 7.7%, MMP = 7.7%), and hypothyroidism (MMD = 7.7%, MMP = 15.4%). Individuals in this population also reported diagnosis of mental health or neurologic conditions such as depression (MMD = 53.8%, MMP = 30.8%), generalized anxiety disorder (MMD = 46.2%, MMP = 46.2%), eating disorder (MMD = 7.7%, MMP = 7.7%), and attention deficit hyperactivity disorder (MMP = 7.7%).

Table 1

Values of Demographic and Self-Reported Health Information for Migraine Study Participants

Variables	MMD (N = 13)	MMP (N= 13)	p
Age (years)	19.69 (1.9)	20.23 (3.1)	0.21
Chronic Health Conditions (%)			
Chronic Pain	4 (30.8)	7 (53.8)	0.23
Pulmonary Disease	1 (7.7)	0 (0)	0.31
High Blood Pressure	1 (7.7)	0 (0)	0.31
Low Blood Pressure	1 (7.7)	0 (0)	0.31
Diabetes Mellitus Type II	1 (7.7)	1 (7.7)	1.00
Hypothyroidism	1 (7.7)	2 (15.4)	0.54
Ethnicity			
West Asian	1 (7.7)	0 (0)	
Black (African)	1 (7.7)	0 (0)	
White (North American, European)	5 (38.5)	5 (38.5)	
Latino	2 (15.4)	0 (0)	
South Asian	5 (38.5)	5 (38.5)	
Southeast Asian	0 (0)	1 (7.7)	
Other	1 (7.7)	0 (0)	0.54
International Classification of Headache Disorders 3rd Edition			
Headaches lasting 4 – 72 hours.	13 (100)	13 (100)	1.00
Unilateral Location	6 (46)	8 (62)	0.43
Moderate to Severe Pain Intensity	11 (85)	13 (100)	0.14
Pulsating Quality	13 (100)	11 (85)	0.14
Aggravated/Triggered by Movement	8 (62)	4 (31)	0.12
Nausea and/or Vomiting	10 (77)	9 (70)	0.66
Photophobia and Phonophobia	11 (85)	11 (85)	1.00
Aura Symptoms			
Visual	10 (77)	8 (44)	0.40
Sensory	7 (54)	6 (46)	0.70
Speech/Language	1 (8)	4 (31)	0.14
Motor	0 (0)	4 (31)	0.03
Brainstem	0 (0)	1 (8)	0.31
Retinal	5 (39)	8 (62)	0.24
Migraine Diagnosis			
Migraine Without Aura	5 (38.5)	1 (7.7)	
Migraine With Aura	8 (61.5)	12 (92.3)	0.06
Medication Usage	6 (46.2)	8 (61.5)	0.37

Migraine Diagnosis by Healthcare Professional			
Migraine Without Aura	6 (46.2)	4 (30.8)	0.38
Migraine With Aura	7 (53.8)	9 (69.2)	0.37
Current Migraine at Assessment	2 (15.4)	5 (38.5)	0.17
Psychological Comorbidities			
Major Depressive Disorder	7 (53.8)	4 (30.8)	0.23
Generalized Anxiety Disorder	6 (46.2)	6 (46.2)	1.00
Eating Disorder	1 (7.7)	1 (7.7)	1.00
Attention Deficit Hyperactivity Disorder	0 (0)	1 (7.7)	0.31
Sex (%)			
Female	13 (50)	13 (50)	1.00

Note. All values presented as means (standard deviations) for numeric and frequency (percentage) for categorical variables. For numeric variables, Independent samples t-tests were utilized as tests of significance. Categorical variables were tested for significance using a chi-square test.

Table 2 presents questionnaire data with both subscales and the total scores. Independent samples t-tests were conducted to determine if there were significant differences between the MMP and MMD groups on these questionnaires. There were no significant differences between both groups on any of the questionnaires. However, both groups scored extremely high on the ATQ, with the MMD group mean of 74.77 (SD = 26.55) and MMP group mean of 74.62 (SD = 24.46) out of a possible 150, indicating elevated levels of negative thoughts. As expected, with high levels of automatic negative thoughts, there were moderate levels of depression indicated by the CES-D and PHQ-9. A score of 16 or above on the CES-D indicates clinical depression. The mean and SD in the MMD and MMP groups were 27.92 (SD = 7.96) and 27.31 (SD = 12.02), respectively. Group means on the PHQ-9 are consistent with these results, with both groups experiencing moderate levels of depression (MMD mean = 14.15, SD = 5.52; MMP mean = 13.23, SD = 5.41). The mean score on the BAI in the MMD and MMP groups were 36.92 (SD = 10.87) and 28.52 (SD = 16.39), respectively. This is categorized as severe levels of anxiety.

Both groups also experienced a severe impact on their lives from their migraines, as measured by the HIT (MMD mean = 67.46, SD = 6.23; MMP mean = 61.08, SD = 8.97). This population also experienced more pain than just "normal everyday" pain as reported on the BPI. Their average pain levels were moderate, rating their pain as 4.00/10 (SD = 2.80) in the MMD group and 4.69/10 (SD = 2.75) in the MMP group. They also indicated pain interferes with their mood (MMD mean = 5.08, SD = 3.52; MMP mean = 4.15, SD = 3.91), sleep (MMD mean = 5.00, SD = 3.58; MMP mean = 4.08, SD =3.82), and school (MMD mean = 5.08, SD = 3.95; MMP mean = 4.08, SD = 3.97).

The PST Manipulation Check indicated participants saw the task as "average" difficulty with MMD and MMP groups having identical means of 3.85 (MMD SD = 0.69; MMP SD = 0.55). Those in the MMD group rated their stress level as "a little stressed" (mean = 2.85, SD = 1.28). The MMP group was slightly more stressed, rating their stress level as "moderately stressed" (mean = 3.08, SD = 0.86). Both groups rated their performance as poor (MMD mean = 1.85, SD = 0.80; MMP mean = 1.69, SD = 0.48). There were no significant differences between groups in the PST Manipulation Check in measures of subjective difficulty, stress level, or subjective performance.

Table 2

Results of Psychometric Questionnaires for Migraine Study Participants

Questionnaire	MMD (N = 13)	MMP (N = 13)	p
Automatic Thought Questionnaire	74.77 (26.55)	74.62 (24.46)	0.84
Beck Anxiety Inventory	36.92 (10.87)	28.54 (16.39)	0.13
Brief Pain Inventory			
Worst Pain	3.46 (2.99)	3.38 (3.10)	0.24
Least Pain	2.38 (2.69)	1.15 (1.90)	0.88
Average Pain	4.00 (2.80)	4.69 (2.75)	0.16
Pain Now	1.54 (1.90)	2.38 (2.47)	0.06
Pain Severity	2.85 (1.84)	2.09 (2.01)	0.77
General Activity	2.69 (3.25)	2.46 (2.73)	0.47

Mood	5.08 (3.52)	4.15 (3.91)	0.48
Walking Ability	1.69 (2.50)	1.46 (1.94)	0.39
Normal Work	3.38 (3.40)	2.38 (2.90)	0.54
Relationships	3.31 (3.20)	2.85 (3.48)	0.51
Sleep	5.00 (3.58)	4.08 (3.82)	0.76
Enjoyment of Life	3.15 (3.10)	4.23 (3.75)	0.25
School	5.08 (3.95)	4.08 (3.97)	0.79
Pain Interference	3.67 (2.85)	3.21 (2.96)	0.98
Center for Epidemiological Studies Depression Scale	27.92 (7.96)	27.31 (12.02)	0.10
Headache Impact Test	67.46 (6.23)	61.08 (8.97)	0.15
Patient Health Questionnaire	14.15 (5.52)	13.23 (5.41)	0.92
PST Manipulation Check			
Subjective Difficulty	3.85 (0.69)	3.85 (0.55)	0.42
Stress Level	2.85 (1.28)	3.08 (0.86)	0.08
Subjective Performance	1.85 (0.80)	1.69 (0.48)	0.59

Note. All values presented as means (standard deviations) for numeric values. Independent samples t-test was utilized to test for significant differences between the MMD and MMP conditions.

Respiration and HRV Analysis

The average heart rate in the MMD group was 79.37 BPM (SD =11.12) and 81.76 BPM (SD = 11.05) in the MMP condition during Baseline (Table 3a). Average heart rate during the Stress phase was 82.75 BPM (SD = 13.48) in the MMD group and 81.59 BPM (SD = 12.65) in the MMP group. During Listening 0 – 5 minutes average heart rate was 79.28 BPM (SD = 13.25) in the MMD group and 80.08 BPM (SD = 11.67) in the MMP group (Table 3a). Average heart rate shifted to 81.47 (SD = 11.77) BPM in the MMD group and 81.45 (SD = 10.85) BPM in the MMP group during Listening 5 – 10 minutes (Table 3a). RMSSD was 45.99 ms (SD = 23.70) during Baseline in the MMD group and 36.83 ms (SD = 15.83) in the MMP group. During Stress, RMSSD was 39.18 ms (SD =15.50) in the MMD group and 44.70 ms (SD = 16.74) in the MMP group. In the Listening 0 – 5 minutes phase, RMSSD was 42.23 ms (SD = 19.35) in the

MMD group and 39.40 ms (SD = 17.59) in the MMP group. RMSSD in the MMD and MMP group were 40.75 ms (SD = 19.18) and 36.31 ms (SD = 14.81) respectively during the Listening 5 – 10 minutes phase (Table 3a).

At Baseline, the average respiration rate in the MMD group was 0.26 Hz (SD = 0.07) and the MMP group was 0.28 Hz (SD = 0.07). During the Stress phase, the average respiration in the MMD group was 0.32 Hz (SD = 0.07) and the MMP group was 0.32 Hz (SD = 0.05). In the MMD condition, the average respiration rate was the same across Listening 0 – 5 minutes and Listening 5 – 10 minutes (mean = 0.28, SD = 0.09). In the MMP group, average respiration rate was 0.25 Hz (SD = 0.08) in Listening 0 – 5 minutes, and 0.26 Hz (SD = 0.09) in Listening 5 – 10 minutes (Table 3b). At Baseline, average HF-HRV in the MMD group was 6.81 ms^2 (SD = 0.24) and the MMP group was 6.27 ms^2 (SD = 1.04). During the Stress phase, the HF-HRV in the MMD group was 6.01 ms^2 (SD = 0.21) and the MMP group was 6.25 ms^2 (SD = 0.91). In the MMD condition, the average HF-HRV was 6.30 ms^2 (SD = 1.20) during Listening 0 – 5 minutes and 6.34 ms^2 (SD = 1.01) during Listening 5 – 10 minutes. In the MMP group, the average HF-HRV was 6.31 ms^2 (SD = 1.20) in Listening 0 – 5 minutes, and 6.12 ms^2 (SD = 1.10) in Listening 5 – 10 minutes (Table 3b).

A 2 (MMD vs MMP) x 4 (Baseline HRV, Stress HRV, Listening 0-5 mins HRV, Listening 5-10 mins HRV) x 4 (Baseline respiration, Stress respiration, Listening 0-5 mins respiration, Listening 5-10 mins respiration) between subjects repeated measures MANOVA was utilized for HF-HRV and respiration statistical analysis. Degrees of freedom for main and interaction effects with factor levels > 2 were adjusted by the Greenhouse-Geisser correction. Results from the MANOVA suggest there is a difference in HF-HRV and respiration over the four experimental phases. There were significant within-subjects effects across experimental phase for both HF-HRV (F [3,72] = 3.34, p = 0.02; Table 4a) and respiration (F[3,72] = 9.04, p = 0.001; Table 4a). Post hoc pairwise comparisons of experimental phase using a Bonferroni correction yielded no significant differences in HF-HRV across phase, however there was a significant decrease between Baseline respiration and Stress respiration (mean difference = -0.05 Hz, p = 0.01; Table 4a) and a significant increase between Stress respiration and Listening 0 – 5 mins respiration (mean difference = 0.05 Hz, p = 0.01; Table 4a).

There was also a significant within-subjects interaction effect between experimental phase and condition for HF-HRV (F[3, 72] = 3.13, p = 0.03; Table 4b). Post hoc pairwise comparisons using a Bonferroni correction found no significant differences in HF-HRV for those in the MMP condition, however there were significant differences in HF-HRV for those in the MMD condition (Table 4b). There was a significant increase in HF-HRV between Baseline and Stress (mean difference = 0.81, p = 0.01; Table 4b). There was a significant within-subjects interaction effect in the MMP group between Stress and Listening 0 – 5 minutes in respiration (mean difference = 0.07, p = 0.03; Table 4c). In the MMD group in respiration, Baseline to Stress was approaching significance (p = 0.052, CI = -0.11, 0.00; Table 4c).

Table 3a

Time Domain Measures During Each Phase According to Condition

	Average HR (BPM)		RMSSD (ms)	
	MMD (N = 13)	MMP (N = 13)	MMD (N = 13)	MMP (N = 13)
Baseline	79.37 (11.12)	81.76 (11.05)	45.99 (23.70)	36.83 (15.83)
Stress	82.75 (13.48)	81.59 (12.65)	39.18 (15.50)	44.70 (16.74)
Listening 0 – 5 minutes	79.28 (13.25)	80.08 (11.67)	42.23 (19.35)	39.40 (17.59)
Listening 5 – 10 minutes	81.47 (11.77)	81.45 (10.85)	40.75 (19.18)	36.31 (14.81)

Note. All values presented as means (standard deviations) for numeric values.

Table 3b

Means and SD of HF-HRV and Respiration During Each Phase According to Condition

	HF-HRV (ms^2)		Respiration (Hz)	
	MMD (N = 13)	MMP (N = 13)	MMD (N = 13)	MMP (N = 13)
Baseline	6.81 (0.24)	6.27 (1.04)	0.26 (0.07)	0.28 (0.07)
Stress	6.01 (0.21)	6.25 (0.91)	0.32 (0.07)	0.32 (0.05)
Listening 0 – 5 minutes	6.30 (1.20)	6.31 (1.20)	0.28 (0.09)	0.25 (0.08)
Listening 5 – 10 minutes	6.34 (1.01)	6.23 (1.10)	0.28 (0.09)	0.26 (0.09)

Note. All values presented as means (standard deviations) for numeric values. HF-HRV values have been log-transformed for normality.

Table 4a

HF-HRV and Respiration Results of Post-hoc Comparisons of Phase

	HF-HRV (ms^2)				Respiration (Hz)			
Phase	Mean Difference	Std. Err.	P	CI	Mean Difference	Std. Err.	P	CI
Baseline to Stress	0.41	0.15	0.08	-0.03, 0.85	**-0.05**	**0.01**	**0.01**	**-0.09, -0.01**
Stress - Listening 0 to 5 minutes	-0.18	0.16	1.00	-0.65, 0.29	**0.05**	**0.02**	**0.01**	**0.01, 0.10**
Listening 0 – 5 minutes to Listening 5 – 10 minutes	0.08	0.10	1.00	-0.19, 0.36	-0.00	0.00	1.00	-0.02, 0.01

Note. Bonferroni adjustment for multiple comparisons

Table 4b

HF-HRV Results of Post-hoc Comparisons of Phase by Condition

	HF-HRV (ms^2)							
	MMD (N = 13)				MMP (N = 13)			
Phase	Mean Difference	Std. Err.	P	CI	Mean Difference	Std. Err.	P	CI
Baseline to Stress	**0.81**	**0.21**	**0.01**	**0.19, 1.42**	0.01	0.21	1.00	-0.60, 0.63
Stress to Listening 0-5 minutes	-0.30	0.23	1.00	-0.95, 0.36	-0.06	0.23	1.00	-0.72, 0.60
Listening 0 – 5 minutes to Listening 5 – 10 minutes	-0.04	0.14	1.00	-0.42, 0.35	0.20	0.14	0.88	-0.19, 0.59

Note. Bonferroni adjustment for multiple comparisons

Table 4c

Respiration Results of Post-hoc Comparisons of Phase by Condition

Respiration (Hz)

Phase	MMD (N = 13) Mean Difference	Std. Err.	P	CI	MMP (N = 13) Mean Difference	Std. Err.	P	CI
Baseline to Stress	-0.05	0.02	0.05	-0.11, 0.00	-0.04	0.02	0.21	-0.10, 0.01
Stress to Listening 0-5 minutes	0.04	0.02	0.56	-0.03, 0.10	**0.07**	**0.02**	**0.03**	**0.01, 0.13**
Listening 0 – 5 minutes to Listening 5 – 10 minutes	-.00	0.01	1.00	-.019, 0.02	-0.01	0.01	1.00	-0.01, 0.01

Note. Bonferroni adjustment for multiple comparisons

5. Discussion

Hypothesis 1: There will be a significant reduction in HF-HRV during cognitive stress induction in those with migraine.

There was no significant difference between Baseline HF-HRV and HF-HRV during Stress in those with migraine in the MMP condition. There was a significant difference in HF-HRV between Baseline HF-HRV and HF-HRV during Stress in the MMD condition (Table 4a). There was interestingly a difference in respiration between Baseline respiration and respirating during Stress in the MMD group (Table 4b). Most individuals rated the task as average difficulty and reported they were "a little stressed" (Table 1). The PST was unsuccessful at evoking a significant reduction in HF-HRV compared to Baseline. This is inconsistent with Azam and colleagues (2016) where all individuals with primary headache conditions experienced a significant decrease in HF-HRV during stress induction. However, there are several reasons why those with migraine may not respond identically to this stressor when compared to those who experience primary headache disorder. Individuals in this population tend to experience high levels of anxiety, depression, and other mental health comorbidities. This study population is experiencing high levels of distress, as indicated by scores on psychometric questionnaires administered at baseline (Table 2). The presence of mental health comorbidities may have changed the participant's reaction to the PST. One potential mechanism may be that those with migraine are in states of chronic cognitive stress. Further work needs to be completed to validate the PST for those with migraine to see if the presence of psychological conditions elicits a different response during the PST.

Previous research indicates that after a low-grade cognitive stressor, similar to the PST, those with migraine have lower noradrenaline levels at baseline when compared to controls, which indicates noradrenergic hypofunction (Leistad et al., 2007). Cortisol levels in migraineurs had a negative relationship with pain recovery (higher cortisol was related to lower pain recovery; Leistad et al., 2006; Leistad, Stovner Lars Jacob, et al., 2007). After exposure to a low-grade cognitive stressor, cardiovascular responses (i.e. blood pressure, heart rate) decreased in migraineurs and healthy controls. The changes in respiration and heart rate of migraineurs in this study are consistent with this literature.

Migraine assessment may have also been a factor in the physiological response of the sample in response to the experimental protocol. More than one-third (38.5%) of the MMP group were currently experiencing a migraine at the time of assessment (ictal period). Zhang and colleagues recently found that the SD of RR intervals (SDRR) was significantly lower ($p < 0.001$) during migraine ictal periods (SDRR = 56.94, SD = 22.09) when compared to the migraine interictal period (period between migraine attacks; SDRR = 115.96, SD = 46.88). SDRR changes were similar to the control group during the interictal period (Zhang et al., 2021). These differences were not significant when HF-HRV values were compared. This may suggest that those with migraine during an interictal period are autonomically similar to healthy controls (Zhang et al., 2021). Additional research needs to be completed exploring the differences in HF-

HRV during the ictal and interictal periods with migraine. This research should include stress induction to examine ANS-recovery and response to MM during ictal versus interictal periods. Future psychophysiological research measuring stress induction in this population should look at additional measures, such as measuring cortisol or blood pressure, to elucidate the relationship between low-grade cognitive stress, migraine, and TTH.

It is unknown how many individuals in this study meet the criteria for chronic migraine and how this impacts ANS functioning. There is currently limited research on the relationship between. migraine, central sensitization, and ANS dysfunction measured by HRV. It is unknown how states of chronic migraine impact HRV. Central sensitization involves a heightened response of nociceptive neurons in the CNS in response to normal afferent sensation. In the cases of migraine, this means smaller triggers of the TGVS can induce migraine (Onan et al., 2023). Future research should be done on chronic migraine, and how this increases central sensitization, and impacts HRV.

Respiration was significantly different between Baseline and Stress (Table 4a). This is in contrast to the results found by Azam and colleagues (Azam et al., 2016) which found that respiration did not significantly differ within their study. This may be due to experimental error as the authors reported respiration data could not be collected for N = 53 (66.25%) participants (Azam et al., 2016). Within current literature, the results are mixed regarding respiration and HF-HRV in migraines during rest and stress induction. Respiratory Sinus Arrhythmia (RSA) has been used as a marker of vagal function and occurs when respiration is synchronous with HRV. During similar studies analyzing ANS metrics (e.g. heart rate, blood pressure, respiration, HRV, skin conductance) in those with migraine, researchers found there was a stronger group difference in subjective measures (stress levels) than objective measures (ANS measures) when examining stress (Rauschel et al., 2015). This is consistent with the present study which found changes in subjective stress levels in both groups (Manipulation Check; Table 2), but no changes in HF-HRV (Table 4b). Respiration has a greater impact on HF-HRV values when compared to its impact RMSSD values (LaBarron et al., 2009; Rauschel et al., 2015). Significant respiration values can be a confounding variable which may reduce effect size (Koenig et al., 2015). However, it is critical these values are included in, and adjust analyses accordingly, especially when stress related changes in respiration may change HRV values and obscure their interpretations (Koenig et al., 2015). Additional research using the PST for stress induction should be completed with a larger sample size to complete analysis similar to Hernando and colleagues which proposes changing the criteria for HF-HRV, LF-HRV, and LF/HF ratio if respiratory frequency is equal to RSA for a more sensitive analysis during stress induction (Hernando et al., 2016).

Hypothesis 2: There will be a significant increase in HF-HRV in those who practice mindfulness when compared to those in the mindfulness description condition.

There was no significant difference in HF-HRV between the MMP and MMD conditions. HF-HRV was consistent across experimental condition (Table 4a). This finding is inconsistent with current literature in which MM is a well-documented tool shown to regulate HF-HRV in several populations, including primary headache disorders and migraine (Jinich-Diamant et al., 2020; Lumma et al., 2015). This may be due to several reasons. In previous research using this MMP recording conducted by Azam and colleagues (2016), individuals chose whether they wanted to keep their eyes open or closed during the recording period, however in the present study our team wanted to limit external distracting factors by having participants keep their eyes open and focused on a fixation cross during the Listening phases. Additional research should be completed to clarify whether meditation with eyes open or closed could impact HF-HRV, especially for light-sensitive populations.

The instruction to keep eyes open may have led to discomfort and increased pain in participants, which could have impacted HF-HRV. Photophobia is a significant issue for those with migraine (with and without aura), with 84.6% of migraineurs in the study population experiencing photophobia. As little as 10 – 15 minutes of light exposure can lead to the onset of migraine or headache symptoms (Artemenko et al., 2022). Those with chronic migraine may be even more susceptible to photophobia and light triggers (Friedman & De Ver Dye, 2009).

Within the study population, 85% of participants reported experiencing photophobia and phonophobia. There is a high likelihood that keeping focused on a computer monitor for 90 minutes may have counteracted any benefit of MM. Participants were also involved in a simultaneous evaluation of respiration, pupillometry and HRV. The use of various scientific equipment (respiration belt, ECG leads and eye-tracking glasses) may have further contributed to participant discomfort when asked to focus on bodily sensations. Further research needs to be completed exploring the HRV changes during MM with eyes closed versus eyes open in healthy controls and those with photophobia or light sensitivity. Additionally, participant burden and comfort for those with migraines should be considered when designing future study protocols.

There is also still much unknown about MM and Migraine. In the present study, participants received a 10-minute “dose” of MM. Participants in the MMP group did not experience a significant increase in HF-HRV compared to those in the MMD condition. This is not consistent with previous literature by Azam and colleagues (2015, 2016) that has found a 10-minute “dose” of MM sufficient to increase HF-HRV after stress induction in perfectionists and those with primary headache conditions. In the present study, this “dose” of 10-minutes of MM might not have been sufficient for those with migraine, as this study population also had high levels of phycological comorbidities, such as anxiety (Table 2). In longer trials of MM, those with migraine seem to experience much benefit. In two recent randomized controlled trials examining Mindfulness-Based Stress Reduction (MBSR) in adults with migraine, the "dose" of MM included eight weekly 2-hour sessions and a "retreat" day. Participants also practiced an average of 34 minutes (SD = 11) of MM 4 days a week. The authors utilized Quantitative Sensory Testing (QST) which utilizes various tests (e.g., heat pain thresholds with thermal probe) to examine physiological changes after exposure to MM throughout the study. Those in the MBSR course had an altered pain experience demonstrated by decreased pain sensitivity during QST, lowered frequency of migraine, improved quality of life and lower depression and anxiety scores (Wells et al., 2014, 2020, 2021). A similar protocol could be adapted using photoplethysmography (PPG) or ECG remote monitoring over 8 weeks, monitoring changes in HF-HRV with meditation and a headache diary throughout the study. Changes in HF-HRV could be observed in this design over time as the "dose" of MM increases.

Migraine is associated with psychological comorbidities, specifically anxiety and depression, which both impact ANS functioning. There is very little research on ANS dysfunction, headache conditions, and psychological conditions like depression and anxiety. Only one study sought to study HRV, migraine and anxiety. Kato completed a study dividing female students (N = 80) into four groups: migraine without aura and high anxiety (N = 19), migraine without aura and low anxiety (N = 21), migraine-free and high anxiety (N = 21), and migraine-free and low anxiety (N= 19; 2000). Participants were exposed to a cognitive and pain stressor (cold pressor). Those with anxiety had higher levels of SNS activity and reduced PSNS activity during cognitive stress and the cold pressor task (Kato, 2000). This study illustrates the need for research to examine the impact of psychological comorbidities on those with migraine, especially anxiety and depression, given the prevalence in this population (Burch et al., 2019; Buse et al., 2013; Lipton et al., 2018, 2019; Scher et al., 2005; Wang et al., 2010). Until there is further research on ANS functioning in migraine and psychological comorbidities, there is an inability to understand the way comorbid conditions impact ANS functioning. In their meta-analyses on headache and HRV, Koenig and colleagues discuss the results indicated a significant main effect of headache disorders on HF-HRV (Hedges' g = - 0.30; 95% CI [-0.69, 0.10]; Koenig, Williams, et al., 2016)). However, within this study, there was a significant risk of bias and meta-regression due to the presence of metal health comorbidities like depression and anxiety in the study population which are themselves associated with chronic reductions in HF-HRV but were not reported by study authors. In the seven studies included in this meta-analysis, five studies had a high risk of bias due to a lack of information on comorbidities, specifically anxiety and depression (Koenig, Williams, et al., 2016). In the present study, anxiety and depression are assessed using validated psychometric questionnaires and self-report. All future research in migraine should assess anxiety and depression, as these conditions are known to impact HF-HRV and are highly prevalent in this population.

Limitations and Future Research

The maintenance of the null hypothesis for this study could be due to several factors. When designing the study protocol, our team opted to accept those with mental health comorbidities. There is limited research on HF-HRV in the presence of multiple comorbidities. Mental health conditions, specifically anxiety (Gorman & Sloan, 2000) and depression (Sgoifo et al., 2015), are associated with changes to the baseline levels of HF-HRV. More research should be done to ascertain the impact of multiple mental health comorbidities on HF-HRV. The presence of other conditions that may impact HRV should be studied with a larger and more diverse sample to determine if the presence of several ANS-associated diseases is associated with decreased ANS recovery after stress. Those with migraine at assessment were also included in the study. 27% of participants reported experiencing a migraine during the laboratory assessment, which may have impacted HF-HRV and the capacity for physiological recovery after stress. More research is needed to examine whether there is a difference in response to stress and meditation during different phases of a migraine attack.

This study did not require participants to complete a headache diary to examine the frequency of migraine and whether participants experience chronic migraine. There are neurophysiological differences between those with chronic migraine and episodic migraine (Aaghaz et al., 2022). In a study comparing those with chronic migraine to those with chronic TTH, HF-HRV measures were higher in the chronic TTH group. However, this difference was not statistically significant (Aaghaz et al., 2022). Future research should explore the differences between chronic and acute headache presentation as there may be differences in HF-HRV between these two groups. Research should also examine chronicity and collect a record of participant headaches. Each type of primary headache disorder should be studied independently to create an autonomic profile of the disease due to different pathophysiology. Data should be collected both during a headache/migraine episode and after the episode to explore whether there are detectable differences in HRV.

Unfortunately, patients or People with Lived Experience (PWLE) were not engaged in the design of the study. Engaging PWLE is critical to ensure research is impactful for those living with migraine conditions. The Canadian Institutes for Health Research (CIHR) recommends PWLE be consulted at all phases of the study (2011). In the present study, PWLE should be engaged to review the content of the MMP condition, especially providing feedback on the gender of the instructor and the content of the meditation. Qualitative interviews should also be conducted with members of the MMP group on their experience during MM.

Future research should be completed to include both healthy controls and a larger, more robust, and representative sample size. As mentioned earlier, those with migraines are prone to psychological comorbidities. All participants in the present study reported anxiety, depression, and/or other psychological comorbidities. Additional research needs to be completed with those who have psychological comorbidity and migraine, compared to those who have no psychological comorbidity and migraine. Larger sample sizes will allow for comparisons in different population subgroups (e.g. migraine without aura and depression). It may also be helpful to have more prolonged exposure to MM and repeated exposure to MM in future research to examine the 'dose' of MM needed to create sustained improvements in HF-HRV.

HRV as a measurement is evolving, including the novel measure of ultra-short HF-HRV, which are measurements in 1-minute epochs instead of 5-minute epochs. This may lead to greater sensitivity in results, which is crucial during exposure to stressful conditions and MM. Further research should be completed with the use of remote monitoring. This may increase ecological validity as participants are exposed to their normal everyday stressors rather than experimentally induced stress. Wearable ECG (e.g. Apple Watch) or PPG may be a way to increase the ecological validity of future HRV research.

Future research involving headache and HRV should integrate neuroimaging (e.g. MRI) to begin to visualize the larger picture of the CNS, PNS, and headache conditions. QST should also be utilized to understand changes in nociception, HRV, and headache conditions. Iterations of this protocol should consider utilizing biological markers of stress such as neuroimaging or measuring cortisol to validate the PST stress response and MMP condition. Most importantly, research should always include PWLE in every phase of the research lifecycle. For example, had PWLE been engaged, concerns around photosensitivity may have been noticed earlier and mitigated.

6. Conclusion

In conclusion, there were no significant differences in HF-HRV between those with migraines in any phase of the study, however there were changes that indicated ANS dysfunction is present in migraine. There was also no difference in ANS stress response during cognitive stress induction. Mindfulness was not successful in increasing HF-HRV as was observed in previous research; however, this is most likely due to issues in the current experimental protocol. There are several recommendations to improve future iterations of this protocol and ANS research in those with headache conditions. There is still much unknown about the similarities and differences between chronic and episodic migraine, especially once additional comorbidities like depression and anxiety are considered. Further research in this area will contribute to understanding about the ANS, headache conditions, stress reactivity, and MM. Integrations with additional measures such as brain activity is also essential to understanding ANS dysfunction and the impact of MM on this population.

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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)

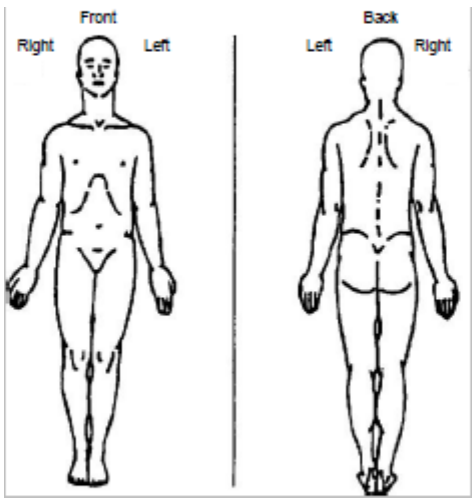
Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by that symptom during the past month, including today, by circling the number in the corresponding space in the column next to each symptom.

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

Brief Pain Inventory (BPI)

1. Throughout our lives, most of us have had pain from time to time (such as minor headaches, sprains, and toothaches). Have you had pain other than these every-day kinds of pain today?
    a. Yes
    b. No
2. On the diagram shade in the areas where you feel pain. Put an X on the area that hurts the most.



3. Please rate your pain by circling the one number that best describes your pain at its worst in the last 24 hours

0	1	2	3	4	5	6	7	8	9	10
No Pain										Pain as bad as you can imagine

4. Please rate your pain by circling the one number that best describes your pain at its least in the last 24 hours

0	1	2	3	4	5	6	7	8	9	10
No Pain										Pain as bad as you can imagine

5. Please rate your pain by circling the one number that best describes your pain on the average

0	1	2	3	4	5	6	7	8	9	10
No Pain										Pain as bad as you can imagine

6. Please rate your pain by circling the one number that tells how much pain you have right now

0	1	2	3	4	5	6	7	8	9	10
No Pain										Pain as bad as you can imagine

7. What treatments or medications are you receiving for your pain?

8. In the last 24 hours, how much relief have pain treatments or medications provided? Please circle the one percentage that shows how much relief you have received

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
No Relief										Complete Relief

9. Circle the one number that describes how, during the past 24 hours, pain has interfered with your:
   a. General Activity

0	1	2	3	4	5	6	7	8	9	10
Does not interfere										Completely Interferes

   b. Mood

0	1	2	3	4	5	6	7	8	9	10
Does not interfere										Completely Interferes

   c. Walking Ability

0	1	2	3	4	5	6	7	8	9	10
Does not interfere										Completely Interferes

d. Normal Work (includes both work outside the home and housework)

0 Does not interfere	1	2	3	4	5	6	7	8	9	10 Completely Interferes

e. Relations with other people

0 Does not interfere	1	2	3	4	5	6	7	8	9	10 Completely Interferes

f. Sleep

0 Does not interfere	1	2	3	4	5	6	7	8	9	10 Completely Interferes

g. Enjoyment of life

0 Does not interfere	1	2	3	4	5	6	7	8	9	10 Completely Interferes

h. School Work (includes both class work and homework)

0 Does not interfere	1	2	3	4	5	6	7	8	9	10 Completely Interferes

Appendix E

Center for Epidemiologic Studies Depression Scale (CES-D)

Below is a list of some of the ways you may have felt or behaved. Please indicate how often You've felt this way during the past week. Respond to all items. Place a check mark in the appropriate column.

During the Past Week…	Rarely or none of the time (less than 1 day)	Some or a little of the time (1-2 days)	Occasionally or a moderate amount of time (3-4 days)	All of the time (5-7 days)
1. I was bothered by things that usually don't bother me	☐	☐	☐	☐
2. I did not feel like eating; my appetite was poor	☐	☐	☐	☐
3. I felt that I could not shake off the blues even with help from my family	☐	☐	☐	☐
4. I felt that I was just as good as other people	☐	☐	☐	☐
5. I had trouble keeping my mind on what I was doing	☐	☐	☐	☐
6. I felt depressed	☐	☐	☐	☐
7. I felt that everything I did was an effort	☐	☐	☐	☐
8. I felt hopeful about the future	☐	☐	☐	☐
9. I thought my life had been a failure	☐	☐	☐	☐
10. I was fearful	☐	☐	☐	☐
11. My sleep was restless	☐	☐	☐	☐
12. I was happy	☐	☐	☐	☐
13. I talked less than usual	☐	☐	☐	☐
14. I felt lonely	☐	☐	☐	☐
15. People were unfriendly	☐	☐	☐	☐
16. I enjoyed life	☐	☐	☐	☐
17. I had crying spells	☐	☐	☐	☐
18. I felt sad	☐	☐	☐	☐
19. I felt that people disliked me	☐	☐	☐	☐
20. I could not "get going"	☐	☐	☐	☐

Appendix F

Headache Impact Test (HIT)

The questionnaire was designed to help you describe and communicate the way you feel and what you cannot do because of headaches.

Question	Never	Rarely	Sometimes	Very Often	Always
1. When you have headaches, how often is the pain severe?	☐	☐	☐	☐	☐
2. How often do headaches limit your ability to do usual daily activities including household work, work, school, or social activities?	☐	☐	☐	☐	☐
3. When you have a headache, how often do you wish you could lie down?	☐	☐	☐	☐	☐
4. In the past 4 weeks, how often have you felt too tired to do work or daily activities because of your headaches?	☐	☐	☐	☐	☐
5. In the past 4 weeks, how often have you felt fed up or irritated because of your headaches?	☐	☐	☐	☐	☐
6. In the past 4 weeks, how often did headaches limit your ability to concentrate on work or daily acitivites?	☐	☐	☐	☐	☐

Appendix G

International Classification of Headache Disorders 3rd Edition (ICHD-3)

1.1 Migraine without Aura

A. At least 5 attacks fulfilling criteria B – D
B. Headache attacks lasting 4 – 72 hours (when untreated or unsuccessfully treated)
C. Headache has at least two of the following four characteristics
   i. unilateral location
   ii. pulsating quality
   iii. moderate or severe pain intensity
   iv. aggravation by or causing avoidance of routine physical activity (e.g. walking or climbing stairs)
D. During headache at least one of the following:
   i. nausea and/or vomiting
   ii. photophobia and phonophobia
E. Not better accounted for by another ICHD-3 diagnosis.

1.2 Migraine with Aura

A. At least two attacks fulfilling criteria B and C
B. One or more of the following fully reversible aura symptoms:
   i. Visual
   ii. Sensory
   iii. Speech and/or language
   iv. Motor
   v. Brainstem
   vi. Retinal
C. At least three of the following six characteristics:
   i. at least one aura symptom spreads gradually over ≥ 5 minutes
   ii. two or more aura symptoms occur in succession
   iii. each individual aura symptom lasts 5 – 60 minutes
   iv. at least one aura symptom is unilateral
   v. at least one aura symptom is positive
   vi. the aura is accompanied, or followed within 60 minutes, by headache
D. Not better accounted for by another ICHD-3 diagnosis.

Appendix H

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 I

Study Consent Form

TITLE: AN EXPLORATION OF THE PHYSIOLOGICAL EFFECTS OF MINDFULNESS MEDITATION WITH THE USE OF HEART RATE VARIABILITY

PRINCIPAL INVESTIGATOR:
Vina Mohabir, BSc., MSc., (cand).

SUPERVISOR:
Dr. Paul Ritvo

You are being asked to take part in a research study. Before agreeing to take part in this study, it is important that you read and understand the following explanation of the proposed study procedures. The following information describes the purpose, procedures, potential harms/risk/discomforts, and the benefits associated with this study. It also describes your right to refuse to participate or to withdraw from any part of the study at any time.

In order to decide whether you wish to participate in this research study, you should understand enough about it to make an informed decision. This is known as the informed consent process. Please ask the researcher to explain any words you do not understand before signing this consent form. Make sure all your questions have been answered to your satisfaction before signing this document.

Purpose:
You have been asked to participate in a study designed to examine the physiological effects of mindfulness meditation. Electrocardiogram (ECG) recordings, pupillometry and respiration measurements will be taken.

Procedure:
Your participation in this study will entail a time commitment of 120 minutes. If you agree to participate in this study, you will be asked to provide your up-to-date medical history during the pre-screening. These questions will help the researcher determine if you are eligible to participate in the study. Feel free to ask the researcher to clarify the questions, if necessary.

Protocol:
If you choose to partake in this study, you will be asked to complete 8 questionnaires, complete a cognitive task, and listen to a 10-minute recording related to mindfulness meditation.

Questionnaires:
(i) Demographic & Health Questionnaire
(ii) International Classification of Headache Disorders 3rd Edition: evaluates the presence of migraines
(iii) Beck Anxiety Inventory: examines baseline anxiety levels
(iv) Center for Epidemiologic Studies Depression Scale: assesses depressive symptoms

(v) Automatic Thoughts Questionnaire: evaluates automatic negative thoughts
(vi) Perfectionism Cognitions Inventory: assess the frequency of cognitions focused on the discrepancies between one's current and ideal self.
(vii) The Pain Catastrophizing Scale: examines elements of pain catastrophizing
(viii) Headache Impact Test: provides a measure of the impact of headaches on functioning
(ix) Patient Health Questionnaire: provides a measure of overall mental health

Cognitive Task:
You will be asked to solve a pattern consisting of four alphanumeric characters presented at the top of the screen that will be followed by a 5^{th} character. You will be asked to click either "True" or "False", respectively, depending on whether or not the 5^{th} character follows the same pattern as the previous four characters. Heart rate variability and respiration measures will be taken during this task.

Listening Task:
You will be asked to sit quietly and still for 10-minutes while listening to a recording related to mindfulness meditation. Heart rate variability and respiration measures will be taken during this task.

Potential Harms, Risks or Discomforts:
Some of the questions ask about private matters such as whether or not you have been clinically diagnosed with a mental disorder or if you have any illnesses/diseases. There is no risk for undergoing ECG recordings or respiration measurements, however, some participants may feel uncomfortable performing a cognitively demanding task while attached to various pieces of equipment.

Potential Benefits:
There are no substantial benefits associated with participating in this study. We hope this investigation will lead to a better understanding of the physiological effects of mindfulness meditation.

Confidentiality:
All information obtained during the study will be held in strict confidence to the fullest extent possible by law. In no case will your personal information be shared with any individuals or groups without your expressed written consent. The experimental data acquired in this study may—in an anonymized form that cannot be connected back to you—be used for teaching purposes, be presented at meetings, published, shared with other scientific researchers or used in future studies. Your name or other identifying information will not be used in any publication or teaching materials without your specific permission. Your information provided online will be password-protected and only research staff will have access to this information. Data will be retained for five years after publication of the study results.

Participation:
Your participation in the study is voluntary; you have the right not to participate, not to answer any questions and/or to terminate participation anytime without prejudice. Your refusal to participate or your withdrawal from the study will not affect your relationship with the researcher

or with York University. If you decide to withdraw from the study and you wish us to destroy the information and data you provided, we will do so upon your request.

Questions:
If you have questions about the research in general or about your role in the study, please feel free to contact Vina Mohabir by email (vinam@yorku.ca) or Dr. Paul Ritvo by telephone at (416) 736-2100 ext. 22396 or by e-mail (pritvo@yorku.ca). This research study has been reviewed and approved by the Human Participants Review Sub-Committee (Certificate #: 2018-128), York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact Ms. Alison Collins-Mrakas, Manager, Research Ethics, Office of Research Ethics, 5th Floor, York Research Tower, York University (telephone 416-736-5914 or e-mail acollins@yorku.ca).

Legal Rights and Signatures:

I, ________________________________, consent to participate in this research study. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

____________________	____________________	____________________
Name of Participant	Signature of Participant	Date
____________________	____________________	____________________
Name of Person Obtaining Consent	Signature of Person Obtaining Consent	Date

Appendix J

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 K

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 L

Randomization Matrix

Migraine	
Participant ID	Condition
1000	MMD
1001	MMP
1002	MMD
1003	MMP
1004	MMD
1005	MMP
1006	MMD
1007	MMP
1008	MMD
1009	MMP
1010	MMD
1011	MMP
1012	MMD
1013	MMP
1014	MMD
1015	MMP
1016	MMD
1017	MMP
1018	MMD
1019	MMP
1020	MMD
1021	MMP
1022	MMD
1023	MMP
1024	MMD
1025	MMP

Appendix M

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 N

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 forwards 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 centers 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 labeled 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 centering 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 honoring 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 O

Study Debriefing Form

TITLE: AN EXPLORATION OF THE PHYSIOLOGICAL EFFECTS OF MINDFULNESS MEDITATION WITH THE USE OF HEART RATE VARIABILITY

PRINCIPAL INVESTIGATOR:
Vina Mohabir, BSc., MSc., (cand).

SUPERVISOR:
Dr. Paul Ritvo

Purpose:
Thank you for participating in our study that is examining the stress reactivity in those with migraines under conditions of stressful performance and mindfulness meditation. Here we explain what is known about stress and its effects on heart rate variability (HRV) and we explain our hypothesis. The last page contains a list of resources that will help you learn more, if interested.

Confidentiality:
You may decide that you do not want your data used in this research. If you would like your data removed from the study and permanently deleted please advise the experimenter. Whether you agree or do not agree to have your data used for this study, you can still receive URPP credit for your participation.

Also, please do not disclose research procedures and/or hypotheses to anyone who might participate in this study in the future as this could affect the results of the study.

Protocol:
The purpose of the rest task was to obtain a baseline HRV measurement.

The sole purpose of using the Pattern Solving Task (PST) was to induce stress. All patterns have been created so that they do not have a correct solution, however feedback for the task was configured using a pre-determined random order, to provide an equal number of "Right" and "Wrong" answers. Thus your results on these five tasks were not indicative of your cognitive/intellectual abilities.

The purpose of the post-stress phase was to assess your recovery from a stressful performance under one of two conditions: (1) listening to a guided mindfulness meditation or (2) listening to a description of mindfulness meditation.

Stress:

The autonomic nervous system (ANS) controls visceral functions of the body (e.g., heart activation) and the imbalance of the ANS plays a role in mental diseases. The ANS is divided into wo systems: the sympathetic ("fight or flight") and parasympathetic ("rest and digest" response) systems. The sympathetic activation of the fight or flight response is the prototypic physiological human response to stress and the parasympathetic activation is involved with recovering from stress. Stress is very common to experience throughout one's daily life, yet an excessive amount of stress can lead to conditions such as hypertension, myologic pain, hyperhidrosis and flushing.

Heart Rate Variability (HRV):

Flexible regulation of autonomic activity is essential for dealing with rapidly changing environmental demands. Autonomic regulation is related to HRV—a measure of the amount of variation in the time intervals between heartbeats. HRV measures were taken at rest, during the stress task and during one of the four post-stress conditions. Reduced HRV indicates a dysregulated system that is "locked in" to a pattern, making it more difficult to respond to physical and environmental demands. Reduced HRV has been found under conditions of worry and mental stress and is a marker for low parasympathetic activation, prefrontal hypoactivity and for disease (e.g., associated with psychosocial stress, cardiovascular morbidity and a high risk of all-cause mortality). Alternatively, increased HRV indicates that that the heart is healthy and it can oscillate spontaneously to respond to physical and environmental demands. Thus, a dysregulated "locked in" system can be distinguished from a regulated "oscillating" system based on HRV measurements.

Our hypothesis:

It is hypothesized that listening to 10-minutes of guided mindfulness meditation will increase HRV, following a stressful task. Differences between the effects of meditation on people diagnosed with migraines and migraine-free individuals will be explored.

Questions:

We hope that this was a positive experience for you and that the post-stress listening intervention helped you recovery from the stressful task. If you have questions about the research in general or about your role in the study, please feel free to contact Vina Mohabir (vinam@yorku.ca) or Dr. Paul Ritvo by telephone at (416) 736-2100 ext. 22396 or by e-mail (pritvo@yorku.ca)

Resources:

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Taylor, S. E., Klein, L. C., Lewis, B. P., Gruenewald, T. L., Gurung, R. A. R., & Updegraff, J. A. (2000). Biobehavioral responses to stress in females: Tend-and-befriend, not fight-or- flight. Psychological Review, 107(3), 411–429.

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Appendix P

Migraine Study Protocol

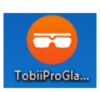
Protocol - An Exploration of Stress Reactivity and Mindfulness Meditation in Individuals with Migraine with the use of Heart Rate Variability & Pupillometry

Summary of Protocol

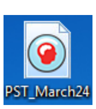
1. **Consent Form & Questionnaires – 30 minutes**
2. **ECG/Respiration Belt/Tobi Glasses Pro 2 Set-Up & Sampling – 5 minutes**
3. **Baseline (ECG/Respiration/Pupillometry) – 5 minutes**
4. **Cognitive Task: Pattern Solving Task (PST)(ECG/Respiration/Pupillometry) – 5 minutes**
5. **Post-Task Questionnaire – 5 minutes**
6. **Listening Intervention: Mindfulness Description or Mindfulness Meditation (ECG/Respiration/Pupillometry) – 10 minutes**
7. **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 Tobii Pro 2 Glasses (Refer to Setting up Tobii Glasses 2 Document):



   - Open Tobii Glasses Controller on laptop
   - Connect Tobii Glasses via Wi-Fi to the Lenevo ThinkPad Laptop
   - Press and hold the power button to turn on the recording unit
   - Go to dashboard and make sure the glasses are detected
5. Set up questionnaires
   - Open survey monkey links for: Consent Form, Questionnaire A, Questionnaire B
6. Set up cognitive task:



   - Login to computer - username: ritvolab, password: ritvolab360
   - Open the “PST Example” PowerPoint
   - Open “PST_March24”
7. 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 in questionnaire the questionnaires (ICHD-3, Demographic & Health Questionnaires)
3) Score the ICHD-3 to verify they experience migraines (with or without aura). Then randomize them into the description or experimental conditions.

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 (under their shirt) below their rib cage, with the black strap facing the front of the diaphragm.
- "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), pupillometry and respiration data for 5 minutes while you are resting, while you complete a cognitive task (PST) that measures your intelligence, and while you listen to a 10 minute audio

2. Prepare the electrodes:
    - Location: box under 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

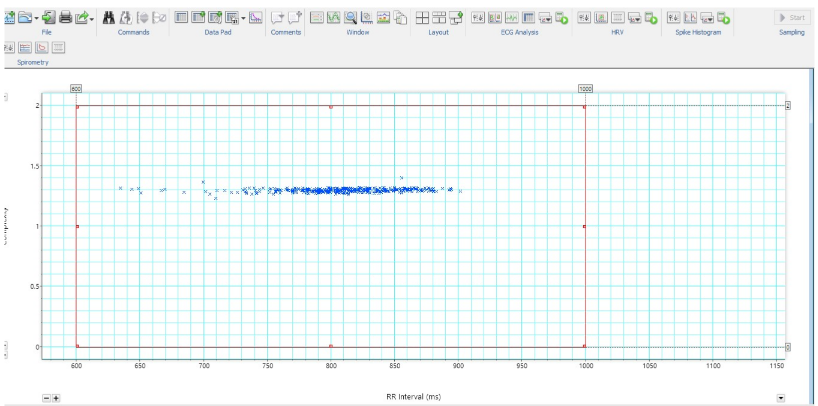
3. Explain where the electrodes go:
    - "The negative (white) electrode must be placed on the inside of your right wrist"
    - "The positive (red) electrode must be placed on the inside of your left wrist"
    - "The ground (black) electrode must be placed on the left ankle (inside facing, tibia)"

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

Pupillometry

1. Go to dashboard on the Tobii Controller Software and make sure the glasses are detected. Look at memory and battery life to make sure they are not low.
2. Click on start new recording. Create a new participant and enter their Participant ID
3. Calibrate the glasses using the Paradigm file named "Fixation" and press the green play button 
4. Enter in participant ID > Press Continue
5. The calibration photo is at the beginning of" paradigm file. Participants should be 0.75 m away from the screen
   - Make sure the gaze data lines up with the screen
   - Click calibrate when you are happy

6. Click record when you are ready. When you are done click the stop button. Make sure the file is saved.
   - You will need to make 3 recordings – baseline, PST and listening

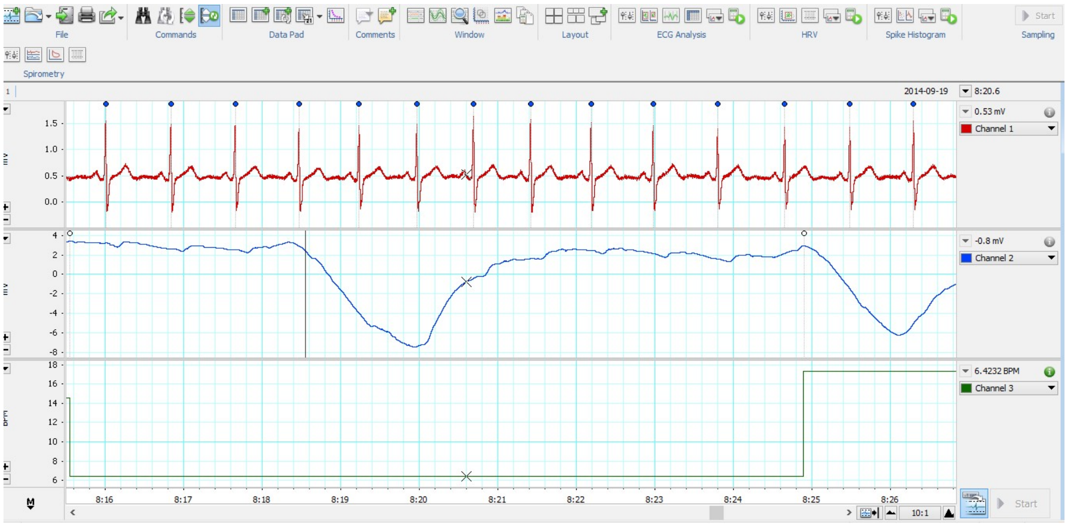


Sampling

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 3 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)
   - Select the beat classifier (under the HRV section) to determine whether heartbeats are falling out of normal ranges (600 ms – 1000 ms), and proceed with discretion as in the beginning the participant's heart rate may simply be high. (There is no need to alert the participant that their heartbeats are 'irregular' or 'not normal').

   - Go back to chart view. 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.

Experimentation

Baseline – 5 minutes

1. "We are ready to begin the experiment. Please turn off your phone or any other distractions. For the next 5 minutes, I need you to remain seated on your chair, and rest with your eyes fixated on the screen while thinking freely. Please do not make any sudden movements or speak during the 5 minutes."
2. Before beginning measure the illumination in the room (in lux using the luxmeter)
3. Press enter on the keyboard and the Paradigm file "Fixation" should go to the next item which is a fixation cross.
   - Enter in participant ID > Press Continue
4. On the Tobii Glasses controller software, press record when you are ready.
5. Press 'Start' on LabChart and allow the recording to continue until 5 minutes, it will be automated to stop at 5 minutes. Press stop recording in the Tobii Glasses controller software.
6. Save the LabChart file as PARTICIPANT#_BL_DATE

Pattern Solving Task (PST) – 5 minutes

1. Open the paradigm file "PST_Mar24" on the desktop computer.
   - The "Pattern Solving Task" paradigm file should be open
2. Open up PowerPoint with PST instructions

- Read the instructions and give them a practice round
- "You need to solve a pattern consisting of 4 alphanumeric characters presented at the top of the screen for 8 seconds. After 8 seconds, a 5th character will be shown and the words "True or False" will appear in the middle of the screen. Press "T" (True) if you believe the 5th character follows the "correct" pattern or "F" (False) if it does not. Immediately after the response, you will receive feedback about whether your answer was right or wrong. A number indicating total "Correct" and "Incorrect" answers (up to the current trial) will remain on the screen also in the bottom right and bottom left areas (corresponding to where the "Right Answer" and "Wrong Answer" feedback appears) throughout the duration of the task
- "If you saw the number sequence "2, 4, 8, 16" and then "32" appeared, would you have pressed "T" or "F"? (Answer: T – true)
- Do you have any questions?

3. Open the "PST" file in LabChart on the laptop
4. In Paradigm, click the green play button 
    - Enter in participant ID > Press Continue
5. Before beginning measure the illumination in the room (in lux using the luxmeter)
6. Read the following instructions to the participant: "You are now going to be completing a cognitive task. This task will measure your intelligence. It is important that you complete this task to the best of your ability. I will be measuring your heart rate variability, breathing, and pupillometry while you complete this task. I will remain in the room while you complete this task."
7. "This task will measure your capacity for cognitive processing which is related to intelligence. The average score on this task is 80-85% correct answers with response time of less than 2 seconds. This is the required minimum performance and your individual performance must be close to or equal the average performance of all subjects, therefore please respond as quickly but as accurately as possible! Also, please do not move or speak during this task. Do you have any questions?"
8. Let them read over the instructions one more time. When they begin press start in LabChart and record in the Tobii Glasses Controller software
9. After the experiment, save the data as PARTICIPANT#_PST_DATE
10. Complete Post PST Questionnaire

Listening Intervention: Meditation or Control (ECG) – 10 minutes

1. Open Lab Chart
    - In the 'Welcome Center' open the "Mindfulness Description" OR "Mindfulness Meditation" system file.
2. Open the Paradigm file "Fixation 2" and press the green play button
    - Enter in participant ID > Press Continue
3. Before beginning measure the illumination in the room (in lux using the luxmeter)
4. On the Tobii Glasses controller software press record and press start on LabChart after you have read the instructions.

Mindfulness Meditation Group:

- "You will now be listening to a guided mindfulness meditation audio recording. This audio will be about 10 minutes long. Please wait for the bell to ring 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 open and fixated on the cross</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 of your breath. 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 if you feel like you need to do so. Then when you are ready, please open your eyes. Do you have any questions?"
- Save file as: PARTICIPANT#_MME_DATE

Control Group:

- "You will now be listening to a description of mindfulness meditation. This audio recording will be 10 minutes long. Please wait for the bell to ring 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 open and fixated on the cross</u> during the entire listening period"
- Step 2. Centering 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 if you feel like you need to do so. Then when you are ready, please open your eyes. Do you have any questions?"
- Save file as: PARTICIPANT#_MMD_DATE

<u>Debrief – 5 minutes</u>

1. Ask participants their impressions of the study: "How did you find the study?"
2. Go over the debriefing form with the participants. Answer any questions they may have.
3. Ask participants to remove electrodes, respiration belt and tobii glasses