Examining the Neuropsychological Role and Malleability of Trait Mindfulness in the Context of Physical Activity and Ecological Momentary Assessment in Older Adults

by

Frederic Taylor Agate
M.Sc., Drexel University, 2016
B.Sc., College of William and Mary, 2012

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We acknowledge and respect the Lək̓ʷəŋən (Songhees and Esquimalt) Peoples on whose territory the university stands, and the Lək̓ʷəŋən and W̱SÁNEĆ Peoples whose historical relationships with the land continue to this day.

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Abstract

Mindfulness practice has shown to benefit health, mood, and cognition in individuals across the lifespan. Trait mindfulness, the degree to which a person is mindful, is a relevant factor when examining the health and neuropsychological benefits of physical activity and exercise, such that it may play moderating and/or mediating roles. Ecological momentary assessment (EMA) may be more sensitive in assessing psychological functioning associated with trait mindfulness compared to traditional measures. Trait mindfulness may, in fact, be impacted by EMA. However, less is known about the interactions of trait mindfulness, physical activity and EMA in older adults. This doctoral dissertation examined the neuropsychological role and malleability of trait mindfulness in the context of physical activity and EMA, in a sample of healthy older adults. Chapter 2 investigated the malleability of trait mindfulness in response to physical activity, and what role this may play in the relationship between physical activity and neuropsychological outcomes. Chapter 3 examined the extent to which engagement in EMA may alter trait mindfulness and how this may indirectly impact neuropsychological functioning (i.e., through mediation), as well as the sensitivity of EMA. Chapter 2 results showed that older adults who underwent an 8-week remote physical exercise training program did not make more gains in trait mindfulness than the control group. Reported physical activity did not predict gains in trait mindfulness, which did not moderate or mediate the relationship between physical activity and neuropsychological outcomes. Trait mindfulness did not predict adherence to the exercise program. According to Chapter 3 results, EMA adherence did not predict changes in trait mindfulness. EMA-measured mood also did not correlate more strongly with trait mindfulness compared to mood measured with traditional questionnaires, but gains in trait mindfulness were associated with greater EMA-measured anxiety and lower traditionally measured anxiety. Higher trait mindfulness was also associated with less variability of EMA-measured anxiety symptoms. Lastly, trait mindfulness did not mediate the relationship between EMA adherence and neuropsychological outcomes, though gains in trait mindfulness were associated with improved cognitive test performance in some areas. Results suggest that in healthy older adults, trait mindfulness may not be malleable in response to physical activity and EMA. Trait mindfulness also may not play a significant role in neuropsychological outcomes relating to physical activity and EMA. However, relationships exist that suggest a role for trait mindfulness in emotion awareness and stability as well as aspects of improved cognitive performance.

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CHAPTER I

General Introduction

In this chapter, I will first discuss mindfulness, including its background, characteristics and practice, as well as its effects on outcomes across the lifespan. I will then introduce trait mindfulness and how it has been measured in the literature. I aim to explore the relationship between mindfulness and physical activity, particularly trait mindfulness, by reviewing existing literature on their associations and proposed shared mechanisms. Lastly, I discuss EMA, its use in psychology research, including mindfulness research, and its association with trait mindfulness.

I. Mindfulness—An Overview

A Brief History of Mindfulness

Mindfulness is the practice of paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally (Kabat-Zinn, 2009). Originating from Buddhism and approximately 2500 years ago, mindfulness has served as a significant component of Buddhist meditation training (Shonin et al., 2015). In Buddhist practice, mindfulness has served as one of the ten factors in an integrated journey involving ethical, meditative, intellectual and wisdom training (Kang & Whittingham, 2010). Interwoven with ethics, which is described as the *intention* to "guard" against unwholesome states of mind, mindfulness functions as a way to *remember* what it is that needs to be guarded and acts as a gatekeeper to prevent such states of mind and consequent suffering (Kang & Whittingham, 2010; Tsering, 2004). In Western health care, mindfulness has been used therapeutically since the 1960s and currently has influences in several therapies within clinical psychology, including Mindfulness-based Stress Reduction, Mindfulness-based Cognitive Therapy, Dialectical Behaviour Therapy and Acceptance and Commitment Therapy (Kostanski & Hassed, 2008).

Principles and Practices of Mindfulness

As Tang (2017) explains, mindfulness contrasts with states of “mind-fulness” and “mindlessness”, which refer to the degree of conscious information processing occurring in the mind at a given time. Rather than being a concept or theory, mindfulness is an experience. Mindfulness can increase overall insight by reorganizing information processing in the brain and allowing an individual to focus their attention and control their actions (Tang, 2017). Instead of automatically experiencing a biased perception of something sensed in the environment—driven by preconceived judgments, ideas or schemas—mindfulness allows an individual to experience clarity that fosters more flexible, and objectively informed, psychological and behavioural responses (Brown et al., 2007).

In their review, Brown and colleagues (2007) propose that the main pillars of mindfulness are awareness and attention. Mindfulness provides a clear awareness of one’s experience of what is happening externally and internally (e.g., thoughts, emotions, sensations). As they allude to, being mindful is like looking into a well-polished mirror that reflects exactly what is passing before it, pure and unobscured. Mindfulness also allows for inputs of experience to enter awareness without becoming entangled in rumination, categorization, or other habitual thought patterns—instead, experiences are simply noted for what is taking place (Brown et al., 2007). In addition to promoting clear awareness, mindfulness allows for focused attention to situational details. Specifically, attention is directed towards the objective qualities or characteristics of what is being observed, allowing an individual to be present in the moment. It is worth mentioning that some believe “nonjudgment” to be a third, independent principle of mindfulness (e.g., Hayes & Feldman, 2004). However, others argue that in its purest form, awareness encompasses nonjudgment and is not distinct from it; in other words, a person having complete awareness of their experience means that they are not judging their experience, but simply observing it (Kabat-Zinn, 2003).

A common practice of mindfulness is mindfulness-based stress reduction (MBSR). Developed by Jon Kabat-Zinn at the University of Massachusetts Medical Center in 1979, MBSR is a type of mindfulness-based intervention (MBI) that is aimed at improving awareness and acceptance of one's difficulties, and in doing so, alleviating suffering (Rosenbaum, 2017). Combining Buddhist meditative traditions with science, Kabat-Zinn describes the intention of MBSR as re-contextualizing the Buddhist fundamental principle of *dharma* within the framework of science, medicine and healthcare (Kabat-Zinn, 2011). In practice, an MBSR program typically follows a group format, in which participants undergo mindfulness practices involving body scans, sitting meditation, and yoga (Link et al., 2016). MBSR programs are usually eight weeks long, and participants typically meet with an instructor for only a few hours a week, with the rest of the time devoted to individual practice, or "homework." The effectiveness of MBSR, or the degree to which one is mindful, is highly dependent on daily practice, strong effort, and kindness towards oneself (Rosenbaum, 2017).

Another popular practice of mindfulness is mindfulness-based cognitive therapy (MBCT). Initially developed to prevent relapse of depression, MBCT works to target cognitive reactivation of negative modes of thinking and feeling (Segal et al., 2018). Like MBSR, MBCT programs are typically eight weeks in duration, and they involve core mindfulness techniques such as body scans, mindful movement, and attention to breathing (Kuyken et al., 2010). Sessions promote attention, awareness and self-compassion toward distressing thoughts and feelings, teaching individuals to identify habitual patterns of reactivity and develop a nonjudgmental view of them. In addition to incorporating mindfulness, MBCT also includes aspects of cognitive therapy and psychoeducation (Sipe & Eisendrath, 2012). Specifically, individuals learn about the risks of avoiding or resisting unwanted thoughts or feelings, as well as how to develop a plan of action for when early signs of such thoughts and feelings are identified. However, unlike traditional cognitive therapy approaches, MBCT does not place emphasis on trying to change thinking patterns—instead, the goal is to realize that thoughts are momentary mental events and not direct representations of one's identity or reflections of truth (Teasdale et al., 2002).

In addition to MBSR and MBCT, there is a variety of other MBIs that are used in research. Mostly variations of MBSR or MBCT, such MBIs may include practice of only some elements of mindfulness (e.g., focused attention meditation) or are infused with other types of training (e.g., Mindfulness-based mind fitness training), and there is significant heterogeneity in duration across practices, with no observed significant effect of duration on outcome (Im et al., 2021).

II. Outcomes of Mindfulness across the Lifespan

There is an abundance of literature on beneficial outcomes of mindfulness for adults, but less is known as it pertains to children and adolescents, as well as older adults. A 2019 review by Semple and Burke, for example, found that although such research for youth has accelerated in recent years, there are varying methodological approaches and limitations among studies, the extent of which makes it difficult to draw overarching conclusions about the effectiveness of MBIs. That said, this section will briefly highlight what empirical evidence exists for outcomes of mindfulness across the lifespan.

Mental Health

The mental health of children and adolescents has been shown to benefit from mindfulness practice. A 2019 meta-analysis by Dunning and colleagues found that across randomized control trials (RCTs), MBIs significantly and positively affected depression and anxiety/stress. The effect sizes for depression were medium (d = .47), while MBIs' effects for anxiety/stress were small (d = .18). An RCT by Vohra et al. (2019) used teacher ratings of adolescents to examine the effects of MBSR compared to usual care, and revealed significant improvement for internalizing problems (e.g., depression, anxiety, and somatization) and adaptive skills (e.g., adaptability, social skills) following an 8-session program. A more recent RCT that compared an MBI to a relaxation program in adolescents aged 12-15 years found greater improvement in resiliency after mindfulness (Volanen et al., 2020). Further, improvements in socio-emotional functioning and depression were seen in girls but not boys. The authors attribute this difference to lower baseline depressive symptoms in boys, and a consequent statistical "floor effect" for that gender in their sample. Overall, empirical evidence primarily supports the effectiveness of mindfulness to reduce depression and anxiety in youth, while promoting resiliency.

In adults, there is robust evidence to support the use of mindfulness interventions to treat mental health. For instance, a meta-analysis by McClintock and colleagues (2019) examining the efficacy of mindfulness retreats for non-clinical adults revealed large pre-post effects for stress, medium effects for anxiety, and small effects for depression and well-being. Clinical populations, in particular, benefit from mindfulness. For example, in their meta-analysis, Hilton et al. (2017) revealed evidence for those who experience chronic pain, with mindfulness meditation significantly improving depression symptoms and quality of life. For adults with anxiety and stress-related disorders, MBIs have demonstrated effectiveness in reducing internalizing symptoms (e.g., anxiety, stress and depression) and distress (de Abreu Costa et al., 2019). Similarly, adults with major depression have shown to benefit from MBCT in particular, with significantly decreased depression compared to those in control conditions, as demonstrated in a 2021 meta-analysis by Seshadri and colleagues.

Older adults undergoing mindfulness have also exhibited improvements in their mental health. Regarding depression specifically, mindfulness meditation has shown to significantly improve depressive symptoms, with medium effects (Reangsing et al., 2021). Interestingly, Reangsing and colleagues (2021) compared the effectiveness of MBSR versus MBCT and there was no difference in efficacy for treating depression. In their systematic review and meta-analysis, Li and Bressington (2019) examined the effects of MBSR in particular on internalizing symptoms in older adults. Although only six RCTs met their inclusion criteria, and still had methodological issues, there was evidence for large effects of MBSR on depression in older adults; however, no pooled significant effect was found for stress or anxiety. In contrast, there is more robust evidence that third wave Cognitive Behavioral Therapy (CBT) approaches with a mindfulness influence (e.g., MBCT, Dialectical Behaviour Therapy, and Acceptance and Commitment Therapy) have moderate effects for both depression and anxiety in older adults (Kishita et al., 2017). It is thus possible that the CBT-related components of third wave is more effective than mindfulness in treating stress and anxiety in older adults; however, more research is needed.

Cognition

In children and adolescents, research on the benefits of mindfulness for cognition has primarily focused on executive functioning (EF) outcomes, and evidence is mixed. For example, Dunning et al.'s (2019) meta-analysis found significant but small effects of MBIs on EF in children and adolescents across RCTs; however, when only including RCTs with an active control group (e.g., participants who undergo a non-mindfulness related intervention), there were no significant effects found on EF. They did find that age was a significant moderator for improvements in EF following MBIs, with larger effects for those of older age (e.g., 14-18 years old), perhaps due to heightened brain plasticity during this time in development (Giedd, 2008). However, small to medium effects of mindfulness interventions have been found in children as young as preschool-age, particularly for working memory (Wood et al., 2018). Of note, Dunning and colleagues (1019) do not detail the exact measures or components of EF that were examined in the studies they assessed. However, one of the studies included in the meta-analysis examined the effects of a brief, 4-week MBSR program on working memory in adolescents, using a computerized task, the Automated Operational Span Task (Quach et al., 2016). Those who underwent mindfulness training showed significant improvements in working memory capacity, while those in comparison groups, hatha yoga and waitlist control groups, did not.

In adults, the effects of mindfulness on cognition also vary. A recent meta-analysis by Im and colleagues (2021) included 25 controlled studies (76% RCTs) that employed MBIs, and examined outcomes of attention, working memory, long-term memory, and EF. Of note, EF tasks measured conflict monitoring, inhibitory control, and cognitive flexibility (i.e., shifting). Results showed that compared to control conditions, MBIs only produced significant effects for EF, and that these effects were small. However, studies that used MBSR or MBCT produced larger effects on attention and EF compared to those that used other MBIs (e.g., ADHD-focused mindful awareness practices, combined breathing and mindfulness mediation technique) perhaps due to typically greater duration of intervention and adherence (Im et al., 2021). Further, although the authors do not note this, one included study appeared to skew and significantly pull down the effects of MBIs on working memory. This study, conducted by Manglani and colleagues (2020), used an abbreviated, 4-week MBSR program, so the full potential effects of MBSR on working memory may not have been captured. Regarding memory, there is some evidence that mindfulness may improve encoding, but not consolidation or retrieval (Lueke & Lueke, 2019). Further, research has demonstrated enhanced processing speed following even brief mindfulness training (Manglani et al., 2020; Zeidan et al., 2010).

Studies using mindfulness training in older adults, although limited in number, have generally found positive effects on cognition in both healthy and cognitively declining individuals. Hazlett-Stevens and colleagues (2019) examined seven RCTs that used either MBSR or MBCT, and found evidence for MBSR improving certain areas of memory performance and EF in older adults with subjective cognitive decline (SCD). However, measures of EF appear limited to inhibitory control and verbal fluency. For older adults with mild cognitive impairment (MCI), recent research has found benefits of mindfulness for working memory capacity and divided attention (Yu et al., 2021). Although less is known about the effects of mindfulness in healthy older adults, mindfulness training has been shown to improve attentional performance after eight weeks (Isbel et al., 2020), but not after an abbreviated, 4-week program (Whitmoyer et al., 2020). A 2019 meta-analysis by Chan and colleagues examined the effects of traditional meditation (i.e., not MBSR, MBCT or other MBI) in healthy older adults and found widespread benefits on cognition, including attention, global cognition, and working memory.

Physical Health

Although research is limited, mindfulness has been demonstrated to have positive effects on physical health outcomes in children and adolescents. A systematic review by Abujaradeh and colleagues (2018) examined 19 studies in which MBIs were implemented in adolescents with chronic diseases. They found evidence of MBIs decreasing physiological stress (i.e., measured by cortisol levels) along with pain. The authors noted that none of the studies that were reviewed included physiological outcomes such as blood pressure, heart rate, or blood sugar level (for those with diabetes), indicating a need for more research measuring such outcomes. However, a more recent systematic review and meta-analysis by Strehli et al. (2021) examined the effectiveness of mind-body physical activity interventions in improving stress-related physiological outcomes in children and adolescents. Although the vast majority of interventions from the included nine studies were yoga-based, moderate pooled effects were observed in children (ages 6-12) for lowering heart rate.

In adults, mindfulness may also lead to improved outcomes of physical health. In particular, there is robust evidence that chronic pain may lessen with mindfulness training (Creswell et al., 2019). In their review of RCTs, Creswell and colleagues (2019) found evidence for 8-week MBIs significant improving pain management in several populations, such as those with chronic lower back pain, chronic pain patients misusing opioids, and people who have rheumatoid arthritis or fibromyalgia. In fact, MBSR was initially developed to treat chronic pain (Kabat-Zinn, 1982), so the robustness of support is not surprising. Although less is known about long-term/sustained effects of MBIs on chronic pain management, a 2020 pilot study by Cayoun and colleagues found that following a MBI involving interoceptive exposure for chronic pain patients, decreases in pain duration and intensity were maintained, or even improved, at 2-month follow-up. In addition to chronic pain, Creswell et al. (2019) found evidence for other MBI health benefits for stress-related conditions, such as decreasing irritable bowel syndrome symptomology and accelerating treatment-related skin clearing in psoriasis patients. Further, MBIs have shown promise in improving physiological outcomes for adults with cardiovascular disease, such as reduction in systolic blood pressure relative to controls (Scott-Sheldon et al., 2020).

For older adults, several aspects of physical health appear to benefit from mindfulness. For example, Hazlett-Stevens and colleagues' 2019 review found strong evidence supporting the use of MBSR to treat chronic insomnia in older adults, as research has shown it can reduce self-reported insomnia symptoms. Similar to youth and adults, older adults have also had improvements in pain management, such as reduced chronic lower back pain and greater acceptance of pain following MBSR (Hazlett-Stevens et al., 2019). Regarding other health outcomes, there is some evidence that MBSR can lower blood pressure in older adults, though with a small effect (Geiger et al., 2016). Additionally, a recent study by Lindsay and colleagues (2021) examined a biomarker for inflammation associated with social stress and withdrawal, glucocorticoid resistance, in older adults who underwent MBSR. They found that MBSR buffered against increases in glucocorticoid resistance, thereby, in theory, reducing risk for chronic inflammatory disease.

III. Trait Mindfulness

Trait mindfulness, also known as dispositional mindfulness, offers another avenue to explore the effects of mindfulness. Simply put, trait mindfulness refers to an individual's general level of mindfulness across situations and time (Sala et al., 2020). In addition to increasing as a result of mindfulness training, trait mindfulness at baseline has shown to moderate the effects of mindfulness training (Shapiro et al., 2011). In contrast to trait mindfulness, state mindfulness is the extent to which an individual experiences mindfulness in a given moment. Both trait and state mindfulness represent ways in which mindfulness can be measured in a person, and not surprisingly, they are highly correlated with one another. For instance, changes in state mindfulness across the duration of an MBI have shown to predict pre-post changes in trait mindfulness (Kiken et al., 2015). However, much more research has studied and measured trait mindfulness compared to state, and in the context of mental health, cognition, and physical health.

Associations of Trait Mindfulness with Mental Health, Cognition and Physical Health

Several studies have found associations between trait mindfulness and mental health. For example, a 2017 meta-analysis by Mesmer-Magnus and colleagues revealed correlates of trait mindfulness with several aspects of mental health, finding moderate effects on negative emotions such as perceived life stress, anxiety and depression, as well as positive emotions like confidence, emotion regulation, and life satisfaction. Moreover, in their systematic review, Tomlinson et al. (2018) identified that trait mindfulness may specifically be linked to adaptive coping processes such as decreased rumination and pain catastrophizing. In students, there is evidence of awareness, a key component of trait mindfulness, as a predictor for anxiety and stress (Medvedev et al., 2018). Regarding mental health concerns relating to the COVID-19 pandemic, higher trait mindfulness has recently shown to be a potential protective factor, as it is associated with lower pandemic stress, anxiety and depression, and more positive coping strategies (Dillard & Meier, 2021).

Trait mindfulness is also correlated with many aspects of cognition. One particular area of cognition that has been studied along with trait mindfulness is EF. For instance, inhibitory control and working memory have been found to have positive correlations with trait mindfulness (Jaiswal et al., 2018; Riggs et al., 2015). Of note, there is evidence that EF may mediate the relationship between trait mindfulness and negative affect, with awareness and nonjudgment being most strongly related to EF (Short et al., 2016). A recent study by Molina-Rodríguez and colleagues (2021) investigated which areas of cognition account for the most variability in trait mindfulness, by administering a battery of cognitive tasks to 90 undergraduates, who also completed a trait mindfulness questionnaire. Results showed that EFs of inhibition and cognitive flexibility were most highly correlated with trait mindfulness, followed by processing speed and abstract reasoning.

In addition to mental health and cognitive outcomes, trait mindfulness is associated with several aspects of physical health. Specifically, trait mindfulness has been linked to positive cardiovascular health, including blood pressure and heart rate variability (Kimmes et al., 2018; Loucks et al., 2015; Lucas-Thompson et al., 2019). There is evidence that increased awareness, in particular, relates to lower diastolic blood pressure when nonjudgment is also high (Ede et al., 2020). There is also robust evidence showing a link between higher trait mindfulness and lower chronic pain (e.g., Petter et al., 2013), and interestingly, higher trait mindfulness has recently been associated with less severe physical discomforts (e.g., morning sickness, abdominal pain, etc.) during pregnancy (Mennitto et al., 2021). A 2020 meta-analysis by Sala and colleagues examined evidence linking trait mindfulness and health behaviours, and found generally positive, but small, associations between both. Specifically, mindfulness positively correlated with healthy eating and sleep, and negatively correlated with alcohol use, and effects were larger for health promoting behaviours than health risk behaviours. An even more nuanced examination revealed several moderating effects, including mindfulness facets and mindfulness measures. For example, awareness had the strongest and most consistent effect on health behaviours as a whole. Commensurately, trait mindfulness's association with health behaviours was strongest when mindfulness measures that robustly assessed for awareness were used.

Measurement of Trait Mindfulness

To date, measurement of trait mindfulness is primarily conducted through self-report questionnaires. Having surged since the beginning of this millennium, the development of such measures has yielded eight commonly used scales that vary from one another in dimensionality/factor structure and length (see Table 1.1). For example, the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006) consists of—as the name implies—five factors, while the Philadelphia Mindfulness Scale (PHLMS; Cardaciotto et al., 2008) is two-factored and the Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) is unidimensional. The Cognitive and Affective Mindfulness Scale—Revised (CAMS-R; Feldman et al., 2007) is the shortest measure, with 12 items, while the FFMQ and Kentucky Inventory of Mindfulness Skills (KIMS; Baer et al., 2004) are the longest, each with 39 items.

Table 1.1. Self-report Measures of Trait Mindfulness

Scale			Items	Factor Structure
CAMS-R	Cognitive and Affective Mindfulness Scale—Revised	Feldman et al. (2007)	12	(4) Acceptance, Attention, Awareness, Present focus
FFMQ	Five Facet Mindfulness Questionnaire	Baer et al. (2006)	39	(5) Accept/nonjudge, Act with awareness, Describe, Nonreactivity, Observe
FMI	Freiburg Mindfulness Inventory – 14-item	Walach et al. (2006)	14	(2) Acceptance, Presence
KIMS	Kentucky Inventory of Mindfulness Skills	Baer et al. (2004)	39	(4) Accept/nonjudge, Act with awareness, Describe, Observe
PHLMS	Philadelphia Mindfulness Scale	Cardaciotto et al. (2008)	20	(2) Acceptance, Awareness
MAAS	Mindful Attention Awareness Scale	Brown & Ryan (2003)	15	(1) Attention/Awareness
SMQ	Southampton Mindfulness Questionnaire	Chadwick et al. (2008)	16	(4) Letting go, Nonaversion, Nonjudgment, Observation
TMS-Trait	Toronto Mindfulness Scale – Trait Version	Davis et al. (2009)	13	(2) Curiosity, Decentering

Adapted from Rau & Williams (2016)

With variability in length and dimensionality among measures of trait mindfulness, comes differences in the extent to which facets of mindfulness are measured. An extensive, multidimensional scale like the FFMQ offers the range to examine the effects of trait mindfulness in a well-rounded fashion, using a facet-level approach. However, such multifaceted measures support a multidimensional construct of mindfulness, in which each component is relatively independent from one another. Further, there is less robustness for each individual facet being measured compared to a scale that emphasizes one or two facets. This may be particularly problematic when there is empirical evidence supporting the relative strength of one or two facets in regard to association with outcomes. For example, as previously mentioned, health behaviors have been found to be more strongly linked with awareness than other facets (Sala et al., 2020). This fits with theoretical conceptualizations that propose a more unidimensional characteristic of mindfulness (e.g., Brown et al., 2007; Kabat-Zinn, 2003). One such measure that robustly assesses awareness is the MAAS.

The MAAS was developed by Brown and Ryan (2003) to measure mindfulness and its role in psychological well-being. It consists of 15 items that are rated on a 6-point Likert scale. Specifically, each item is a statement of which the individual rates the frequency, from “Almost Always” to “Almost Never.” Interestingly, the items themselves actually reflect mindlessness (e.g., “I find myself doing things without paying attention”), as the authors determined that such statements were more easily accessible given evidence that mindless states are more common than mindful states. As previously mentioned, the factor structure of the MAAS is unidimensional, which was initially revealed through exploratory factor analysis and subsequently through confirmatory factory analysis in different samples.

Initially developed using non-clinical undergraduate students and adults from North America, the MAAS has since been validated for use in several cultural populations (e.g., Barros et al., 2015; Deng et al., 2012). Of note, although it has been validated in clinical populations (e.g., Carlson & Brown, 2005), the MAAS has primarily been used in research with nonclinical samples (Mesmer-Magnus et al., 2017). However, it has been the most commonly used measure in studies of mindfulness with nonclinical samples (Mesmer-Magnus et al., 2017), and in intervention studies, mindfulness training has indeed been found to positively correlate with scores on the MAAS (Quaglia et al., 2016). In terms of reliability, the MAAS has high test-retest reliability as well as internal consistency, as demonstrated at its inception and again more recently (Osman et al., 2016). In addition to being used to investigate relationships between trait mindfulness and outcomes of mood and cognition, the MAAS has been found to be a particularly strong measure when examining outcomes of health behaviors (Sala et al., 2020). Further, it is the most commonly used measure of trait mindfulness in research assessing the correlates of trait mindfulness with physical activity and exercise (Yang & Conroy, 2020).

IV. Mindfulness and Physical Activity

Behavioral Correlates

Behaviorally, studies have examined trait mindfulness and its relationship with physical activity, finding significant associations. For example, a particular health behaviour assessed by Sala and colleagues in their 2020 meta-analysis was physical activity, which they found was positively associated with trait mindfulness. Interestingly, gender was found to moderate this relationship, in which the relationship between trait mindfulness and physical activity was attenuated when there was a higher percentage of men in a sample. Moreover, associations between trait mindfulness and physical activity were greater when physical activity was assessed through self-report questionnaires compared to objective measures. Although this may be partially due to shared method variance, objective measures in previous studies often do not measure physical exercise *habits* over time, while questionnaires do (Sala et al., 2020). Commonly used questionnaires include the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003), Godin Leisure-Time Exercise Questionnaire (GLTEQ; Godin & Shephard, 1985), and the Physical Activity, Exercise, and Sport Questionnaire (Fuchs et al., 2015), as determined by a separate systematic review (Yang & Conroy, 2020).

Sala et al. (2020) detail many proposed reasons for the association between trait mindfulness and physical activity. First, due to the strong correlation of trait mindfulness with state mindfulness, those who have high trait mindfulness may be more likely to experience greater state mindfulness while participating in physical activity; this may in turn lead to higher satisfaction and reinforce participation in physical activity. This fits with evidence suggesting that satisfaction may mediate the effect of state mindfulness on physical activity (Tsafou et al., 2016; Tsafou et al., 2017).

Another explanation for the relationship between physical activity and trait mindfulness is that participation in physical activity may lead to increased trait mindfulness (Sala et al., 2020). Support for this effect has been seen in RCTs (de Bruin et al., 2016; Mothes et al., 2014). For example, a study by Mothes et al. (2014) revealed significant changes in trait mindfulness that occurred over the course of a 12-week program of aerobic exercise in healthy men, in contrast to a relaxation training program that was not associated with significant changes. An RCT by de Bruin and colleagues (2016) also found significant increases in trait mindfulness in young adults following a 5-week physical exercise program, and this change was comparable to that observed following a 5-week mindfulness meditation training program in a different group.

A proposed explanation for this directional relationship is that bouts of physical activity/exercise enhance acute awareness of body sensations (e.g., breathing, muscle tension), as well as internal affective state, thereby increasing one's state mindfulness and, over time, their trait mindfulness (Demarzo et al., 2014). As previously mentioned, changes in state mindfulness across the duration of mindfulness training has coincided with increases in trait mindfulness (Kiken et al., 2015), so such a mechanism is plausible.

Lastly, trait mindfulness may serve a moderating role in the relationship between motivation to engage in physical activity and actually participating in physical activity, thereby promoting adherence (Sala et al., 2020). Research by Ruffault et al. (2016) supports this hypothesis, finding evidence that the correlation between intrinsic motivation and self-reported physical activity level is strongest in those with higher trait mindfulness, and weakest in those with lower trait mindfulness. With increased awareness and self-regulation, an individual may be better able to translate their motivated intentions into action, particularly for health behaviours such as physical activity. More specifically, higher mindful awareness could allow an individual to more easily accept uncomfortable, or otherwise negative, thoughts and sensations that are likely to occur during physical activity (e.g., pain, fatigue), thereby facilitating sustained physical activity (Schneider et al., 2019). Indeed, a study by Ulmer et al. (2010) discovered that adults who are successful at maintaining exercise tend to have higher levels of trait mindfulness and acceptance, which they theorize may help to navigate cognitive, emotional and behavioral barriers to an exercise regimen. This may be especially evident in novice, or previously sedentary, exercisers who are more likely to perceive exercise as threatening, even when acknowledging the long-term health benefits.

Of course, these proposed "models" are not mutually exclusive, as trait mindfulness may play a dual mediating and moderating role. In their hypothesis and theory article, Demarzo and colleagues (2014) propose that mindfulness might both mediate and moderate the effects of physical activity and exercise on cardiovascular response to stress. Specifically, they hypothesize that baseline trait mindfulness may moderate the effects of physical activity (PA) on post-PA trait mindfulness, which then mediates the effect of PA on cardiovascular response to stress. However, much more research is needed to test this complex model, such as the use of modeling covariance structures (Demarzo et al., 2014). Due to the link between mindfulness and other outcomes, this model might apply to dependent variables relating to mood, cognition, and physical health.

Neural Commonalities

In addition to relationships found behaviorally, mindfulness and physical activity have several neural commonalities. For example, a systematic review by Van der Stouwe and colleagues (2018) revealed strong evidence of long-term hippocampal volume increases from physical exercise in adults, and a buffering effect of exercise on deterioration of hippocampal functioning in older adults. Mindfulness has also been associated with enhanced grey matter density in hippocampus that is also linked to cognitive (e.g., memory) and stress-related benefits (Greenberg et al., 2019; Hölzel et al., 2011; Tang et al., 2015). Regarding another brain area involved in emotion regulation, decreased connectivity between the dlPFC and other brain regions has been associated with exercise training (Van der Stouwe et al., 2018) as well as mindfulness (Barnhofer et al., 2021). In terms of the insula, an area involved in awareness and linked with mindfulness (Lazar et al., 2005, Tang et al., 2015), volume increases have been seen following physical activity in both adults (Killgore et al., 2013) and older adults (Rehfeld et al., 2018). A brain region heavily involved in attention regulation during mindfulness meditation (Hölzel et al., 2011; Kwak et al., 2020; Marchand, 2014), the ACC has also shown to be affected by aerobic exercise, which may slow its volume loss in older adults (Li et al., 2017). Lastly, there is research suggesting that exercise and mindfulness meditation may both benefit white matter integrity and connectivity in aging individuals (Laneri et al., 2016; Wassenaar et al., 2019).

There are also neural commonalities between mindfulness and physical activity on a more molecular level. Two examples of such compounds found in the literature are cortisol and brain-derived neurotrophic factor (BDNF). Regarding the former, physical activity and fitness level have both been associated with reduced cortisol secretion during psychosocial stress (Wood et al., 2018); this reduction has also been found following mindfulness training (Fan et al., 2014). There is evidence that BDNF, a protein thought to promote neuroplasticity (Kowiański et al., 2018), may increase following MBIs, according to a systematic review and meta-analysis by Gomutbutra and colleagues (2020). Similarly, aerobic exercise is also associated with increased BDNF concentrations, as supported by a 2016 meta-analysis by Dinoff et al. Taken together, physical activity and mindfulness appear to share several neural mechanisms, providing further evidence of a strong relationship between one another.

V. Ecological Momentary Assessment – A Brief Overview

Differing from more retrospective reporting methods in psychology research, ecological momentary assessment (EMA) is a category of assessment methodology that employs measurement in real-time. As indicated in its name, a key feature of EMA is its collection of data in an individual's real-world, "ecological" environment (Shiffman et al., 2008). In addition, participants are asked to assess their current state, in that moment ("momentary"), rather than recalling or summarizing their experiences over the course of a long period of time (e.g., the past two weeks). In their 2008 review, Shiffman and colleagues identify two further features that are typical in EMA: (1) assessments are usually completed over several time points, to capture variability of experiences and behaviour across time and situations; and (2) these time points, although variable, are often purposefully selected based on events of interest (e.g., eating a meal), by random sampling, or by other sampling schemes according to the nature of the study. Essentially, EMA attempts to capture the dynamic ebb and flow of moment-to-moment, real-world experiences and behaviour across time and circumstances (Shiffman et al., 2008).

There has been a variety of data collection instruments used in EMA methodology since its inception. These have included diaries, phone calls, text messages and more recently, apps for smartphones (Runyan & Steinke, 2015). Diaries, for example, have been a staple assessment tool in psychology research, and have varied in methodology, from early—and still popular—use of paper-and-pencil diaries, to more recent electronic/digitized diaries (Bolger et al., 2003). In randomized sampling designs, pagers have been used to send notifications (beeps) to prompt participants to complete diary cards (Larson & Csikszentmihalyi, 2014).

However, it is through the use of smartphone apps that EMA has recently surged in research. This particular medium of EMA offers familiarity and convenience to participants who are otherwise used to using their device, and it allows researchers to customize the content and formatting of surveys (Runyan & Steinke, 2015). EMA is also more accessible, as users are more easily able to respond quickly to notifications; this also makes it easier and more practical for researchers to use random sampling time points and limit convenience sampling that is more prevalent in other modes of EMA. Limited time windows to respond to questions can be utilized to further decrease convenience sampling (Runyan & Steinke, 2015). Recruitment has also enhanced due to smartphone platforms for EMA, as the number of people who own smartphones has drastically increased in recent years, including over 70% of the population in the Western world (de Vries et al., 2021).

There are several advantages of EMA compared to more traditional, retrospective reporting methods. For instance, EMA circumvents limitations associated with autobiographical memory, which can be unreliable and inaccurate due to random error and/or bias (Shiffman et al., 2008). EMA's assessment of experiences and behaviours as they occur in natural environments also promotes ecological validity, increasing the generalizability of findings to an individual's real-life experiences. Practically speaking, it is significantly easier and less costly to distribute EMA to a wider range of people geographically, as there is no need to ship study materials such as palm pilots (de Vries et al., 2021). Smartphones also typically possess sensors that can collect data continuously, such as accelerometers, that can be incorporated into EMA as objective data. EMA also allows for greater assessment of within-person processes, which often differ from between-person processes that are captured through traditional methods (Russell & Gajos, 2020).

EMA also comes with drawbacks. Primary concerns are ethical in nature, as there are potential issues relating to privacy, confidentiality, and data storage (de Vries et al., 2021). Personal and possibly identifying information such as GPS location are routinely collected through smartphone EMA, and data are typically stored in remote servers outside of a research institute. In addition to ethical considerations, a high portion of a population may be excluded from participation for not possessing a smartphone, potentially skewing the demographic characteristics (e.g., socioeconomic status) of a sample.

EMA Use in Psychology Research Across the Lifespan

EMA has been extensively used in psychology research to examine mood and behaviour across the lifespan. In children and adolescents, EMA has been sensitive in detecting changes in affective states (Russell & Gajos, 2020; Wen et al., 2018). A recent review by Russell and Gajos (2020) examined the uses of EMA in studies of child and adolescent mental and behavioral health, and found widespread applicability. Studies have used EMA in children with and without psychopathology. In children with psychopathology, EMA has examined symptom experiences in children with ADHD receiving stimulant treatment (Whalen et al., 2006), as well as those with high anxiety who have displayed higher levels of anger, sadness, and fatigue compared to other youth (Henker et al., 2002). EMA has also been used, although less extensively, in youth with autism spectrum disorder (ASD), revealing changes in positive experiences and emotions following social interactions (Cordier et al., 2016). Russell and Gajos (2020) also discovered research using EMA to examine within-person changes in youth following situations and events in everyday life. For example, they have found evidence for EMA's sensitivity in detecting change in the context of eating behaviors, self-injury, stress, substance use, and physical activity. Regarding studies examining the effects of physical activity, a 2018 study by Wen and colleagues found increases in positive affect following bouts of physical activity, and decreases in positive affect after periods of sedentary behaviour. Parents involved in youth studies have also been involved in EMA, demonstrating changes in mood-related outcome such as affect and overall wellbeing (e.g., Janssen et al., 2020).

In addition to children and adolescents, adults have also been examined in psychology research through EMA. For example, EMA in adults has shown sensitivity for detecting intra-individual variability in affect based on characteristics of social interactions, according to a 2019 systematic review and meta-analysis by Liu and colleagues. EMA has also shown differences in momentary affect in adults that are based on location (e.g., at “home,” “work,” “family/friend’s house,” etc.), and that this may be moderated by personality (Sandstrom et al., 2016). In clinical adult populations, EMA has also demonstrated utility. For instance, a 2015 study by Merwin et al. found that in adults with diabetes, EMA data showed that negative affect was a predictor of insulin restriction, and that most of the variance in affect were due to within-person fluctuations.

Although less studied, EMA has also shown to be a sensitive assessment tool in older adults. Regarding non-clinical older adult populations, EMA has been used to study factors predicting health-related activities. For instance, a recent study by Hevel and colleagues (2021) examined the interactions between EMA-reported affect, behavior, context and sedentary behavior, and found that social and physical context moderated the association between sedentary behavior and affect. EMA has also demonstrated use in clinical populations (Paolillo et al., 2018). For example, in those with HIV infection, and those without, EMA-measured mood and pain predicted alcohol and cannabis use (Paolillo et al., 2018). In fact, stronger effects have been seen when EMA methods are used versus traditional paper-and-pencil measures when it comes to assessing depression in older adults (Moore et al., 2016). One possible reason for this is that the repeated measurements in EMA reduces variability of estimates, by “washing out” state effects that can bias/skew a single point-in-time measure (Moore et al., 2016). Further, the ability of EMA to counteract the limitations of memory, as seen in traditional measures, is particularly relevant in an older adult population that is associated with decreased memory performance (Tulving & Craik, 2000). EMA has been proposed as a way of promoting mHealth (mobile health) for older adults with depression and anxiety (Grossman et al., 2020). Specifically, EMA can be used to inform clinicians of real-time symptomatology, leading to in-person assessment follow-up or intervention.

VI. EMA and Mindfulness

More specifically, EMA has been a useful methodology in mindfulness research. A recent systematic review by Enkema and colleagues (2020) investigated research employing EMA methodology to assess associations between mindfulness and mental health outcomes. Findings from the 23 included studies indicated that EMA is sensitive to detecting positive associations between mindfulness and mental health, demonstrating some evidence for producing larger effect sizes compared to more traditional measures and method designs. These associations were seen in experimental studies (i.e., using mindfulness training as an intervention), as well as observational studies that examined relationships between trait and/or state mindfulness and mental health (Enkema et al., 2020). One such observational study found that higher trait mindfulness, in college students was associated with greater emotion differentiation (i.e., insight) and less emotional difficulties as reported through EMA (Hill & Updegraff, 2012). A more recent study by Szeto et al. (2019) found associations between EMA-measured craving and drinking with trait mindfulness in alcohol-dependent patients, such that those higher in trait mindfulness exhibited less craving, which in turn led to less drinking behavior. Overall, EMA has demonstrated value as an effective methodology in detecting associations between mindfulness and mental health outcomes, with some evidence indicating that EMA is more powerful than traditional measures in measuring these relationships.

In addition to demonstrating assessment-related utility in mindfulness research, EMA may have therapeutic benefits as well. In particular, there is emerging evidence to suggest that EMA may, as a byproduct, increase trait mindfulness (Runyan et al., 2013). It has been theorized that this occurs through increases in attention and self-awareness by repeatedly facing questions about one’s behaviours, thoughts and emotions in close contextual and temporal proximity to when they occur; this mindfulness enhancement in turn can lead to positive change in behavior, thought patterns or states (Shiffman, 2009). In this way, EMA can be repurposed and altered to provide ecological momentary intervention (EMI). Runyan and colleagues (2013) tested the feasibility and effectiveness of an EMA/EMI smartphone app in promoting self-awareness of time-management in college students, and found that the vast majority (80.5%) endorsed greater awareness, with some (43.9%) even changing how they spent their time. A more recent study by Folkersma et al. (2021) used EMI to treat depression in adults, and based on qualitative analysis of interviews, it was found that increased self-awareness and insight were among the greatest benefits endorsed by participants, in addition to self-management. However, there was no significant change in the degree of depressive symptoms themselves, indicating that EMI (or EMA) that increases self-awareness and insight may help individuals to confront and deal with their symptoms rather than reduce the symptoms themselves (Folkersma et al., 2021). In contrast, reduction of worrying has been seen in young adults with Generalized Anxiety Disorder, even after a brief (e.g., 10-day) period of EMI (LaFreniere & Newman, 2016).

In summary, mindfulness practice and trait mindfulness are associated with benefits pertaining to mental health, cognition, and physical health. There are many measures of trait mindfulness, which vary in factor structure, but those that emphasize assessment of awareness (e.g., the MAAS) are most sensitive to correlating with health behaviours, such as engagement in physical activity. Research has found there to be a strong relationship between mindfulness and physical activity/exercise, behaviorally and through common neural correlates. Various moderating and mediating roles of trait mindfulness in the context of physical activity have been proposed, and further research is needed to test these hypotheses. In addition, research has demonstrated that EMA is a sensitive methodology to measuring psychological factors associated with mindfulness practice and trait mindfulness, having several advantages (and some disadvantages) compared to traditional paper-and-pencil measures. Further, there is evidence that the process of undergoing EMA may actually enhance trait mindfulness, through increased self-awareness, as well as aspects of psychological wellbeing. In sum, there is a gap in the literature exploring the relationships between trait mindfulness, physical activity, EMA, and neuropsychological outcomes in the older adult population. Chapter 2 examines (a) the malleability of trait mindfulness in response to physical activity, and (b) what role (e.g., moderating and/or mediating) trait mindfulness may play in the relationship between physical activity and neuropsychological outcomes, in older adults. Chapter 3 investigates (a) the extent to which engagement in EMA may alter trait mindfulness and how this may indirectly impact neuropsychological functioning (i.e., through mediation), and (b) the sensitivity of EMA in detecting associations between psychological outcomes and trait mindfulness.

CHAPTER II

Examining the Malleability and Role of Trait Mindfulness in Neuropsychological Outcomes of a Remote Physical Exercise Program in Older Adults

2.1 Abstract

Background: The practice of mindfulness has exhibited utility in enhancing neuropsychological outcomes pertaining to mood and cognition, in addition to benefitting overall health. These effects have been observed in individuals across the lifespan, and are associated with trait mindfulness, which represents the degree to which a person is generally mindful. Research has further demonstrated that trait mindfulness is a relevant factor when examining the health and neuropsychological benefits of physical activity and exercise, such that it may play a moderating and/or mediating role. However, less is known about how trait mindfulness may interact with neuropsychological outcomes in older adults following physical activity. This study investigates the malleability of trait mindfulness in response to physical activity in older adults, and what role this may play in the relationship between physical activity and neuropsychological outcomes. Method: A total of 75 older adults, divided into an Active Group (n= 43; 70% women; age 65-81) and a Waitlist Control Group (n= 32; 69% women; age 65-86), took part in the study. Participants in the Active Group underwent an 8-week remote physical exercise training program. All participants completed online questionnaires assessing trait mindfulness, mood and executive functioning, as well as a cognitive task battery, a total of three times: at baseline (Week 1), post-training (Week 9), and 3-week follow-up (Week 12). Participants also completed brief daily surveys of physical activity on their phone or tablet. Results: The Active Group did not show greater improvements in trait mindfulness compared to the Waitlist Control Group, and reported physical activity did not predict gains in trait mindfulness. Additionally, trait mindfulness did not moderate or mediate the relationship between physical activity and neuropsychological outcomes. Trait mindfulness did not play a significant role in predicting adherence to the exercise program. Conclusions: In healthy older adults, physical activity may

not impact trait mindfulness and conversely, trait mindfulness may not influence engagement in physical activity. As such, trait mindfulness does not appear to play an integral role in neuropsychological outcomes from physical exercise.

2.2 Introduction

Mindfulness

Mindfulness is the practice of paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally (Kabat-Zinn, 2009). Originating from Buddhism approximately 2500 years ago, mindfulness has served as a significant component of Buddhist meditation training (Shonin et al., 2015). In their review, Brown and colleagues (2007) propose that the main pillars of mindfulness are awareness and attention. Specifically, mindfulness provides a clear awareness of one's experience of what is happening externally and internally (e.g., thoughts, emotions, sensations), while directing attention towards the objective qualities or characteristics of what is being observed, allowing an individual to be present in the moment. Psychology research employing mindfulness-based interventions (MBIs) has unveiled benefits across the lifespan, in regard to improved mental health (Dunning et al., 2019; McClintock et al., 2019; Reangsing et al., 2021), cognition (Hazlett-Stevens et al., 2019; Im et al., 2021; Wood et al., 2018), and physical health (Abujaradeh et al., 2018; Creswell et al., 2019; Hazlett-Stevens et al., 2019).

Trait Mindfulness

Trait mindfulness, also known as dispositional mindfulness, refers to an individual's general level of mindfulness across situations and time (Sala et al., 2020). In addition to increasing as a result of mindfulness training, trait mindfulness at baseline has shown to moderate the effects of mindfulness training (Shapiro et al., 2011). In contrast to trait mindfulness, state mindfulness is the extent to which an individual experiences mindfulness in a given moment. Both trait and state mindfulness represent ways in which mindfulness can be measured in a person, and not surprisingly, they are highly correlated with one another. For instance, changes in state mindfulness across the duration of a mindfulness-based intervention have shown to predict pre-post changes in trait mindfulness (Kiken et al., 2015). However, much more research has studied and measured trait mindfulness compared to state. Like MBIs, trait mindfulness is associated with enhanced mental health (Medvedev et al., 2018; Mesmer-Magnus et al., 2017; Tomlinson et al., 2018) and physical health (Kimmes et al., 2018; Loucks et al., 2015; Lucas-Thompson et al., 2019; Sala et al., 2020). Regarding cognition, trait mindfulness is particularly associated with greater executive functioning (EF), such as inhibition, working memory and shifting/cognitive flexibility (Jaiswal et al., 2018; Molina-Rodríguez et al., 2021; Riggs et al., 2015).

To date, measurement of trait mindfulness is primarily conducted through self-report questionnaires. Commonly used scales differ in the extent to which they measure facets of mindfulness. Extensive, multidimensional scales offer the range to examine the effects of trait mindfulness in a well-rounded fashion, using a facet-level approach (Rau & Williams, 2016). Such multifaceted measures support a multidimensional construct of mindfulness, in which each component is relatively independent from one another. Examples of scales that consist of several factors include the 5-factor Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006) or the 4-factor Cognitive and Affective Mindfulness Scale—Revised (CAMS-R; Feldman et al., 2007). Conversely, questionnaires that consist of one or two factors offer greater robustness in measuring a specified facet of trait mindfulness, which may be particularly useful when there is empirical evidence supporting the relative strength of one or two trait mindfulness facets in regard to association with outcomes. Further, these scales fit with theoretical conceptualizations that propose a more unidimensional characteristic of mindfulness (e.g., Brown et al., 2007; Kabat-Zinn, 2003). Examples of such scales include the single-factor Mindful Attention

Awareness Scale (MAAS; Brown & Ryan, 2003) or the 2-factor Philadelphia Mindfulness Scale (PHLMS; Cardaciotto et al., 2008).

Trait Mindfulness and Physical Activity

Studies have examined trait mindfulness and its relationship with physical activity, finding significant associations. For example, physical activity was a health behaviour assessed by Sala and colleagues in their 2020 meta-analysis, which they found was positively associated with trait mindfulness. Interestingly, gender moderated this relationship, such that the association between trait mindfulness and physical activity was attenuated when there was a higher percentage of men in a given sample. Additionally, correlations between trait mindfulness and physical activity were larger when the latter was assessed through self-report questionnaires rather than objective measures. Although this is attributed to possible shared method variance, objective measures in previous studies typically do not capture physical exercise habits (i.e., over time), whereas questionnaires do (Sala et al., 2020). Commonly used questionnaires include the International Physical Activity Questionnaire (IPAQ; Craig et al., 2003), Godin Leisure-Time Exercise Questionnaire (GLTEQ; Godin & Shephard, 1985), and the Physical Activity, Exercise, and Sport Questionnaire (Fuchs et al., 2015), as determined by a separate systematic review (Yang & Conroy, 2020).

Sala et al. (2020) outline several proposed reasons why trait mindfulness may be associated with physical activity. First, due to the strong correlation of trait mindfulness with state mindfulness, those who have high trait mindfulness may be more likely to experience greater state mindfulness while participating in physical activity; this may in turn lead to higher satisfaction and reinforce participation in physical activity. Indeed, there is evidence suggesting that satisfaction may mediate the effect of state mindfulness on physical activity (Tsafou et al., 2016; Tsafou et al., 2017).

Second, rather than trait mindfulness leading to physical activity, participation in physical activity may lead to increased trait mindfulness (Sala et al., 2020). Support for such a phenomenon has been seen in randomized control trials (RCTs; de Bruin et al., 2016; Mothes et al., 2014). For example, a study by Mothes et al. (2014) revealed significant changes in trait mindfulness that occurred over the course of a 12-week program of aerobic exercise in healthy men, in contrast to a relaxation training program that was not associated with significant changes. An RCT by de Bruin and colleagues (2016) also found significant increases in trait mindfulness in young adults following a 5-week physical exercise program, and this change was comparable to that observed following a 5-week mindfulness meditation training program in a different group. A theorized explanation for this directional relationship is that bouts of physical activity/exercise enhance acute awareness of body sensations (e.g., breathing, muscle tension), as well as internal affective state, thereby increasing one’s state mindfulness and, over time, their trait mindfulness (Demarzo et al., 2014). As previously mentioned, changes in state mindfulness across the duration of mindfulness training has coincided with increases in trait mindfulness (Kiken et al., 2015), so such a mechanism is plausible.

Lastly, Sala and colleagues (2020) propose that trait mindfulness may serve a moderating role in the relationship between motivation to engage in physical activity and actually undergoing physical activity. Research by Ruffault et al. (2016) supports this hypothesis, finding evidence that the correlation between intrinsic motivation and self-reported physical activity level is strongest in those with higher trait mindfulness, and weakest in those with lower trait mindfulness. With increased awareness and self-regulation, an individual may be better able to translate their motivated intentions into action, particularly for health behaviours such as physical activity. More specifically, higher mindful awareness could allow an individual to more easily accept uncomfortable, or otherwise negative, thoughts and sensations that are likely to occur during physical activity (e.g., pain, fatigue), thereby facilitating sustained physical activity (Schneider et al., 2019). Indeed, a study by Ulmer et al. (2010) discovered that adults who are successful at maintaining exercise tend to have higher levels of trait mindfulness and acceptance, which they theorize may help to navigate cognitive, emotional and behavioral barriers to an exercise regimen. This may be especially evident in novice, or previously sedentary, exercisers who are more likely to perceive exercise as threatening, even when acknowledging the long-term health benefits.

Of course, these proposed “models” are not mutually exclusive, as trait mindfulness may play a dual mediating and moderating role. In their hypothesis and theory article, Demarzo and colleagues (2014) propose that mindfulness might both mediate and moderate the effects of physical activity and exercise on cardiovascular response to stress. Specifically, they hypothesize that baseline trait mindfulness may moderate the effects of physical activity (PA) on post-PA trait mindfulness, which then mediates the effect of PA on cardiovascular response to stress. However, much more research is needed to test this complex model, such as the use of modeling covariance structures (Demarzo et al., 2014). Due to the link between mindfulness and other outcomes, this model might apply to dependent variables relating to mental health, cognition, and physical health.

Taken together, mindfulness practice and trait mindfulness are associated with enhanced mental health, cognition (particularly EF) and physical health. Research has found there to be a strong relationship between trait mindfulness and health behaviours like physical activity/exercise. Various moderating and mediating roles of trait mindfulness in the context of physical activity have been proposed, and further research is needed to test these hypotheses, particularly in older adults and regarding neuropsychological outcomes. The purpose of the present study is to examine the role(s) of trait mindfulness in neuropsychological outcomes of a remote physical exercise training program in older adults. We hypothesize that (a) older adults who engage in a physical exercise program will experience greater increases in trait mindfulness compared to control group participants, (b) trait mindfulness will both moderate and mediate the relationship between engagement in physical exercise and neuropsychological outcomes relating to mood and cognition; and (c) baseline trait mindfulness will significantly predict adherence to the exercise program.

2.3 Method

2.3.1 Participants

A total of 75 participants took part in the study. They were divided into two groups: 43 in the Active Group and 32 in the Waitlist Control Group (see Table 2.1). Participants were recruited from various organizational, provincial, and national newsletters and listservs in Canada, in addition to social media posts and advertisements. They included older adults living in Canada who were at least 65 years of age and had access to a computer and smartphone or tablet. Participants were excluded if they (a) already regularly engaged in moderate-vigorous physical activity more than four times per week, (b) failed a health screener (PAR-Q+), (c) had a significant neurological history, including traumatic brain injury (TBI), or (d) had a history of substance abuse.

Table 2.1. Sociodemographic Characteristics of Participants in Study 1 at Baseline

Baseline characteristic	Active group (n= 43)		Waitlist control group (n= 32)		Full sample (n= 75)	
	n	%	*n*	%	*n*	%
Gender						
Female	30	70	22	69	52	69
Male	13	30	10	31	23	31
Race/ethnicity						
White	42	98	32	100	74	99
South Asian	1	2	0	0	1	1
Highest educational level						
High School	5	12	1	3	6	8
College/University	16	37	17	53	33	44
Master's Degree	10	23	4	13	14	19
Doctoral Degree	2	5	1	3	3	4
Other	3	7	3	9	6	8
Province						
Ontario	4	9	5	16	9	12
British Columbia	34	79	23	72	57	76
Nova Scotia	3	7	0	0	3	4
Prince Edward Island	1	2	0	0	1	1
Manitoba	1	2	0	0	1	1
Quebec	0	0	3	9	3	4
Alberta	0	0	1	3	1	1
Urban	36	84	22	69	58	77
Rural	7	16	10	31	17	23

Note. Participants were on average 69.9 years old (*SD* = 4.3), and participant age did not differ between groups. Median income was $80,000-99,999 for both groups. Average body mass index (BMI) was 26.9 (*SD* = 5.1), and there were no differences between groups.

2.3.2 Measures

Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003)

The MAAS was developed by Brown and Ryan (2003) to measure trait mindfulness and its role in psychological well-being. It consists of 15 items that are rated on a 6-point Likert scale. Specifically, each item is a statement of which the individual rates the frequency, from “Almost Always” to “Almost Never.” Interestingly, the items themselves actually reflect mindlessness (e.g., "I find myself doing things without paying attention"), as the authors determined that such statements were more easily accessible given evidence that mindless states are more common than mindful states. The MAAS has been the most commonly used measure in studies of mindfulness with nonclinical samples (Mesmer-Magnus et al., 2017), and in intervention studies, mindfulness training has indeed been found to positively correlate with scores on the MAAS (Quaglia et al., 2016). In terms of reliability, the MAAS has high test-retest reliability as well as internal consistency, as demonstrated at its inception and again more recently (Osman et al., 2016). In addition to being used to investigate relationships between trait mindfulness and outcomes of mood and cognition, the MAAS has been found to be a particularly strong measure when examining outcomes of health behaviors (Sala et al., 2020). Further, it is the most commonly used measure of trait mindfulness in research assessing the correlates of trait mindfulness with physical activity and exercise (Yang & Conroy, 2020). Total score on the MAAS will be used in analyses.

Physical Activity

Using the Ethica application (Ethica Data, 2020), which works on all smartphones and tablets, participants were asked to complete a brief survey indicating the amount of time that day that was spent in the following activity levels: *sedentary* activity (e.g., no effort, such as watching TV, sitting, reading a book); *light* activity (e.g., minimal effort with normal breathing and regular movement, such as walking, golfing, cleaning, etc.); *moderate* activity (e.g., moderate effort with increased breathing and quicker movements, such as fast walking, casual biking, etc.); and *vigorous* activity (e.g., effortful, with heard breathing and quick, fast movements such as running, fast-paced sports, aerobic classes, etc.). Participants responded using a pull-down menu for "hours" and "minutes." Total amount of moderate-vigorous exercise will be used in analyses.

Geriatric Depression Scale-Short Form (GDS-SF; Sheikh & Yesavage, 1986)

The GDS-SF is an established 15-item self-report questionnaire that measures depressive symptoms. Each item consists of a "Yes/No" question, and the participant answers based on how they have been feeling over the past week. Lower scores indicate less depression whereas higher scores indicate greater depression. The GDS-SF has been used extensively with the older adult population, including those who are healthy and live in the community. It demonstrates high sensitivity and specificity, successfully differentiating depressed from non-depressed individuals (Sheikh & Yesavage, 1986). Total score for the GDS-SF will be used in analyses.

Generalized Anxiety Disorder 7-item Scale (GAD-7; Spitzer et al., 2006)

The GAD-7 is a brief 7-item self-report questionnaire that measures anxiety. Each item consists of potential problems experienced (e.g., feeling nervous), of which the participant is asked to rate the frequency over the past 2 weeks. Each item is rated using a 4-point Likert scale, ranging from "Not at all" to "Nearly every day." Lower scores indicate less anxiety whereas higher scores indicate greater anxiety. The GAD-7 has been used extensively with the older adult population, including those who are healthy and live in the community. It demonstrates high sensitivity and specificity for Generalized Anxiety Disorder, and moderate sensitivity and specificity for other related anxiety disorders (e.g., Social Anxiety Disorder; Spitzer et al., 2006). Total score for the GAD-7 will be used in analyses.

Executive Function Index (EFI; Spinella, 2005)

The EFI is a 27-item self-report questionnaire that measures executive behaviour. Participants rate how well each item/statement describes them, using a 5-point Likert scale ranging from “Not at all” to “Very much.” While there is an overall composite score, items fall under five different subscales: Strategic Planning (SP), Organization (ORG), Impulse Control (IC), Empathy (EM), and Motivational Drive (MD). Higher scores indicate better executive behaviour. The EFI has robustly correlated with other self-report scales of executive behaviour (e.g., the Frontal Systems Behavior Scale), and its internal consistency is acceptable (Spinella, 2005). Total score for the EFI will be used in analyses.

Simon Task (Simon, 1969)

The Simon Task is a measure of inhibition. During the task, the words “Left” or “Right” will appear randomly on either side of a cross in the middle of the screen. If the word “Left” appears on either side, participants must click “F”. If the word “Right” appears on either side, participants must click “J”. Trials were “congruent” if the word presented on the same side as the appropriate response key (e.g., “Right” on the right side of the screen), and trials were “incongruent” if the word presented on the opposite side (e.g., “Right” on the left side). The Simon Task has been used in research to demonstrate effects of mindfulness on inhibition (Colzato et al., 2015; Eichel & Stahl, 2017). The difference between mean reaction time of congruent versus incongruent trials is the primary outcome variable.

N-Back (2-Back; Kirchner, 1958)

The 2-Back is a cognitive task that measures updating of working memory. During the task, a series of letters appears on the participant’s computer screen, one at a time for 1 second each. For each letter, the participant must press “F” on their keyboard for “yes” if that letter is the same as 2 letters ago, or “J” for “no” if it is different from 2 letters ago. The 2-Back has been used in mindfulness research, demonstrating correlations with trait mindfulness (e.g., Ruocco & Wonders, 2013). Total accuracy on the 2-Back (i.e., number of “hits”) will be used in analyses.

Cued Task Switching (Allport et al., 1994)

Cued Task Switching measures a participant's ability to shift between two sets of rules in a single task. There are two sets of stimuli: words (COLOUR and SHAPE) and shape (square or rectangle that is blue or green). First a word is presented, followed by a shape. If the word is "COLOUR", participants must click "F" if the shape is blue and "J" if it is green. If the word is "SHAPE", participants must click "F" for square and "J" for a rectangle. Performance on Cued Task Switching paradigms has specifically been shown to correlate with trait mindfulness (Aguerre et al., 2021). The primary outcome variable is switch cost, which is the difference in reaction time between consecutive trials and switch trials.

Iowa Gambling Task (Bechara et al., 1994)

The Iowa Gambling Task is a measure of higher-order executive functions. Participants are given $2000 and presented with four decks (A, B, C, D). They are told that each deck pays a reward that sometimes has a fee, and are instructed to make the most money possible. Decks A and B happen to pay $100 but have a fee of $250, whereas decks C and D pay $50 but have a fee of $50. The task is designed so that in order to make the most money over time, participants should choose decks C and D. Conversely, participants who choose decks A and B will lose money over time. The Iowa Gambling Task has been demonstrated to correlate with trait mindfulness (e.g., Lakey et al., 2007). The total score, based on money gained and lost, will be used in analyses.

Sustained Attention Reaction Test (SART)

The SART measures sustained attention and processing speed. Adapted from other sustained attention tasks (e.g., Sustained Attention to Response Task by Robertson et al., 1997), this task instructs participants to stare at the middle of the screen as a series of letters are presented, and to press the spacebar whenever an “X” is presented. Participants are asked to answer as quickly and as accurately as possible. Research has shown strong associations between mindfulness and sustained attention as measured by the SART (e.g., Ueberholz & Fiocco, 2022). Mean reaction time on hits (i.e., responses to “X”) is the main outcome variable used in analyses.

Hebb Learning (Page et al., 2006)

The Hebb Learning task measures memory of a list of words (animal names) and their order of presentation. The task has two parts: first, a list of animals is presented for 2 seconds per animal. Then, nine drawings of animals in a 3x3 grid are presented in random order and participants are asked to recall the wordlist by clicking on each animal in the same order the words were presented. Some lists of animals are repeated multiple times. Although this particular task has not been used in mindfulness research, other wordlist learning tasks have, demonstrating high sensitivity to the effects of mindfulness (Lueke & Lueke, 2019). The primary outcome variable is number of correctly recalled animals.

2.3.3 Procedure

This study was approved by the Human Research Ethics Board at the University of Victoria (Protocol Number: 19-0455). All data collection, as well as the physical exercise training program, was conducted remotely, online or through a phone/tablet application. Recruitment and participation in the study was rolling, rather than having all participants start at the same time. After answering screening questions, participants were randomly assigned via block randomization to the Active group or Waitlist Control group, and providing signed, informed consent. All participants were then added to an online platform that contained study materials, including links to assessment questionnaires and cognitive tasks, as well as workout videos for those in the Active group. Participants were given a week to complete a Baseline assessment that involved completing a questionnaire battery on Qualtrics (qualtrics.com), including history questionnaire inquiring about demographics (see Appendix A), mood and EF scales; they also completed a cognitive task battery on Gorilla (gorilla.sc), which has been validated for use as an online experiment-building platform (Anwyl-Irvine et al., 2020). In total, the questionnaires and cognitive tasks took approximately 1.5 hours to complete. All participants repeated these same measures, except the history questionnaire, two more times throughout the course of the study: at 9 weeks (post-training), and 12 weeks (3-week follow-up). In addition to these primary assessment timepoints, participants were prompted in the evening to complete daily surveys of physical activity on the Ethica app throughout their participation (see Appendix C).

Physical Exercise Training Program

Upon completion of their Baseline assessment, participants in the Active group underwent an 8-week remote physical exercise training program. During each week, they were expected to complete a total of 3 hours of moderate-to-vigorous physical exercise split between at-home guided workouts (1 hour) and physical exercise of their choosing (2 hours, e.g., fast-paced walking, biking, tennis, etc.). More specifically, participants completed two 30-minute-long online video-recorded workouts, which were led by trained kinesiologists and involved a blend of aerobic and anaerobic exercises.

2.3.4 Statistical Analyses

To account for possible effects of gender, an independent samples *t*-test was conducted comparing trait mindfulness between men and women in the overall sample. Although age effects are not necessarily anticipated given the restricted age range of older adults, a bivariate correlation was also used to determine if there is a significant relationship between age and trait mindfulness in the overall sample. Further, bivariate correlations were conducted to test for effects of education level and socioeconomic status (estimated by total annual income) on trait mindfulness.

A two-way repeated measures ANOVA was computed to determine if there are significant differences in trait mindfulness between the Active group and Control group across three time points: baseline, 9 weeks (post-training) and 12 weeks (3-week follow-up). Further, a linear regression was conducted to assess if, across all participants, amount of reported moderate-vigorous physical activity predicts changes in trait mindfulness.

To examine the theory that trait mindfulness acts as a moderator for the relationship between physical activity and neuropsychological outcomes, linear regressions were conducted with baseline trait mindfulness, total amount of reported moderate-vigorous physical activity (throughout the 8-week program), and their interaction as the predictor variables, and changes in GDS, GAD-7, EFI, and cognitive task scores as the dependent variables. To assess trait mindfulness as a mediator, structural equation modeling was used to test direct, indirect and total effects, with change in trait mindfulness as the mediator, total amount of reported moderate-vigorous physical activity (throughout the 8-week program) as the independent variable, and changes in GDS, GAD-7, EFI, cognitive task scores as the dependent variables.

To determine whether trait mindfulness predicts adherence to the physical exercise training program, a linear regression was conducted within the Active group using baseline trait mindfulness as the predictor and total amount of reported physical activity across the 8-week program as the dependent variable.

2.4 Results

Assumptions for all analyses were met, and statistical outliers were excluded appropriately. Regarding attrition, 26% of participants actively withdrew at some point during the study (n=20). Listwise deletion was used for participants with missing data, including those who withdrew from the study. In other words, only participants with complete data were used in analyses.

2.4.1 Preliminary Analyses

To control for potential covariates of age, gender, education level and socioeconomic status, analyses were conducted comparing baseline trait mindfulness on each of these dimensions. Age was not significantly correlated with trait mindfulness (r = 0.07, p = 0.58). However, there was a significant difference in trait mindfulness in the overall sample between men and women, $t(68) = -2.92$, $p < 0.01$, $d = -0.74$, such that men were more mindful than women at baseline. Bivariate correlations revealed no significant relationship between trait mindfulness and education level (r = -0.09, p = 0.52) or socioeconomic status as estimated by total annual income (r = -0.18, p = 0.14).

2.4.2 Trait Mindfulness and Physical Activity

A 2 x 3 Mixed Model ANCOVA, using gender as a covariate, showed an overall significant within group effect for trait mindfulness across the three time points: baseline, 9 weeks (post-training) and 12 weeks (3-week follow-up), such that all participants gained trait mindfulness, $F(2, 72) = 3.49$, $p = .04$, $\eta^2_p = .09$. No significant effects were found between groups or genders, nor were there any significant interaction effects between group, gender and trait mindfulness. Post Hoc analyses regarding the main within group effect of trait mindfulness revealed a plateauing effect after 9 weeks, such that there was a minimal difference in trait mindfulness between 9 weeks and 12 weeks (*t*= 0.01, *p* = 1.00, *d* < .01), but a medium effect between baseline and 9 weeks (*t*= -2.29, *p* = 0.08, *d* = -0.32). Figure 2.1 depicts the change in trait mindfulness across the Active and Control groups. Active group participants reported undergoing an average of 263 minutes of moderate-to-vigorous physical activity per week at baseline and increasing to 439 minutes post training program. Control group participants reported an average of 289 minutes of moderate-to-vigorous physical activity per week at baseline and 311 minutes after the same time period as the training program (8 weeks). As well, current mindfulness meditation practice was assessed at baseline for only some participants, as this question was introduced later into the study. Of the entire sample, six participants endorsed practicing mindfulness meditation (three in the Active group and three in the Waitlist Control group).

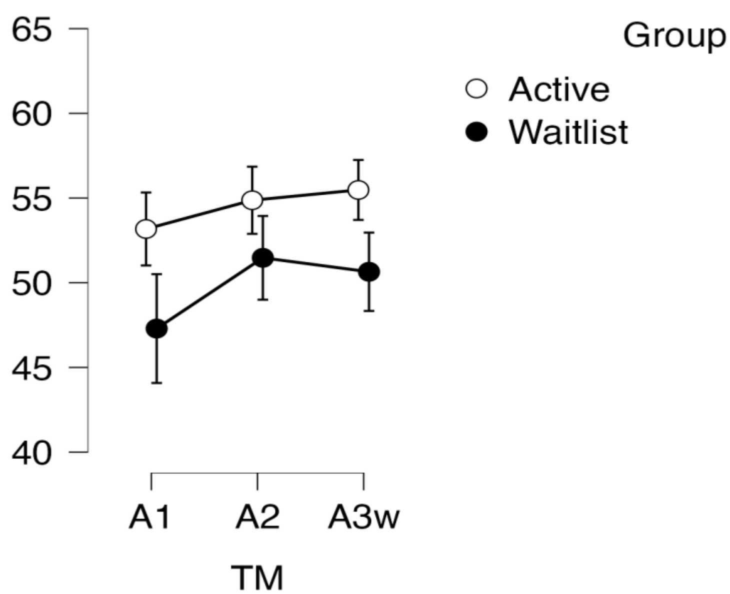

Figure 2.1. Trait mindfulness (TM) across Baseline, 9-weeks, and 12-weeks in the Active group and Waitlist Control group.

A linear regression revealed that, across all participants, reported moderate-vigorous physical activity did not significantly predict changes in trait mindfulness, $F(1, 36) = 0.17$, $p = 0.68$, $R^2 = 0.005$.

2.4.3 Trait Mindfulness Role as Moderator for Neuropsychological Outcome

To test the potential role of trait mindfulness as a moderator for the effects of physical activity on neuropsychological outcomes, separate linear regressions were conducted with each outcome as a dependent variable, and trait mindfulness and physical activity forming an interaction term. No test revealed a significant moderating effect of trait mindfulness (see Table 2.2). Although the regression model was significant for working memory (N-back), the interaction term did not significantly predict the outcome ($t = 1.82$, $p = 0.08$).

Table 2.2. Results of Moderation Analysis of Trait Mindfulness

Outcome	**Total df**	F	p	R^2
EFI	39	1.14	0.35	0.09
GDS	39	0.89	0.46	0.07
GAD-7	39	0.04	0.99	0.003
Simon Task	33	1.56	0.22	0.14
N-back	31	3.07	0.04*	0.25
CTS	32	0.57	0.64	0.06
Iowa Gambling	34	1.09	0.37	0.10
Hebb Learning	34	0.40	0.75	0.04
SART	29	1.26	0.31	0.13

*$p < 0.05$

2.4.4 Trait Mindfulness Role as Mediator for Neuropsychological Outcome

Structural equation modeling did not reveal any significant mediating effects of trait mindfulness on the relationship between physical activity engagement and neuropsychological outcomes. There were no significant direct effects of physical activity on neuropsychological change aside from working memory performance (see Table 2.3). However, no significant indirect effect was observed, $z = 0.12$, $p = 0.90$, indicating that trait mindfulness did not serve as a mediator. Of note, there were indirect effects between gains in trait mindfulness and changes in reported executive functioning (z = 1.96, p = 0.05) and learning/memory (z = 2.03, p = 0.04).

Table 2.3. Direct Effects of Physical Activity on Neuropsychological Change

Outcome	**z-value**	***p***
EFI	0.74	0.46
GDS	-0.44	0.66
GAD-7	-0.19	0.85
Simon Task	-1.01	0.31
N-back	-2.09	0.04*
CTS	-1.07	0.29
Iowa Gambling	1.28	0.20
Hebb Learning	-0.71	0.48
SART	0.56	0.58

*p < 0.05

2.4.5 Trait Mindfulness and Adherence to Physical Exercise

A linear regression showed that within the Active group, baseline trait mindfulness did not significantly predict adherence to the physical exercise program, $F(1,35) = 2.15$, $p = 0.15$, $R^2 = 0.06$. By the end of the program, 69% of Active group participants were adhering to it.

2.5 Discussion

The purpose of the present study was to examine the malleability of trait mindfulness from physical activity in older adults, its moderating or mediating role with neuropsychological outcomes, and its potential effect on exercise adherence. Trait mindfulness was repeatedly measured in older adults who engaged in a fully remote 8-week physical exercise training program and completed online neuropsychological measures, as well as in waitlist control participants. Contrary to our hypotheses, the Active group did not make significantly more gains in trait mindfulness than the control group, and reported physical activity did not significantly predict gains in trait mindfulness. Further, trait mindfulness did not moderate or mediate the relationship between physical activity and neuropsychological outcomes relating to mood and cognition. Lastly, contrary to hypotheses, trait mindfulness did not significantly predict adherence to the exercise program.

2.5.1 Trait Mindfulness and Physical Activity

Findings suggest that in healthy older adults, trait mindfulness is not significantly affected by engagement in physical activity. One possible explanation for this relates to the characteristics of our sample, such as age and healthiness. Older adults may respond differently to physical exercise than younger counterparts. For instance, older adults may be more prone to experiencing physical discomfort from exercise, and in doing so, may engage more in mind wandering associated with discomfort. Indeed, pain catastrophizing has been shown to be linked to engagement in physical activity, and may lead to increased sedentary behavior (Zhaoyang et al., 2020). These effects may counteract otherwise beneficial influences of physical activity on trait mindfulness across older adults, but more research is needed to elucidate competing processes. Of note, men in the overall sample were more mindful than woman at baseline. Although there is evidence to suggest that the association between physical activity and trait mindfulness is stronger in women (Sala et al., 2020), there is not a strong indication that either gender is more mindful than the other. That said, the present study's results do fit with previous research finding men to be more mindful than women while exhibiting less rumination and psychological distress (Kingery et al., 2023).

Additionally, the healthy nature of our sample may play a role in why trait mindfulness was not affected by physical activity. Much of the research examining beneficial effects of physical activity has been done in clinical samples, in which there is some condition that is being treated (e.g., low mood, obesity, etc.). In our sample, there may have been a "therapeutic ceiling effect" in which there was less room for growth in trait mindfulness and other outcomes. From a statistical standpoint, there may have been less variability throughout the sample to detect significant effects. Further, effects of physical activity on trait mindfulness have been shown to be small in studies (e.g., Mothes et al., 2014), and our analyses may have been underpowered to detect these smaller effects.

There is also a possibility that the MAAS questionnaire is not the most sensitive measure for detecting effects of physical activity on trait mindfulness. There is some evidence to suggest that the relationship between trait mindfulness and physical activity may be stronger when the former is measured multidimensionally (Sala et al., 2020). Questionnaires that measure additional aspects of mindfulness, such as nonjudgment, may be more sensitive. In this way, the construct validity, and specifically the structural validity, of the MAAS may be less than other scales such as the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006). Despite this, the MAAS is most commonly used in studies with nonclinical samples (Mesmer-Magnus et al., 2017), as well as in research specifically examining correlates of trait mindfulness with physical activity and exercise (Yang & Conroy, 2020). Overall, the MAAS has also shown to be a particularly strong measure for trait mindfulness when examining outcomes of health behaviors (Sala et al., 2020).

2.5.2 Trait Mindfulness Role as Moderator or Mediator for Neuropsychological Outcome

Results indicate that trait mindfulness did not moderate or mediate the relationship between physical activity and neuropsychological outcomes. A possible moderating effect of trait mindfulness on working memory was close but not significant. Due to a lack of significant direct effects of physical activity on changes in neuropsychological outcomes, trait mindfulness also did not mediate the relationship between physical activity and neuropsychological outcome. Interestingly, however, physical activity had a direct effect on working memory such that increases in physical activity led to decreases in working memory capacity on a task. This result would suggest a harmful effect of physical activity on cognition, but considering the lack of known empirical support for this phenomenon in the literature, this is likely an incidental and not meaningful finding. Conversely, there were significant indirect effects of trait mindfulness on reported executive functioning and learning/memory, and in the expected direction. These findings are supported by other research that has found mindfulness to be associated with enhanced executive functioning (Jaiswal et al., 2018; Riggs et al., 2015; Rodríguez et al., 2021; Short et al., 2016) and memory (e.g, Lueke & Lueke, 2019). Mindfulness activates neural networks associated with executive functioning and memory, such as the prefrontal cortex (e.g., Barnhofer et al., 2021) and hippocampus (Greenberg et al., 2019; Hölzel et al., 2011; Tang et al., 2015). Lastly, the relationship between physical activity on mood symptoms changes may have been counteracted by external factors relating to pandemic stress, which has had a well-documented effect on mood (e.g., Kujawa et al., 2020; Turna et al., 2021). That said, the staggered nature of participation in the current study (i.e., cohorts differing in start time) helped control for changes in pandemic stress that may have resulted from ebbs and flows of social restrictions.

2.5.3 Trait Mindfulness and Adherence to Physical Exercise

In Active group participants, baseline trait mindfulness did not predict adherence to the physical exercise program. This result indicates that individual differences in trait mindfulness may not directly influence engagement in physical activity. It is possible that some aspects of trait mindfulness may, in fact, lead to avoidance behaviors. For instance, greater awareness of physical discomfort from exercise, in those higher in trait mindfulness, may lead to reluctance to engage in physical activity compared to individuals lower in trait mindfulness who may divert their attention away from body sensations when exercising (i.e., using methods of distraction). More research is needed to determine how to best tailor strategies to promote engagement in physical activity.

2.5.4 Strengths and Limitations

There were many strengths with the present study. For instance, this study provided opportunities for physical exercise to older adults who were otherwise not exercising, in many cases due to Covid-related restrictions. It was also far-reaching, able to recruit Canadians across a number of different provinces. This study also addressed a gap in mindfulness and physical exercise research, primarily by investigating the relationship between the two in older adults; most research to date has examined this in adults. The screening process, including use of the PAR-Q+ questionnaire, was instrumental and effective at identifying healthy older adults and helped ensure that the recruited sample did not have any significant health risks to participating. Data collection was also rich, as several cognitive tasks were used to measure executive functioning—this contrasts with studies that only use a single measure for executive functioning (e.g., Stroop test).

There were also limitations to the current study. One such area may have been the duration of the physical exercise training program. Although physical activity lasting even as little as four weeks has shown to benefit cognition and mood (e.g., Hopkins et al., 2012), longer exercise programs, such as 12 weeks (Mothes et al., 2014), may be optimal to see changes in trait mindfulness; it may take longer for repeated changes in state mindfulness, due to exercise, to translate to changes in trait mindfulness. Although the study addressed a gap in research in this way, the healthy nature of the sample (in terms of cognitive and psychological functioning) likely limited the ability to detect effects of physical exercise on trait mindfulness and neuropsychological outcomes. Similarly, according to baseline data on physical activity, the sample did not appear to be sedentary at baseline, limiting the effects of a training program. Further, control group participants endorsed significant engagement in physical activity, thereby limiting differences between groups in this area. Another limitation of the study was the absence of a global cognitive screener that could have identified participants with cognitive impairment. Instead, this was relied on through self-report in the form of screening questions. It is therefore possible that some participants were not as cognitively intact as presumed. Regarding recruitment, participants needed access to technology (e.g., a computer/laptop and smartphone or tablet), so this did affect the representation of socioeconomic status in our sample. Although novel, and primarily due to Covid-19 pandemic restrictions (e.g., no face-to-face data collection), the remote nature of the study posed challenges, such as technological issues with accessing material. As has been seen in eHealth research (Eysenbach, 2005), there may have been more attrition compared to in-person research, which in turn would have resulted in a smaller sample size and decreased statistical power. Indeed, to detect a medium effect in the ANCOVA analysis, a sample size of 158 was needed, and regression analyses needed a sample size of 55. Lastly, although reported health behaviors such as physical activity have shown to correlate most strongly with trait mindfulness (Sala et al., 2020), the inclusion of an objective measure of physical activity could have controlled for possible subjective biases.

2.5.5 Future Directions

Future research is needed to continue to investigate the relationship of trait mindfulness and physical activity in older adults. Studies may want to use a longer exercise training program than the one in the current study, lasting at least 12 weeks. It would also be helpful to have some measure of state mindfulness throughout, so see how state mindfulness changes may be more sensitive to physical activity than trait mindfulness changes. Studies may employ data collection and physical exercise programs that are in person rather than remote, which may help with attrition. Studies that are fully remote may benefit from incorporating added elements like psychoeducation and opportunities for social identification that may help with adherence (Reis et al., 2023). In the hopes of seeing stronger relationships between trait mindfulness, physical activity, and neuropsychological outcomes, future research may want to use clinical samples of older adults (e.g., those with mild cognitive impairment, major depression, etc.).

2.5.6 Conclusion

In conclusion, the present study aimed to explore the intersection of trait mindfulness, physical activity, and neuropsychological outcomes in older adults in an entirely remotely conducted study. The findings revealed that trait mindfulness in healthy older adults was not significantly influenced by engaging in physical activity, contrary to hypotheses. Various factors, including sample characteristics and possible limitations of the trait mindfulness measure, may have contributed to these results. Although trait mindfulness did not act as a moderator or mediator between physical activity and neuropsychological outcomes, it did show indirect positive effects on memory and reported executive functioning, providing further support for mechanistic commonalities between trait mindfulness and these areas of cognition and functioning in older adults. In the present study, baseline trait mindfulness did not predict adherence to the exercise program, suggesting that individual differences in trait mindfulness may not directly influence engagement in physical activity. Future research is needed to better understand the complexities of trait mindfulness in the context of physical activity and its effects on mood, cognition, and daily functioning.

CHAPTER III

Investigating the Impact of Ecological Momentary Assessment on Trait Mindfulness and Related Neuropsychological Outcomes in Older Adults

3.1 Abstract

Background: The practice of mindfulness has exhibited utility in enhancing neuropsychological outcomes pertaining to mood and cognition. These effects have been observed in individuals across the lifespan, and are associated with trait mindfulness, which represents the degree to which a person is generally mindful. Further, there is evidence that trait mindfulness may be impacted by ecological momentary assessment (EMA) methodology, which may be more sensitive than traditional paper-and-pencil measures to detecting related changes in psychological outcomes. However, less is known about interactions between trait mindfulness, EMA and neuropsychological outcomes in older adults. This study examines the extent to which engagement in EMA may alter trait mindfulness and how this may indirectly impact neuropsychological functioning (i.e., through mediation); further, sensitivity of EMA in detecting differences associated with trait mindfulness is explored. Method: A total of 75 participants (69% women; age 65-86) took part in the study. All participants completed a series of online questionnaires measuring trait mindfulness, mood and executive functioning, as well as a cognitive task battery, a total of three times: at baseline (Week 1), Week 9 and Week 13. In addition, participants completed an EMA protocol that included a total of four "bursts" over the course of 13 weeks: at baseline (Week 1), Week 5, Week 9, and Week 13. Each burst consisted of twice daily surveys for 7 consecutive days, with questions assessing participants' current psychological functioning (e.g., affective states). Results: EMA adherence did not significantly predict changes in trait mindfulness. EMA-measured mood did not correlate more strongly with trait mindfulness compared to mood measured with traditional questionnaires, and higher trait mindfulness was associated with less variability in EMA-measured anxiety. Gains in trait mindfulness were associated with increases in EMA-measured anxiety and decreases in traditionally-measured anxiety. Trait mindfulness did not significantly mediate the relationship between EMA adherence and neuropsychological outcomes. Conclusions: In healthy older adults, repeated emotion self-assessment may not affect trait mindfulness and lead to neuropsychological benefits. Although not necessarily correlating more strongly with trait mindfulness, EMA-measured mood can be used to detect emotion awareness while traditional questionnaires can assess emotion burden.

3.2 Introduction

Mindfulness

Mindfulness is the practice of paying attention in a particular way: on purpose, in the present moment, and nonjudgmentally (Kabat-Zinn, 2009). Originating from Buddhism approximately 2500 years ago, mindfulness has served as a significant component of Buddhist meditation training (Shonin et al., 2015). In their review, Brown and colleagues (2007) propose that the main pillars of mindfulness are awareness and attention. Specifically, mindfulness provides a clear awareness of one's experience of what is happening externally and internally (e.g., thoughts, emotions, sensations), while directing attention towards the objective qualities or characteristics of what is being observed, allowing an individual to be present in the moment. Psychology research employing mindfulness-based interventions (MBIs) has unveiled benefits across the lifespan, in regard to improved mental health (Dunning et al., 2019; McClintock et al., 2019; Reangsing et al., 2021) and cognition (Hazlett-Stevens et al., 2019; Im et al., 2021; Wood et al., 2018).

Trait Mindfulness

Trait mindfulness, also known as dispositional mindfulness, refers to an individual's general level of mindfulness across situations and time (Sala et al., 2020). In addition to increasing as a result of mindfulness training, trait mindfulness at baseline has shown to moderate the effects of mindfulness training (Shapiro et al., 2011). In contrast to trait mindfulness, state mindfulness is the extent to which an individual experiences mindfulness in a given moment. Both trait and state mindfulness represent ways in which mindfulness can be measured in a person, and not surprisingly, they are highly correlated with one another. For instance, changes in state mindfulness across the duration of a mindfulness-based intervention have shown to predict pre-post changes in trait mindfulness (Kiken et al., 2015). However, much more research has studied and measured trait mindfulness compared to state. Like MBIs, trait mindfulness is associated with enhanced mental health (Medvedev et al., 2018; Mesmer-Magnus et al., 2017; Tomlinson et al., 2018). Regarding cognition, trait mindfulness is particularly associated with greater executive functioning (EF), such as inhibition, working memory and shifting/cognitive flexibility (Jaiswal et al., 2018; Molina-Rodríguez et al., 2021; Riggs et al., 2015).

To date, measurement of trait mindfulness is primarily conducted through self-report questionnaires. Commonly used scales differ in the extent to which they measure facets of mindfulness. Extensive, multidimensional scales offer the range to examine the effects of trait mindfulness in a well-rounded fashion, using a facet-level approach (Rau & Williams, 2016). Such multifaceted measures support a multidimensional construct of mindfulness, in which each component is relatively independent from one another. Examples of scales that consist of several factors include the 5-factor Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006) and the 4-factor Cognitive and Affective Mindfulness Scale—Revised (CAMS-R; Feldman et al., 2007). Conversely, questionnaires that consist of one or two factors offer greater robustness in measuring a specified facet of trait mindfulness, which may be particularly useful when there is empirical evidence supporting the relative strength of one or two trait mindfulness facets in regard to association with outcomes. Further, these scales fit with theoretical conceptualizations that propose a more unidimensional characteristic of mindfulness (e.g., Brown et al., 2007; Kabat-Zinn, 2003). Examples of such scales include the single-factor Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) or the 2-factor Philadelphia Mindfulness Scale (PHLMS; Cardaciotto et al., 2008).

Ecological Momentary Assessment – A Brief Overview

Differing from more retrospective reporting methods in psychology research, ecological momentary assessment (EMA) is a category of assessment methodology that employs measurement in real-time. As indicated in its name, a key feature of EMA is its collection of data in an individual's real-world, "ecological" environment (Shiffman et al., 2008). In addition, participants are asked to assess their current state, in that moment ("momentary"), rather than recalling or summarizing their experiences over the course of a longer period of time (e.g., the past two weeks). In their 2008 review, Shiffman and colleagues identify two further features that are typical in EMA: (1) assessments are usually completed over several time points, to capture variability of experiences and behaviour across time and situations; and (2) these time points, although variable, are often purposefully selected based on events of interest (e.g., eating a meal), by random sampling, or by other sampling schemes according to the nature of the study. Essentially, EMA attempts to capture the dynamic ebb and flow of moment-to-moment, real-world experiences and behaviour across time and circumstances (Shiffman et al., 2008).

There has been a variety of data collection instruments used in EMA methodology since its inception (e.g., diaries, journaling), but it is through the use of smartphone apps that EMA has recently surged. This particular medium of EMA offers familiarity and convenience to participants who are otherwise used to using their device, and it allows researchers to customize the content and formatting of surveys (Runyan & Steinke, 2015). EMA is also more accessible, as users are more easily able to respond quickly to notifications; this also makes it easier and more practical for researchers to use random sampling time points and limit convenience sampling that is more prevalent in other modes of EMA. Limited time windows to respond to questions can be utilized to further decrease convenience sampling (Runyan & Steinke, 2015).

Recruitment has also enhanced due to smartphone platforms for EMA, as the number of people who own smartphones has drastically increased in recent years, including over 70% of the population in the Western world (de Vries et al., 2021).

EMA and Mindfulness

EMA has been a useful methodology in mindfulness research. A recent systematic review by Enkema and colleagues (2020) investigated research employing EMA methodology to assess associations between mindfulness and mental health outcomes. Findings from the 23 included studies indicated that EMA is sensitive to detecting positive associations between mindfulness and mental health, demonstrating some evidence for producing larger effect sizes compared to more traditional measures and method designs. These associations were seen in experimental studies (i.e., using mindfulness training as an intervention), as well as observational studies that examined relationships between trait and/or state mindfulness and mental health (Enkema et al., 2020). One such observational study found that higher trait mindfulness, in college students, was associated with greater emotion differentiation (i.e., insight) and less emotional difficulties as reported through EMA (Hill & Updegraff, 2012). A more recent study by Szeto et al. (2019) found associations between EMA-measured craving and drinking with trait mindfulness in alcohol-dependent patients, such that those higher in trait mindfulness exhibited less craving, which in turn led to less drinking behavior. Overall, EMA has shown value as an effective methodology in detecting associations between mindfulness and mental health outcomes, with some evidence indicating that EMA is more powerful than traditional measures in measuring these relationships.

In addition to demonstrating assessment-related utility in mindfulness research, EMA may have therapeutic benefits as well. In particular, there is emerging evidence to suggest that

EMA may, as a byproduct, increase mindfulness (Runyan et al., 2013). It has been theorized that this occurs through increases in attention and self-awareness by repeatedly facing questions about one's behaviours, thoughts and emotions in close contextual and temporal proximity to when they occur; this mindfulness enhancement in turn can lead to positive change in behavior, thought patterns or states (Shiffman, 2009). In this way, EMA can be repurposed and altered to provide ecological momentary intervention (EMI). Runyan and colleagues (2013) tested the feasibility and effectiveness of an EMA/EMI smartphone app in promoting self-awareness of time-management in college students, and found that the vast majority (80.5%) endorsed greater awareness, with some (43.9%) even changing how they spent their time. A more recent study by Folkersma et al. (2021) used EMI to treat depression in adults, and based on qualitative analysis of interviews, it was found that increased self-awareness and insight were among the greatest benefits endorsed by participants, in addition to self-management. However, there was no significant change in the degree of depressive symptoms themselves, indicating that EMI (via an EMA approach) that increases self-awareness and insight may help individuals to confront and deal with their symptoms rather than reduce the symptoms themselves (Folkersma et al., 2021). In contrast, reduction of worrying has been seen in young adults with Generalized Anxiety Disorder, even after a brief (e.g., 10-day) period of EMI (LaFreniere & Newman, 2016).

Taken together, four main themes have emerged from the literature: (a) mindfulness practice and trait mindfulness are associated with enhanced mental health and cognition, (b) EMA is sensitive to detecting changes in mindfulness and its association with mental health, (c) individuals with higher trait mindfulness may exhibit greater differentiation of emotionality assessed with EMA, and (d) undergoing an EMA regiment may increase mindfulness through attention and self-awareness. The purpose of the current study is to examine the relationship between EMA and trait mindfulness, as well as related neuropsychological outcomes, in older adults. We hypothesize that (a) older adults with higher adherence to EMA will exhibit greater increases in trait mindfulness, (b) mood changes captured through EMA will correlate more strongly with changes in trait mindfulness compared to mood changes that are measured with more traditional questionnaires, (c) older adults with higher trait mindfulness will demonstrate greater differentiation in emotionality than those with lower trait mindfulness, and (d) trait mindfulness will mediate the relationship between EMA adherence and neuropsychological outcomes relating to mood and cognition.

3.3 Method

3.3.1 Participants

A total of 75 participants took part in the study (see Table 3.1). Participants were recruited from various organizational, provincial, and national newsletters and listservs in Canada, in addition to social media posts and advertisements. They included older adults living in Canada who were at least 65 years of age and had access to a computer and smartphone or tablet. As part of study examining the effects of a physical exercise training program, participants were excluded if they (a) already regularly engaged in moderate-vigorous physical activity more than four times per week, (b) failed a health screener (PAR-Q+), (c) had a significant neurological history, including traumatic brain injury (TBI), or (d) had a history of substance abuse.

Table 3.1. Sociodemographic Characteristics of Participants in Study 2 at Baseline

Baseline characteristic	*n*	%
Gender		
Female	52	69
Male	23	31
Race/ethnicity		
White	74	99
South Asian	1	1
Highest educational level		
High School	6	8
College/University	33	44
Master's Degree	14	19
Doctoral Degree	3	4
Other	6	8
Province		
Ontario	9	12
British Columbia	57	76
Nova Scotia	3	4
Prince Edward Island	1	1
Manitoba	1	1
Quebec	3	4
Alberta	1	1
Urban	58	77
Rural	17	23

Note. Participants were on average 69.9 years old (*SD* = 4.3), median income was $80,000-99,999.

3.3.2 Measures

Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003)

The MAAS was developed by Brown and Ryan (2003) to measure trait mindfulness and its role in psychological well-being. It consists of 15 items that are rated on a 6-point Likert scale. Specifically, each item is a statement of which the individual rates the frequency, from "Almost Always" to "Almost Never." Interestingly, the items themselves actually reflect mindlessness (e.g., "I find myself doing things without paying attention"), as the authors determined that such statements were more easily accessible given evidence that mindless states are more common than mindful states. The MAAS has been the most commonly used measure in studies of mindfulness with nonclinical samples (Mesmer-Magnus et al., 2017), and in intervention studies, mindfulness training has indeed been found to positively correlate with scores on the MAAS (Quaglia et al., 2016). In terms of reliability, the MAAS has high test-retest reliability as well as internal consistency, as demonstrated at its inception and again more recently (Osman et al., 2016). In addition to being used to investigate relationships between trait mindfulness and outcomes of mood and cognition, the MAAS has been found to be a particularly strong measure when examining outcomes of health behaviors (Sala et al., 2020). Further, it is the most commonly used measure of trait mindfulness in research assessing the correlates of trait mindfulness with physical activity and exercise (Yang & Conroy, 2020). Total score on the MAAS will be used in analyses.

Ecological Momentary Assessment on the Ethica Application

EMA was conducted using the Ethica application (Ethica Data, 2020), which runs on smartphones and tablets. The primary design for EMA surveys followed a "burst" pattern, in which surveys were released 2 times a day for 7 consecutive days. These bursts occurred a total of 4 times over the course of 13 weeks, to align with a physical exercise training program that was part of a larger study. Surveys were released at randomized times during the morning (between 6:30am and 8:30am) and evening (between 6:30pm and 8:30pm). Morning surveys primarily involved questions about their current states (e.g., mood, arousal and health), as well as questions about their environment (see Appendix B). Questions about mood included items grouped into positive emotions and negative emotions. Positive emotion items (e.g., "in good spirits") were derived from the National Survey of Daily Experiences (NSDE; Ryff & Almeida, 2009), and negative emotion items (e.g., “fearful”) were derived from EMA adaptations to the National Institutes of Health (NIH) Patient Reported Outcomes Measurement Information System (PROMIS) depression and anxiety short forms (Moore et al., 2016). Participants rated the extent to which they were experiencing all mood/affect items using a 5-point Likert scale (“not at all” to “very much”). Evening surveys included these items as well as questions about physical activity and nutrition. Each burst EMA survey took approximately 5 minutes to complete.

Geriatric Depression Scale-Short Form (GDS-SF; Sheikh & Yesavage, 1986)

The GDS-SF is an established 15-item self-report questionnaire that measures depressive symptoms. Each item consists of a “Yes/No” question, and the participant answers based on how they have been feeling over the past week. Lower scores indicate less depression whereas higher scores indicate greater depression. The GDS-SF has been used extensively with the older adult population, including those who are healthy and live in the community. It demonstrates high sensitivity and specificity, successfully differentiating depressed from non-depressed individuals (Sheikh & Yesavage, 1986). Total score for the GDS-SF will be used in analyses.

Generalized Anxiety Disorder 7-item Scale (GAD-7; Spitzer et al., 2006)

The GAD-7 is a brief 7-item self-report questionnaire that measures anxiety. Each item consists of potential problems experienced (e.g., feeling nervous), of which the participant is asked to rate the frequency over the past 2 weeks. Each item is rated using a 4-point Likert scale, ranging from “Not at all” to “Nearly every day.” Lower scores indicate less anxiety whereas higher scores indicate greater anxiety. The GAD-7 has been used extensively with the older adult population, including those who are healthy and live in the community. It demonstrates high sensitivity and specificity for Generalized Anxiety Disorder, and moderate sensitivity and specificity for other related anxiety disorders (e.g., Social Anxiety Disorder; Spitzer et al., 2006). Total score for the GAD-7 will be used in analyses.

Executive Function Index (EFI; Spinella, 2005)

The EFI is a 27-item self-report questionnaire that measures executive behaviour. Participants rate how well each item/statement describes them, using a 5-point Likert scale ranging from “Not at all” to “Very much.” While there is an overall composite score, items fall under five different subscales: Strategic Planning (SP), Organization (ORG), Impulse Control (IC), Empathy (EM), and Motivational Drive (MD). Higher scores indicate more enhanced executive behaviour. The EFI has robustly correlated with other self-report scales of executive behaviour (e.g., the Frontal Systems Behavior Scale), and its internal consistency is acceptable (Spinella, 2005). Total score for the EFI will be used in analyses.

Simon Task (Simon, 1969)

The Simon Task is a measure of inhibition. During the task, the words “Left” or “Right” will appear randomly on either side of a cross in the middle of the screen. If the word “Left” appears on either side, participants must click “F”. If the word “Right” appears on either side, participants must click “J”. Trials were “congruent” if the word presented on the same side as the appropriate response key (e.g., “Right” on the right side of the screen), and trials were “incongruent” if the word presented on the opposite side (e.g., “Right” on the left side). The Simon Task has been used in research to demonstrate effects of mindfulness on inhibition (Colzato et al., 2015; Eichel & Stahl, 2017). The difference between mean reaction time of congruent versus incongruent trials is the primary outcome variable.

N-Back (2-Back; Kirchner, 1958)

The 2-Back is a cognitive task that measures updating of working memory. During the task, a series of letters appears on the participant's computer screen, one at a time for 1 second each. For each letter, the participant must press "F" on their keyboard for "yes" if that letter is the same as 2 letters ago, or "J" for "no" if it is different from 2 letters ago. The 2-Back has been used in mindfulness research, demonstrating correlations with trait mindfulness (e.g., Ruocco & Wonders, 2013). Total accuracy on the 2-Back (i.e., number of "hits") will be used in analyses.

Cued Task Switching (Allport et al., 1994)

Cued Task Switching measures a participant's ability to shift between two sets of rules in a single task. There are two sets of stimuli: words (COLOUR and SHAPE) and shape (square or rectangle that is blue or green). First a word is presented, followed by a shape. If the word is "COLOUR", participants must click "F" if the shape is blue and "J" if it is green. If the word is "SHAPE", participants must click "F" for square and "J" for a rectangle. Performance on Cued Task Switching paradigms has specifically been shown to correlate with trait mindfulness (Aguerre et al., 2021). The primary outcome variable is switch cost, which is the difference in reaction time between consecutive trials and switch trials.

Iowa Gambling Task (Bechara et al., 1994)

The Iowa Gambling Task is a measure of higher-order executive functions. Participants are given $2000 and presented with four decks (A, B, C, D). They are told that each deck pays a reward that sometimes has a fee, and are instructed to make the most money possible. Decks A and B happen to pay $100 but have a fee of $250, whereas decks C and D pay $50 but have a fee of $50. The task is designed so that in order to make the most money over time, participants should choose decks C and D. Conversely, participants who choose decks A and B will lose money over time. The Iowa Gambling Task has been demonstrated to correlate with trait mindfulness (e.g., Lakey et al., 2007). The total score, based on money gained and lost, will be used in analyses.

Sustained Attention Reaction Test (SART)

The SART measures sustained attention and processing speed. Adapted from other sustained attention tasks (e.g., Sustained Attention to Response Task by Robertson et al., 1997), this task instructs participants to stare at the middle of the screen as a series of letters are presented, and to press the spacebar whenever an “X” is presented. Participants are asked to answer as quickly and as accurately as possible. Research has shown strong associations between mindfulness and sustained attention as measured by the SART (e.g., Ueberholz & Fiocco, 2022). Mean reaction time on hits (i.e., responses to “X”) is the main outcome variable used in analyses.

Hebb Learning (Page et al., 2006)

The Hebb Learning task measures memory of a list of words (animal names) and their order of presentation. The task has two parts: first, a list of animals is presented for 2 seconds per animal. Then, nine drawings of animals in a 3x3 grid are presented in random order and participants are asked to recall the wordlist by clicking on each animal in the same order the words were presented. Some lists of animals are repeated multiple times. Although this particular task has not been used in mindfulness research, other wordlist learning tasks have, demonstrating high sensitivity to the effects of mindfulness (Lueke & Lueke, 2019). The primary outcome variable is number of correctly recalled animals.

3.3.3 Procedure

This study was approved by the Human Research Ethics Board at the University of Victoria (Protocol Number: 19-0455). All data collection was conducted remotely, online or through a phone/tablet application. After answering screening questions, participants provided signed, informed consent. Participants were then added to an online platform that contained study materials, including links to assessment questionnaires and cognitive tasks. Participants were given a week to complete an initial baseline assessment that involved completing a questionnaire battery on Qualtrics (qualtrics.com), including a history questionnaire inquiring about demographics (see Appendix A), mood and EF scales; they also completed a cognitive task battery on Gorilla (gorilla.sc), which has been validated for use as an online experiment-building platform (Anwyl-Irvine et al., 2020). In total, the questionnaires and cognitive tasks took approximately 1.5 hours to complete. All participants repeated these same measures (except the history questionnaire) two more times throughout the course of the study: at 10 weeks and 13 weeks.

In addition to these primary assessment timepoints, participants completed a total of 4 EMA bursts over the course of 13 weeks: at baseline (Week 1), Week 5, Week 10, and Week 13. Before starting, participants were sent instructions via email on how to download the Ethica app, create an account, and register for the study. Once registered, surveys were triggered to begin on the following day. In addition to completing the burst surveys over a total of 4 weeks, participants completed daily, abbreviated (i.e., <1-minute long) surveys inquiring about their physical activity each day (see Appendix C).

3.3.4 Statistical Analyses

To account for possible effects of gender, an independent samples *t*-test was conducted comparing trait mindfulness between men and women in the overall sample. Although age effects were not necessarily anticipated given the restricted age range of older adults, a bivariate correlation was used to determine if there is a significant relationship between age and trait mindfulness in the overall sample. Further, bivariate correlations were conducted to test for effects of education level and socioeconomic status (estimated by total annual income) on trait mindfulness.

To test whether adherence to EMA predicts increases in trait mindfulness, a linear regression was conducted, with total percentage of completed burst surveys as the independent variable (i.e., adherence), and total change in trait mindfulness (i.e., Week 1 to Week 13) as the dependent variable.

To determine whether mood changes assessed through EMA would correlate more strongly with changes in trait mindfulness compared to changes in mood that are measured with more traditional questionnaires, bivariate correlations were conducted with EMA mood changes, GDS and GAD-7 changes, and trait mindfulness change as variables.

To examine potential differences in differentiation of EMA-assessed emotionality based on level of trait mindfulness, bivariate correlations were conducted with baseline trait mindfulness, negative emotion (i.e., PROMIS anxiety and depression items) differentiation, and positive emotion (i.e., NSDE positive affect items) differentiation as variables. Variance values indicating emotion differentiation were calculated for positive emotions, depressive symptoms, and anxiety symptoms.

To assess trait mindfulness as a mediator for the relationship between EMA adherence and neuropsychological outcomes, structural equation modeling was used to test direct, indirect and total effects, with total change in trait mindfulness as the mediator, total percentage of completed burst surveys as the independent variable, and total change in GDS, GAD-7, EFI, and cognitive task scores as the dependent variables.

3.4 Results

All assumptions for analyses were satisfied, and statistical outliers were removed as necessary. In terms of attrition, 26% of participants (n=20) dropped out at various stages throughout the study. Listwise deletion was used to handle missing data, including data missing due to attrition; only participants with complete data were used in analyses.

3.4.1 Preliminary Analyses

Preliminary analyses were carried out to assess the impact of age, gender, education level, and socioeconomic status as potential covariates of baseline trait mindfulness. Age did not show a significant correlation with trait mindfulness ($r = 0.07$, $p = 0.58$). However, a significant difference in trait mindfulness between men and women in the overall sample was found, $t(68) = -2.92$, $p < 0.01$, with men having greater trait mindfulness than women at baseline. Bivariate correlations indicated no significant associations between trait mindfulness and education level ($r = -0.09$, $p = 0.52$) or socioeconomic status as estimated by total annual income ($r = -0.18$, $p = 0.14$).

3.4.2 EMA Adherence and Trait Mindfulness

A linear regression showed that across all participants, total percentage of completed burst surveys did not significantly predict changes in trait mindfulness $F(1,40) = 0.13$, $p = 0.72$, $R^2 = 0.003$. Average adherence was 79% of released surveys. Of note, current mindfulness meditation practice was accounted for at baseline for only some participants, due to this question being incorporated later in the study. Only six participants endorsed practicing mindfulness meditation.

3.4.3 EMA Mood Correlations with Trait Mindfulness

Table 3.2 shows bivariate correlations between changes in trait mindfulness and mood as measured through EMA versus standardized paper-and-pencil questionnaires. Changes in trait mindfulness did not significantly correlate with mood changes as assessed by standardized questionnaires, but did for changes in anxiety ratings as measured through EMA burst surveys, $r = 0.38$, $p = 0.02$. Further, after visual inspection of scatterplots, an outlier was removed from the analysis involving the traditional measure of anxiety (GAD-7), and a significant correlation was found, $r = -0.35$, $p = 0.02$. In sum, gains in trait mindfulness were associated with increases in EMA-measured anxiety, but linked with decreases in GAD-measured anxiety.

Table 3.2. Bivariate Correlations of Changes in Trait Mindfulness and Mood

Pearson's Correlations

Variable		MAAS_A1-A3w Change	GDS_A1-A3w Change	GAD-7_A1-A3w Change	Burst A1-A3w Positive Affect Change	Burst A1-A3w Anxiety Change	Burst A1-A3w Depression Change
1. MAAS_A1-A3w Change	n	—					
	Pearson's r	—					
	p-value	—					
2. GDS_A1-A3w Change	n	42	—				
	Pearson's r	0.082	—				
	p-value	0.606	—				
3. GAD-7_A1-A3w Change	n	41	43	—			
	Pearson's r	-0.353*	0.379 *	—			
	p-value	0.021	0.012	—			
4. Burst A1-A3w Positive Affect Change	n	41	42	42	—		
	Pearson's r	0.138	-0.099	-0.204	—		
	p-value	0.390	0.533	0.194	—		
5. Burst A1-A3w Anxiety Change	n	41	42	42	50	—	
	Pearson's r	0.375 *	0.310 *	0.261	-0.107	—	
	p-value	0.016	0.045	0.095	0.462	—	
6. Burst A1-A3w Depression Change	n	41	42	42	50	50	—
	Pearson's r	0.147	0.005	-0.165	0.009	0.635 ***	—
	p-value	0.359	0.974	0.296	0.951	< .001	—

* p < .05, ** p < .01, *** p < .001

3.4.4 Trait Mindfulness and EMA-Assessed Emotion Differentiation

Table 3.3 shows bivariate correlations between baseline trait mindfulness and mood variance. Trait mindfulness was significantly, but negatively, correlated with anxiety symptom variance, $r = -0.32$, $p = 0.01$, meaning that participants higher in trait mindfulness showed less emotion differentiation.

Table 3.3. Bivariate Correlations of Baseline Trait Mindfulness and Mood Variance

Pearson's Correlations

Variable		MAAS A1	Burst A1 Positive Affect Variance	Burst A1 Anxiety Variance	Burst A1 Depression Variance
1. MAAS A1	Pearson's r	—			
	p-value	—			
2. Burst A1 Positive Affect Variance	Pearson's r	0.129	—		
	p-value	0.315	—		
3. Burst A1 Anxiety Variance	Pearson's r	-0.319 *	0.046	—	
	p-value	0.011	0.709	—	
4. Burst A1 Depression Variance	Pearson's r	-0.021	-0.062	0.338 **	—
	p-value	0.872	0.616	0.005	—

* p < .05, ** p < .01, *** p < .001

3.4.5 Trait Mindfulness Role as Mediator for EMA Adherence and Neuropsychological Outcome

Structural equation modeling did not reveal any significant mediating effects of trait mindfulness on the relationship between EMA adherence and neuropsychological outcomes. There were no significant direct effects of EMA on neuropsychological change (see Table 3.4). Of note, there were indirect effects between increases in trait mindfulness and gains in working memory ($z = 3.37$, $p < .001$), shifting ($z = -2.14$, $p = 0.03$), and attention ($z = -2.67$, $p = 0.01$).

Table 3.4. Direct Effects of EMA on Neuropsychological Change

Outcome	**z-value**	***p***
EFI	-0.52	0.60
GDS	-1.43	0.15
GAD-7	-0.39	0.70
Simon Task	-1.66	0.10
N-back	0.60	0.55
CTS	-1.53	0.13
Iowa Gambling	-0.02	0.99
Hebb Learning	0.96	0.34
SART	-0.57	0.57

3.5 Discussion

The purpose of the present study was to examine the malleability of trait mindfulness from engagement in EMA, its role in the relationship between EMA adherence and neuropsychological outcomes, and the sensitivity of EMA in detecting associations between mood and trait mindfulness. Trait mindfulness was repeatedly measured in older adults who engaged in a total of four one-week long EMA "bursts" that included twice daily surveys, in addition to completing online neuropsychological measures. Contrary to our hypotheses, EMA adherence did not significantly predict changes in trait mindfulness. Further, EMA-measured mood did not correlate more strongly with trait mindfulness compared to mood measured with traditional questionnaires, and higher trait mindfulness was associated with less differentiation of EMA-measured anxiety. Contrary to hypotheses, trait mindfulness did not significantly mediate the relationship between EMA adherence and neuropsychological outcomes relating to mood and cognition. However, indirect effects showed that gains in trait mindfulness were associated with improved performance on tasks measuring attention, working memory, and shifting.

3.5.1 EMA Adherence and Trait Mindfulness

The results of the current study demonstrated that EMA adherence did not predict changes in trait mindfulness. Specifically, trait mindfulness was not affected by frequency of emotion "check-ins" in older adults across a 13-week period. These results suggest that repeated, directed attention to emotional states may not impact trait mindfulness to the degree that was anticipated. There may be at least two reasons for this in our study. First, the way in which participants tuned into their emotions may have been a factor. Although there were no measures to account for this, it is possible that some participants may not have paid attention fully each time and instead answered questions too quickly. In such cases, participants' check-ins may not have affected their level of awareness that would be captured in trait mindfulness, particularly by the MAAS whose primary tenets are attention and awareness (Brown & Ryan, 2003). This potential effect is supported by research demonstrating a strong link between attention and trait mindfulness, such that those who exhibit greater attention are higher in trait mindfulness (Verhaeghen, 2021). That said, this same logic would suggest that those who are higher in trait mindfulness may be more likely to attend to EMA survey questions and tune in to their emotional states. Therefore, this may not necessarily be a likely explanation for the findings.

A more likely reason for EMA adherence not impacting trait mindfulness in the sample may have to do with the present study's EMA design. Specifically, the frequency and duration of EMA survey administration may not have been high enough to affect trait mindfulness, even in participants who responded to each survey. Typical duration of EMA burst surveys were less than 5 minutes, and even if participants had actually meditated instead for that long, it may not have been enough duration to impact mindfulness. Likewise, survey frequency, which included consecutive weeks of non-responding in between bursts, may not have been enough to affect change in trait mindfulness. Indeed, research has demonstrated that the effectiveness of meditation in leading to the application of daily mindfulness—essentially, trait mindfulness—is enhanced through greater duration and frequency of meditation sessions (Lacaille et al., 2018). The same could apply to EMA surveys, but certainly more research is needed to determine this.

3.5.2 Trait Mindfulness and EMA-Assessed Mood and Emotion Differentiation

Results indicate that the relationship between trait mindfulness and mood is not stronger when assessed with EMA versus traditional questionnaires. This suggests that EMA is not any more sensitive to detecting associations between in mood and trait mindfulness compared to traditional questionnaires. Although emotion evaluation through EMA is more in-the-moment, and aligned with the principle of mindfulness, psychometric considerations are warranted. For example, there are psychometric commonalities between the measurement of trait mindfulness and the measurement of mood using traditional questionnaires in terms of question wording and response format. Both require individuals to think about their feelings or behavior over a previous period of time, rather than in the moment, as well as ask individuals to rate the frequency of phenomena. These similarities are relevant psychometric considerations and may influence correlations between measures (Groves et al., 2009).

An interesting, and initially perplexing, finding is the correlation between gains in trait mindfulness with decreases in questionnaire-measured anxiety, but increases in EMA-measured anxiety. A possible explanation for this difference is the way in which anxiety symptoms are assessed. In the anxiety questionnaire, symptoms are rated based on the degree to which the individual is *bothered* by them (e.g., bothered by trouble relaxing), whereas in the EMA items, individuals rate the extent to which they *experienced* certain feelings (e.g., feeling uneasy). Core facets of mindfulness include attention and awareness, as well as nonjudgment (Brown et al., 2007; Kabat-Zinn, 2009), so it's possible that participants in our sample who gained trait mindfulness may have also gained awareness of anxiety symptoms but were less bothered by them. This would lend support to the notion that mindfulness increases individuals' awareness of their internal states, and in doing so, lessens their judgment of their experiences (Kabat-Zinn, 2003; O'Brien et al., 2018).

Contrary to hypotheses, higher baseline trait mindfulness was associated with less emotion differentiation. This indicates that in our sample, participants with greater trait mindfulness showed less nuance in their rating of similar emotions. The initial interpretation is that less emotion differentiation reflects less awareness of experienced emotions, which contradicts mindfulness and the measurement of trait mindfulness. However, this interpretation assumes that individuals who rate their emotions similarly are, in actuality, experiencing emotions at varying levels. Conversely, it is possible that ratings of low emotion variability actually reflect true emotional states. This may subsequently mean that individuals who are high in trait mindfulness may experience more emotional stability, a notion that is supported in the literature (e.g., Ayesha et al., 2020; Bajaj et al., 2019).

3.5.3 Trait Mindfulness Role as Mediator for EMA Adherence and Neuropsychological Outcome

Structural equation modeling did not show a significant mediating effect of trait mindfulness on the relationship between EMA adherence and neuropsychological outcomes. This was largely due to a lack of significant direct effects, which indicated that participating in EMA may not impact mood or cognition. These results contrast with previous research finding benefits of EMA for reducing anxiety (LaFreniere & Newman, 2016) but support other research showing no reduction in depressive symptoms following EMA (Folkersma et al., 2021). However, a difference for the current study is that the EMA items did not consist of therapeutic, cognitive-behavioral techniques (e.g., thought challenging) whereas previous research has. This may suggest that just raising awareness may not be enough to improve mood.

Of note, however, significant indirect effects were observed between trait mindfulness and aspects of cognition, such that gains in trait mindfulness were associated with improvements in cognitive performance. Specifically, increases were observed in performance on tasks measuring working memory, shifting, and attention. These findings are supported by research demonstrating positive effects on attention and executive functioning by mindfulness practice (Hazlett-Stevens et al., 2019; Isbel et al., 2020; Yu et al., 2021) and trait mindfulness (Jaiswal et al., 2018; Molina-Rodríguez et al., 2021; Riggs et al., 2015). Indeed, there is robust evidence to suggest that mindfulness and executive functioning share several neural correlates. For instance, the anterior cingulate cortex (ACC) is a brain region heavily involved in attention regulation that has shown activation during mindfulness meditation (Hölzel et al., 2011; Kwak et al., 2020; Marchand, 2014). Mindfulness has also been associated with changes in the hippocampus (Marchand, 2014), which has demonstrated involvement in working memory (e.g., Cabeza et al., 2002).

3.5.4 Strengths and Limitations

The current study had numerous strengths. For instance, it had a broad reach of participation, recruiting participants from a multitude of Canadian provinces. This study also filled a research gap by exploring the interactions of EMA, mindfulness, and neuropsychological functioning, and doing so in a comparatively understudied age range including healthy older adults. Additionally, the richness and variety of data collection was notable, incorporating EMA, traditional questionnaires, and cognitive measures. Both reported and tested executive functioning were assessed, the latter of which with numerous cognitive tasks measuring executive functions of inhibition, working memory, and shifting.

This study was not without its limitations. One such area could be the use of a sample with generally healthy cognitive and psychological functions, which may have constrained the ability to detect the effects of EMA on trait mindfulness and neuropsychological outcomes due to ceiling effects. In other words, since the sample was already functioning relatively well, there was potentially less room for positive change over the course of participation. Additionally, the requirement for participants to have access to specific technology for EMA (i.e., a smartphone or tablet) limited the study’s representation of socioeconomic status and potential generalizability of findings. Another limitation was relying on self-report of cognitive health during the screening process, rather than using a global cognitive screener. It is therefore possible that some participants were not as cognitively intact as presumed and could have been impaired. In addition, the fully remote nature of the study, although novel and primarily due to Covid-19 pandemic restrictions (e.g., no face-to-face data collection), presented challenges including technological hurdles of accessing materials compared to in-person studies. This remote design may have contributed to higher attrition rates, leading to a smaller sample size and reduced statistical power, which is consistent with findings in eHealth research (Eysenbach, 2005). Indeed, to detect a medium effect in regression analyses, a sample size of 55 was needed. Lastly, although appropriate for the purposes of the original study, the gaps in time (multiple weeks) of when participants completed EMA surveys assessing their mood likely limited effects on trait mindfulness.

3.5.5 Future Directions

To further explore the dynamics between EMA, trait mindfulness, and neuropsychological functioning in older adults, future studies might consider using a more consistent EMA survey schedule. Twice daily surveys that are released over the course of several consecutive weeks may have a greater impact on trait mindfulness, for instance. Alternatively, each survey could be longer in duration and/or occur several times a day. Future studies may also benefit from incorporating a measure of state mindfulness along with trait mindfulness; this would offer insight into how state mindfulness may differentially correlate with EMA-measured mood, as well as how it may be more sensitive to EMA. Additionally, conducting studies with in-person data collection (for non-EMA measures), instead of fully remote data collection, may help mitigate attrition issues. For studies that are fully remote, incorporation of psychoeducation and opportunities for social identification, which may help with adherence (Reis et al., 2023), may be beneficial. Lastly, future research could focus on clinical samples, such as those with mild cognitive impairment or a mood disorder, in order to yield more robust findings on the relationships between EMA, trait mindfulness, and neuropsychological functioning.

3.5.6. Conclusion

In conclusion, the present study aimed to explore the dynamics of EMA, trait mindfulness, and neuropsychological outcomes in older adults. Results indicated that participation in EMA did not significantly influence changes in trait mindfulness over a 13-week period, highlighting the need for further exploration of the optimal frequency and duration of EMA surveys to potentially enhance mindfulness. EMA did not demonstrate greater sensitivity in detecting associations between mood and trait mindfulness compared to traditional questionnaires. However, EMA-measured anxiety correlated differently with trait mindfulness compared with traditionally measured anxiety in a way that indicated gains in trait mindfulness may be associated with increased awareness but decreased in judgment of symptoms. Further, individuals with higher trait mindfulness showed less emotion differentiation, suggesting a potential link between mindfulness and emotional stability. Although gains in trait mindfulness did not mediate the relationship between EMA adherence and neuropsychological outcomes, it was associated with improvements in attention and executive functions of working memory and shifting, providing evidence for potential benefits of trait mindfulness on cognitive functioning in older adults. Future research is needed to further elucidate the complex relationships between EMA, trait mindfulness, and neuropsychological functioning.

CHAPTER IV

Conclusion

In this chapter, I will first review the main findings of the two studies. Afterwards, I will discuss implications, such as those relating to malleability of trait mindfulness and its role in neuropsychological outcomes of physical activity and EMA. I will then address the contributions of the studies to the literature. Lastly, I will outline limitations in the studies, as well as areas for future research before providing final comments.

I. Main Findings

Taken together, the two studies aimed to explore the neuropsychological role and malleability of trait mindfulness in the context of physical activity (Chapter 2) and EMA (Chapter 3) in older adults. Specifically, Chapter 2 examined the malleability of trait mindfulness in response to physical activity, and what role (e.g., moderating and/or mediating) trait mindfulness may play in the relationship between physical activity and neuropsychological outcomes. Chapter 3 investigated the extent to which engagement in EMA may alter trait mindfulness and how this may indirectly impact neuropsychological functioning (i.e., through mediation), and the sensitivity of EMA in detecting associations between psychological outcomes and trait mindfulness.

Contrary to our hypotheses, the results in Chapter 2 showed that older adults who underwent an 8-week remote physical exercise training program did not make significantly more gains in trait mindfulness than the control group. Further, reported physical activity did not significantly predict gains in trait mindfulness. Also contrary to hypotheses, trait mindfulness did not moderate or mediate the relationship between physical activity and neuropsychological outcomes relating to mood and cognition. However, indirect effects were observed indicating an association between gains in trait mindfulness and increases in reported executive functioning and performance on learning/memory testing. Lastly, trait mindfulness did not significantly predict adherence to the exercise program.

Contrary to our hypotheses, results in Chapter 3 revealed that EMA adherence did not significantly predict changes in trait mindfulness. EMA-measured mood did not correlate more strongly with trait mindfulness compared to mood measured with traditional questionnaires, and higher trait mindfulness was associated with less variability of EMA-measured anxiety. In addition, gains in trait mindfulness were associated with increases in EMA-measured anxiety but decreases in traditionally measured anxiety symptoms. Contrary to hypotheses, trait mindfulness did not significantly mediate the relationship between EMA adherence and neuropsychological outcomes relating to mood and cognition. However, indirect effects were observed between increases in trait mindfulness and enhanced cognitive test performance in attention, working memory, and shifting.

II. Implications and Contributions

Trait Mindfulness Malleability

Results of these studies indicate that in older adults, trait mindfulness may not be very malleable in response to physical activity and engagement in EMA. Regarding physical activity, this contrasts with research supporting associations of mindfulness with physical health and exercise (de Bruin et al., 2016; Ede et al., 2020; Loucks et al., 2015; Lucas-Thompson et al., 2019; Mothes et al., 2014; Sala et al., 2020; Yang & Conroy, 2020), including neural commonalities (e.g., Greenberg et al., 2019; Hölzel et al., 2011; Tang et al., 2015; Van der Stouwe et al., 2018). However, most of these previous studies utilized mindfulness-based interventions, examined trait mindfulness in adults, or employed physical exercise programs of different length (e.g., 12 weeks). Results of the current studies imply that in older adults, physical activity may not enhance trait mindfulness as an alternative to other activities like mindfulness meditation. Support for EMA as a potential influencer of trait mindfulness is much scarcer in the literature, rendering the investigation by the current studies as primarily explorative in nature. Still, possible reasons for null results include the relatively healthy nature of the sample, as well as its age range; trait mindfulness and factors influencing it have not been examined much in older adults.

Although trait mindfulness did not appear to be affected by physical activity and EMA, its overall change across the entire sample indicates some malleability. There is a question now of what may have influenced this change. One possibility could be effects from participating in a research study, particularly during a time in which many interests and hobbies may have been impeded due Covid-19 pandemic restrictions. Factors relating to the pandemic itself, such as easing of restrictions or vaccine development, could have indirectly impacted trait mindfulness (e.g., through improved mood).

Trait Mindfulness Role in Neuropsychological Outcomes of Physical Activity and EMA

Results indicated that trait mindfulness may not act as a mediator for either physical activity or EMA adherence in terms of affecting neuropsychological outcomes. This lack of role is hinged on the notion that engagement in physical activity and EMA may not have the direct effects on mood and cognition in healthy older adults that was anticipated. Rather, the presence of indirect effects suggests a stronger connection between trait mindfulness and neuropsychological outcomes. Specifically, gains in trait mindfulness may be associated with improvements in shifting, working memory, attention, and learning/memory task performance, as well as reported executive functioning. These relationships fit with previous findings demonstrating behavioral and neural commonalities between mindfulness and cognitive areas relating to executive functioning (Hölzel et al., 2011; Jaiswal et al., 2018; Kwak et al., 2020; Marchand, 2014; Molina-Rodríguez et al., 2021; Riggs et al., 2015).

Other Implications

Results also indicate that an older adult's trait mindfulness heading into an exercise program may not differentially impact their adherence to physical activity or degree of neuropsychological effects associated with physical activity. In addition, although EMA did not show overall greater sensitivity to detecting associations between trait mindfulness and psychological outcomes, it revealed associations between trait mindfulness and anxiety awareness and variability. Specifically, results indicate that in older adults, greater trait mindfulness may be associated with less variability in in-the-moment anxiety feelings. Gains in trait mindfulness may also bring about heightened awareness of anxiety while mitigating its distressing impact, highlighting the coupled nature of awareness and nonjudgment in mindfulness.

Contributions to Literature

The main contributions of the studies involved addressing gaps in research. For instance, there is already much research that demonstrates cognitive, emotional, and physical benefits of mindfulness practice. There is also evidence of trait mindfulness being associated with certain health behaviors like physical activity, as well as neural correlations between mindfulness and physical activity. The present studies investigated trait mindfulness in healthy older adults, a relatively understudied population, testing proposed mechanisms and pathways in the context of physical activity and EMA that have not been fully examined in the literature. The fully remote nature of methodology (e.g., recruitment, data collection, physical exercise training program) is also a unique aspect that helps fill a gap in research, specifically that which investigates trait mindfulness.

More specifically, the first study tested a hypothesis in the literature that trait mindfulness may be impacted by physical activity and act as a potential moderator and/or mediator of physical activity's effects on cognition and mood. Although results did not find support for this, there are relevant qualifiers surrounding population (healthy older adults), length of physical exercise training program (8 weeks), and delivery of exercise program (remote) that provide nuance. Further, this first study provided evidence that engagement in physical activity may not be contingent upon one's trait mindfulness. It is important to note that the lack of significant associations found between physical activity and neuropsychological outcomes does not mean that physical activity lacks beneficial effects; there is too much evidence in the literature that suggests otherwise.

The second study provided an exploratory investigation into how engagement in EMA, a methodology growing in popularity, may itself impact trait mindfulness. This is an important consideration particularly when outcomes relating to trait mindfulness (e.g., mood and cognition) are being measured. Results did not indicate an effect of EMA engagement on trait mindfulness, or other outcomes for that matter, indicating that the practice of EMA may, in itself, not confound results when used in research examining trait mindfulness, mood, or cognition. More broadly, this study and its results support the utility of EMA in detecting in-the-moment awareness and variability of emotion, offering an alternative angle from traditional measures. It provides further support to the notion that gains in trait mindfulness are associated with increases in awareness, of anxiety in this case, but decreases in judgement.

III. Limitations and Future Research

Although these studies had many strengths, there were limitations that warrant consideration and may inform directions for future research. For instance, although appropriate for the purposes of the original study, the 8-week duration of the physical exercise training program may have not been long enough to significantly increase trait mindfulness compared to longer programs. The healthy nature of our sample—in terms of physical, psychological, and cognitive functioning—may have also limited our ability to detect the effects of physical exercise on trait mindfulness and neuropsychological outcomes, due to “ceiling” effects. Inclusion criteria involving technological requirements may have also limited the generalizability of findings due to the resulting constraints on socioeconomic representation. Although the fully remote nature of the studies was novel and primarily due to Covid-19 pandemic restrictions for research at the time (i.e., face-to-face data collection was not permitted), it may have contributed to higher than typical attrition and reduced statistical power of most analyses. Lastly, week-long gaps between surveys inquiring about in-the-moment emotions may have limited EMA effects on trait mindfulness.

Future research examining the effects of physical activity on trait mindfulness may wish to utilize longer physical exercise programs (e.g., 12 weeks), in addition to including measures of state mindfulness that may be acutely sensitive to the effects of physical activity. The use of clinical samples, such as those with mild cognitive impairment or mood disorders, may enhance the understanding of effects between physical activity, trait mindfulness, and neuropsychological outcomes. In terms of EMA effects, studies may benefit from implementing a more consistent EMA survey design that asks about emotions, such as survey completion over consecutive weeks. To help control for possible biases in self-reported physical activity, future research may wish to use objective measures of physical activity, such as Fitbits. To help limit attrition, fully remote studies may benefit from incorporating added elements like psychoeducation and opportunities for social identification.

IV. Conclusion

Taken together, these studies examined the malleability of trait mindfulness and its role in the context of physical activity and EMA in older adults. Contrary to hypotheses, results demonstrated limited malleability of trait mindfulness in response to both physical activity and EMA engagement. In addition, trait mindfulness did not significantly moderate or mediate the relationship between physical activity or EMA and neuropsychological outcomes relating to mood and cognition. Despite these null findings, the studies did offer nuanced insights into potential indirect effects of trait mindfulness on cognitive performance and reported executive functioning, as well as associations of emotion awareness, nonjudgment, and stability with trait mindfulness. Further, the studies addressed gaps in the literature by examining a relatively understudied population in trait mindfulness research and utilizing a fully remote methodology, albeit with some limitations. Future studies may involve using longer durations of physical exercise training programs, samples representing clinical populations, and altering EMA design to increase sensitivity in detecting associations with trait mindfulness. In sum, while the studies' results were generally not anticipated, they provide important insights and considerations for future research that investigates the interactions between trait mindfulness, physical activity, EMA, and neuropsychological functioning in older adults.

References

Abujaradeh, H., Safadi, R., Sereika, S. M., Kahle, C. T., & Cohen, S. M. (2018). Mindfulness-based interventions among adolescents with chronic diseases in clinical settings: a systematic review. *Journal of Pediatric Health Care*, *32*(5), 455-472.

Aguerre, N. V., Bajo, M. T., & Gómez-Ariza, C. J. (2021). Dual mechanisms of cognitive control in mindful individuals. *Psychological Research*, *85*(5), 1909-1921.

Allport, A., Styles, E. A., & Hsieh, S. (1994). Shifting intentional set: Exploring the dynamic control of tasks. *Attention and Performance XV: Conscious and Nonconscious Information Processing*, *15*, 421-452.

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, *52*(1), 388-407.

Ayesha, T., Akbar, W., & Shai, S. (2020). Mediating role of emotional stability and self-esteem between mindfulness and psychological wellbeing. *International Journal of Psychosocial Rehabilitation*, *24*(1), 5161-5174.

Baer, R.A., Smith, G.T., & Allen, K.B. (2004). Assessment of mindfulness by self-report: The Kentucky inventory of mindfulness skills. *Assessment, 11*(3), 191–206.

Baer, R.A., Smith, G.T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment, 13*(1), 27–45.

Bajaj, B., Gupta, R., & Sengupta, S. (2019). Emotional stability and self-esteem as mediators between mindfulness and happiness. *Journal of Happiness Studies*, *20*, 2211-2226.

Bandura, A. (2005). The primacy of self-regulation in health promotion. *Applied Psychology*, *54*(2), 245-254.

Barnhofer, T., Reess, T. J., Fissler, M., Winnebeck, E., Grimm, S., Gärtner, M., ... & Hölzel, B. K. (2021). Effects of mindfulness training on emotion regulation in patients with depression: reduced dorsolateral prefrontal cortex activation indexes early beneficial changes. *Psychosomatic Medicine, 83*(6), 579-591.

Barros, V. V. D., Kozasa, E. H., Souza, I. C. W. D., & Ronzani, T. M. (2015). Validity evidence of the Brazilian version of the Mindful Attention Awareness Scale (MAAS). *Psicologia: Reflexão e Crítica*, *28*, 87-95.

Bechara, A., Damasio, A. R., Damasio, H., & Anderson, S. W. (1994). Insensitivity to future consequences following damage to human prefrontal cortex. *Cognition*, *50*(1-3), 7-15.

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: Capturing life as it is lived. *Annual Review of Psychology*, *54*(1), 579-616.

Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review, 108*(3), 624–652.

Botvinick, M. M., Cohen, J. D., & Carter, C. S. (2004). Conflict monitoring and anterior cingulate cortex: an update. *Trends in Cognitive Sciences*, *8*(12), 539-546.

Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *Proceedings of the National Academy of Sciences*, *104*(27), 11483-11488.

Brewer, J. A., Worhunsky, P. D., Gray, J. R., Tang, Y. Y., Weber, J., & Kober, H. (2011). Meditation experience is associated with differences in default mode network activity and connectivity. *Proceedings of the National Academy of Sciences*, *108*(50), 20254-20259.

Brown, K.W., & Ryan, R.M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84*(4), 822–848.

Brown, K. W., Ryan, R. M., & Creswell, J. D. (2007). Mindfulness: Theoretical foundations and evidence for its salutary effects. *Psychological Inquiry*, *18*(4), 211-237.

Bulmer, L., Stanley, C., Loffredo, L., Mills, R., & Doyle, L. (2021). Building a foundation in self-awareness: Genetic counseling students' experiences with self-care, reflection, and mindfulness. *Journal of Genetic Counseling*. https://doi.org/10.1002/jgc4.1539

Cabeza, R., Dolcos, F., Graham, R., & Nyberg, L. (2002). Similarities and differences in the neural correlates of episodic memory retrieval and working memory. *Neuroimage*, *16*(2), 317-330.

Cardaciotto, L., Herbert, J.D., Forman, E.M., Moitra, E., & Farrow, V. (2008). The assessment of present-moment awareness and acceptance: The Philadelphia Mindfulness Scale. *Assessment*, *15*(2), 204–223.

Carlson, L. E., & Brown, K. W. (2005). Validation of the Mindful Attention Awareness Scale in a cancer population. *Journal of Psychosomatic Research*, *58*(1), 29-33.

Cayoun, B., Simmons, A., & Shires, A. (2020). Immediate and lasting chronic pain reduction following a brief self-implemented mindfulness-based interoceptive exposure task: A pilot study. *Mindfulness*, *11*(1), 112-124.

Chadwick, P., Hember, M., Symes, J., Peters, E., Kuipers, E., & Dagnan, D. (2008). Responding mindfully to unpleasant thoughts and images: Reliability and validity of the Southampton mindfulness questionnaire (SMQ). *British Journal of Clinical Psychology, 47*(Pt 4), 451–455.

Chambers, R., Lo, B. C. Y., & Allen, N. B. (2008). The impact of intensive mindfulness training on attentional control, cognitive style, and affect. *Cognitive Therapy and Research*, *32*(3), 303-322.

Chiesa, A., Calati, R., & Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clinical Psychology Review*, *31*(3), 449-464.

Colzato, L. S., Sellaro, R., Samara, I., & Hommel, B. (2015). Meditation-induced cognitive-control states regulate response-conflict adaptation: Evidence from trial-to-trial adjustments in the Simon task. *Consciousness and Cognition*, *35*, 110-114.

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Cordier, R., Brown, N., Chen, Y. W., Wilkes-Gillan, S., & Falkmer, T. (2016). Piloting the use of experience sampling method to investigate the everyday social experiences of children with Asperger syndrome/high functioning autism. *Developmental Neurorehabilitation*, *19*(2), 103-110.

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., ... & Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise*, *35*(8), 1381-1395.

Creswell, J. D., Lindsay, E. K., Villalba, D. K., & Chin, B. (2019). Mindfulness training and physical health: mechanisms and outcomes. *Psychosomatic Medicine*, *81*(3), 224-232.

Davis, K.M., Lau, M.A., & Cairns, D.R. (2009). Development and preliminary validation of a trait version of the Toronto Mindfulness Scale. *Journal of Cognitive Psychotherapy*, *23*(3), 185–197.

De Abreu Costa, M., de Oliveira, G. S. D. A., Tatton-Ramos, T., Manfro, G. G., & Salum, G. A. (2019). Anxiety and stress-related disorders and mindfulness-based interventions: A systematic review and multilevel meta-analysis and meta-regression of multiple outcomes. *Mindfulness*, *10*(6), 996-1005.

De Bruin, E. I., Van der Zwan, J., & Bögels, S. M. (2016). A RCT comparing daily mindfulness meditations, biofeedback exercises, and daily physical exercise on attention control, executive functioning, mindful awareness, self-compassion, and worrying in stressed young adults. *Mindfulness*, *7*(5), 1182-1192.

Demarzo, M. M. P., Montero-Marin, J., Stein, P. K., Cebolla, A., Provinciale, J. G., & García-Campayo, J. (2014). Mindfulness may both moderate and mediate the effect of physical fitness on cardiovascular responses to stress: a speculative hypothesis. *Frontiers in Physiology*, *5*, 1-8.

Deng, Y. Q., Li, S., Tang, Y. Y., Zhu, L. H., Ryan, R., & Brown, K. (2012). Psychometric properties of the Chinese translation of the mindful attention awareness scale (MAAS). *Mindfulness*, *3*(1), 10-14.

De Vries, L. P., Baselmans, B. M., & Bartels, M. (2021). Smartphone-based ecological momentary assessment of well-being: A systematic review and recommendations for future studies. *Journal of Happiness Studies*, *22*(5), 2361-2408.

Dillard, A. J., & Meier, B. P. (2021). Trait mindfulness is negatively associated with distress related to COVID-19. *Personality and Individual Differences*, *179*, 110955.

Dinoff, A., Herrmann, N., Swardfager, W., Liu, C. S., Sherman, C., Chan, S., & Lanctôt, K. L. (2016). The effect of exercise training on resting concentrations of peripheral brain-derived neurotrophic factor (BDNF): A meta-analysis. *PloS One*, *11*(9), e0163037.

Dunning, D. L., Griffiths, K., Kuyken, W., Crane, C., Foulkes, L., Parker, J., & Dalgleish, T. (2019). Research Review: The effects of mindfulness-based interventions on cognition and mental health in children and adolescents–a meta-analysis of randomized controlled trials. *Journal of Child Psychology and Psychiatry*, *60*(3), 244-258.

Dutcher, J. M., Boyle, C. C., Eisenberger, N. I., Cole, S. W., & Bower, J. E. (2021). Neural responses to threat and reward and changes in inflammation following a mindfulness intervention. *Psychoneuroendocrinology*, *125*, 105114.

Ede, D. E., Walter, F. A., & Hughes, J. W. (2020). Exploring how trait mindfulness relates to perceived stress and cardiovascular reactivity. *International Journal of Behavioral Medicine*, *27*(4), 415-425.

Eichel, K., & Stahl, J. (2017). The role of mindfulness and emotional stability in error detection. *Mindfulness*, *8*(2), 311-324.

Enkema, M. C., McClain, L., Bird, E. R., Halvorson, M. A., & Larimer, M. E. (2020). Associations between mindfulness and mental health outcomes: A systematic review of ecological momentary assessment research. *Mindfulness*, *11*(11), 2455-2469.

Ethica Data. (2020). *Ethica* [Mobile app]. App Store. https://ethicadata.com

Eysenbach, G. (2005). The law of attrition. *Journal of Medical Internet Research*, *7*(1), e402.

Fan, Y., Tang, Y. Y., & Posner, M. I. (2014). Cortisol level modulated by integrative meditation in a dose-dependent fashion. *Stress and Health*, *30*(1), 65-70.

Feldman, G., Hayes, A., Kumar, S., Greeson, J., & Laurenceau, J. P. (2007). Mindfulness and emotion regulation: The development and initial validation of the Cognitive and Affective Mindfulness Scale-Revised (CAMS-R). *Journal of Psychopathology and Behavioral Assessment*, *29*(3), 177-190.

Folkersma, W., Veerman, V., Ornée, D. A., Oldehinkel, A. J., Alma, M. A., & Bastiaansen, J. A. (2021). Patients' experience of an ecological momentary intervention involving self-monitoring and personalized feedback for depression. *Internet Interventions, 26*, 100436.

Fuchs, R., Klaperski, S., Gerber, M., & Seelig, H. (2015). Messung der bewegungs-und sportaktivität mit dem BSA-Fragebogen. *Zeitschrift für Gesundheitspsychologie*, *23* (2), 60-76.

Geiger, P. J., Boggero, I. A., Brake, C. A., Caldera, C. A., Combs, H. L., Peters, J. R., & Baer, R. A. (2016). Mindfulness-based interventions for older adults: A review of the effects on physical and emotional well-being. *Mindfulness*, *7*(2), 296-307.

Giedd, J. N. (2008). The teen brain: Insights from neuroimaging. *Journal of Adolescent Health*, *42*(4), 335-343.

Godin, G., & Shephard, R. J. (1985). A simple method to assess exercise behavior in the community. *Canadian Journal of Applied Sport Sciences*, *10*(3), 141-146.

Gomutbutra, P., Yingchankul, N., Chattipakorn, N., Chattipakorn, S., & Srisurapanont, M. (2020). The effect of mindfulness-based intervention on brain-derived neurotrophic factor (BDNF): A systematic review and meta-analysis of controlled trials. *Frontiers in Psychology*, *11*, 1-10.

Gratz, K. L., & Roemer, L. (2004). Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the difficulties in emotion regulation scale. *Journal of Psychopathology and Behavioral Assessment*, *26*(1), 41-54.

Greenberg, J., Romero, V. L., Elkin-Frankston, S., Bezdek, M. A., Schumacher, E. H., & Lazar, S. W. (2019). Reduced interference in working memory following mindfulness training is associated with increases in hippocampal volume. *Brain Imaging and Behavior*, *13*(2), 366-376.

Gross, J. J. (1998). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, *2*(3), 271-299.

Grossman, J. T., Frumkin, M. R., Rodebaugh, T. L., & Lenze, E. J. (2020). mHealth assessment and intervention of depression and anxiety in older adults. *Harvard Review of Psychiatry*, *28*(3), 203-214.

Groves, R. M., Fowler Jr, F. J., Couper, M. P., Lepkowski, J. M., Singer, E., & Tourangeau, R. (2009). *Survey methodology* (Vol. 561). John Wiley & Sons.

Hayes, A. M., & Feldman, G. (2004). Clarifying the construct of mindfulness in the context of emotion regulation and the process of change in therapy. *Clinical Psychology: Science and Practice*, *11*(3), 255-262.

Hazlett-Stevens, H., Singer, J., & Chong, A. (2019). Mindfulness-based stress reduction and mindfulness-based cognitive therapy with older adults: A qualitative review of randomized controlled outcome research. *Clinical Gerontologist*, *42*(4), 347-358.

Henker, B., Whalen, C. K., Jamner, L. D., & Delfino, R. J. (2002). Anxiety, affect, and activity in teenagers: Monitoring daily life with electronic diaries. *Journal of the American Academy of Child & Adolescent Psychiatry*, *41*(6), 660-670.

Hevel, D. J., Dunton, G. F., & Maher, J. P. (2021). Acute bidirectional relations between affect, physical feeling states, and activity-related behaviors among older adults: An ecological momentary assessment study. *Annals of Behavioral Medicine, 55*(1), 41-54.

Hill, C. L., & Updegraff, J. A. (2012). Mindfulness and its relationship to emotional regulation. *Emotion*, *12*(1), 81-90.

Hölzel, B. K., Carmody, J., Vangel, M., Congleton, C., Yerramsetti, S. M., Gard, T., & Lazar, S. W. (2011). Mindfulness practice leads to increases in regional brain gray matter density. *Psychiatry Research: Neuroimaging*, *191*(1), 36-43.

Hölzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011). How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science*, *6*(6), 537-559.

Hopkins, M. E., Davis, F. C., VanTieghem, M. R., Whalen, P. J., & Bucci, D. J. (2012). Differential effects of acute and regular physical exercise on cognition and affect. *Neuroscience*, *215*, 59-68.

Im, S., Stavas, J., Lee, J., Mir, Z., Hazlett-Stevens, H., & Caplovitz, G. (2021). Does mindfulness-based intervention improve cognitive function?: A meta-analysis of controlled studies. *Clinical Psychology Review*, *84*, 101972.

Isbel, B., Lagopoulos, J., Hermens, D., Stefanidis, K., & Summers, M. J. (2020). Mindfulness improves attention resource allocation during response inhibition in older adults. *Mindfulness*, *11*(6), 1500-1510.

Jaiswal, S., Tsai, S. Y., Juan, C. H., Liang, W. K., & Muggleton, N. G. (2018). Better cognitive performance is associated with the combination of high trait mindfulness and low trait anxiety. *Frontiers in Psychology*, *9*, 1-15.

Jakobsen, J. C., Gluud, C., Wetterslev, J., & Winkel, P. (2017). When and how should multiple imputation be used for handling missing data in randomised clinical trials–a practical guide with flowcharts. *BMC Medical Research Methodology*, *17*(1), 1-10.

Janssen, L. H., Kullberg, M. L. J., Verkuil, B., van Zwieten, N., Wever, M. C., van Houtum, L. A., ... & Elzinga, B. M. (2020). Does the COVID-19 pandemic impact parents' and adolescents' well-being? An EMA-study on daily affect and parenting. *PloS one*, *15*(10), e0240962.

Kabat-Zinn, J. (1982). An outpatient program in behavioral medicine for chronic pain patients based on the practice of mindfulness meditation: Theoretical considerations and preliminary results. *General Hospital Psychiatry*, *4*(1), 33-47.

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology: Science and Practice, 10*, 144–156.

Kabat-Zinn, J. (2009). *Wherever you go, there you are: Mindfulness meditation in everyday life*. Hachette Books.

Kabat-Zinn, J. (2011). Some reflections on the origins of MBSR, skillful means, and the trouble with maps. *Contemporary Buddhism*, *12*(01), 281-306.

Kang, C., & Whittingham, K. (2010). Mindfulness: A dialogue between Buddhism and clinical psychology. *Mindfulness*, *1*(3), 161-173.

Kiken, L. G., Garland, E. L., Bluth, K., Palsson, O. S., & Gaylord, S. A. (2015). From a state to a trait: Trajectories of state mindfulness in meditation during intervention predict changes in trait mindfulness. *Personality and Individual Differences*, *81*, 41-46.

Killgore, W. D., Olson, E. A., & Weber, M. (2013). Physical exercise habits correlate with gray matter volume of the hippocampus in healthy adult humans. *Scientific Reports*, *3*(1), 1-6.

Kimmes, J. G., May, R. W., Seibert, G. S., Jaurequi, M. E., & Fincham, F. D. (2018). The association between trait mindfulness and cardiovascular reactivity during marital conflict. *Mindfulness*, *9*(4), 1160-1169.

Kingery, J. N., Bodenlos, J. S., Schneider, T. I., Peltz, J. S., & Sindoni, M. W. (2023). Dispositional mindfulness predicting psychological adjustment among college students:

The role of rumination and gender. *Journal of American College Health*, *71*(5), 1584-1595.

Kirchner, W. K. (1958). Age differences in short-term retention of rapidly changing information. *Journal of Experimental Psychology*, *55*(4), 352-358.

Kishita, N., Takei, Y., & Stewart, I. (2017). A meta-analysis of third wave mindfulness-based cognitive behavioral therapies for older people. *International Journal of Geriatric Psychiatry*, *32*(12), 1352-1361.

Kostanski, M., & Hassed, C. (2008). Mindfulness as a concept and a process. *Australian Psychologist*, *43*(1), 15-21.

Kowiański, P., Lietzau, G., Czuba, E., Waśkow, M., Steliga, A., & Moryś, J. (2018). BDNF: a key factor with multipotent impact on brain signaling and synaptic plasticity. *Cellular and Molecular Neurobiology*, *38*(3), 579-593.

Kujawa, A., Green, H., Compas, B. E., Dickey, L., & Pegg, S. (2020). Exposure to COVID-19 pandemic stress: Associations with depression and anxiety in emerging adults in the United States. *Depression and Anxiety*, *37*(12), 1280-1288.

Kuyken, W., Watkins, E., Holden, E., White, K., Taylor, R. S., Byford, S., ... & Dalgleish, T. (2010). How does mindfulness-based cognitive therapy work?. *Behaviour Research and Therapy*, *48*(11), 1105-1112.

Kwak, S., Kim, S. Y., Bae, D., Hwang, W. J., Cho, K. I. K., Lim, K. O., ... & Kwon, J. S. (2020). Enhanced attentional network by short-term intensive meditation. *Frontiers in Psychology*, *10*, 1-12.

Lacaille, J., Sadikaj, G., Nishioka, M., Carrière, K., Flanders, J., & Knäuper, B. (2018). Daily mindful responding mediates the effect of meditation practice on stress and mood: The role of practice duration and adherence. *Journal of Clinical Psychology*, *74*(1), 109-122.

LaFreniere, L. S., & Newman, M. G. (2016). A brief ecological momentary intervention for generalized anxiety disorder: A randomized controlled trial of the worry outcome journal. *Depression and Anxiety*, *33*(9), 829-839.

Lakey, C. E., Campbell, W. K., Brown, K. W., & Goodie, A. S. (2007). Dispositional mindfulness as a predictor of the severity of gambling outcomes. *Personality and Individual Differences*, *43*(7), 1698-1710.

Laneri, D., Schuster, V., Dietsche, B., Jansen, A., Ott, U., & Sommer, J. (2016). Effects of long-term mindfulness meditation on brain's white matter microstructure and its aging. *Frontiers in Aging Neuroscience*, *7*. https://doi.org/10.3389/fnagi.2015.00254

Larson, R., & Csikszentmihalyi, M. (2014). The experience sampling method. In *Flow and the foundations of positive psychology* (pp. 21-34). Springer, Dordrecht.

Lazar, S. W., Kerr, C. E., Wasserman, R. H., Gray, J. R., Greve, D. N., Treadway, M. T., ... & Fischl, B. (2005). Meditation experience is associated with increased cortical thickness. *Neuroreport*, *16*(17), 1893-1897.

Li, M. Y., Huang, M. M., Li, S. Z., Tao, J., Zheng, G. H., & Chen, L. D. (2017). The effects of aerobic exercise on the structure and function of DMN-related brain regions: a systematic review. *International Journal of Neuroscience*, *127*(7), 634-649.

Li, S. Y. H., & Bressington, D. (2019). The effects of mindfulness-based stress reduction on depression, anxiety, and stress in older adults: A systematic review and meta-analysis. *International Journal of Mental Health Nursing*, *28*(3), 635-656.

Liu, H., Xie, Q. W., & Lou, V. W. (2019). Everyday social interactions and intra-individual variability in affect: A systematic review and meta-analysis of ecological momentary assessment studies. *Motivation and Emotion*, *43*(2), 339-353.

Linden, D. E., Habes, I., Johnston, S. J., Linden, S., Tatineni, R., Subramanian, L., ... & Goebel, R. (2012). Real-time self-regulation of emotion networks in patients with depression. *PloS One*, *7*(6), e38115.

Lindsay, E. K., Chin, B., Greco, C. M., Young, S., Brown, K. W., Wright, A. G., ... & Creswell, J. D. (2018). How mindfulness training promotes positive emotions: Dismantling acceptance skills training in two randomized controlled trials. *Journal of Personality and Social Psychology*, *115*(6), 944-973.

Link, J. S., Barker, T., Serpa, S., Pinjala, M., Oswald, T., & Lashley, L. K. (2016). Mild traumatic brain injury and mindfulness-based stress reduction: A review. *Archives of Assessment Psychology*, *6*(1), 7-32.

Loucks, E. B., Britton, W. B., Howe, C. J., Eaton, C. B., & Buka, S. L. (2015). Positive associations of dispositional mindfulness with cardiovascular health: the New England Family Study. *International Journal of Behavioral Medicine*, *22*(4), 540-550.

Lucas-Thompson, R. G., Miller, R. L., Seiter, N. S., & Prince, M. A. (2019). Dispositional mindfulness predicts cortisol, cardiovascular, and psychological stress responses in adolescence. *Psychoneuroendocrinology*, *110*, 104405.

Lueke, A., & Lueke, N. (2019). Mindfulness improves verbal learning and memory through enhanced encoding. *Memory & Cognition*, *47*(8), 1531-1545.

Manglani, H. R., Samimy, S., Schirda, B., Nicholas, J. A., & Prakash, R. S. (2020). Effects of 4-week mindfulness training versus adaptive cognitive training on processing speed and working memory in multiple sclerosis. *Neuropsychology*, *34*(5), 591-604.

Marchand, W. R. (2014). Neural mechanisms of mindfulness and meditation: Evidence from neuroimaging studies. *World Journal of Radiology*, *6*(7), 471-479.

McClintock, A. S., Rodriguez, M. A., & Zerubavel, N. (2019). The effects of mindfulness retreats on the psychological health of non-clinical adults: A meta-analysis. *Mindfulness*, *10*(8), 1443-1454.

Medvedev, O. N., Norden, P. A., Krägeloh, C. U., & Siegert, R. J. (2018). Investigating unique contributions of dispositional mindfulness facets to depression, anxiety, and stress in general and student populations. *Mindfulness*, *9*(6), 1757-1767.

Mennitto, S., Ditto, B., & Da Costa, D. (2021). The relationship of trait mindfulness to physical and psychological health during pregnancy. *Journal of Psychosomatic Obstetrics & Gynecology*, *42*(4), 313-319.

Merwin, R. M., Dmitrieva, N. O., Honeycutt, L. K., Moskovich, A. A., Lane, J. D., Zucker, N. L., ... & Kuo, J. (2015). Momentary predictors of insulin restriction among adults with type 1 diabetes and eating disorder symptomatology. *Diabetes Care*, *38*(11), 2025-2032.

Mesmer-Magnus, J., Manapragada, A., Viswesvaran, C., & Allen, J. W. (2017). Trait mindfulness at work: A meta-analysis of the personal and professional correlates of trait mindfulness. *Human Performance*, *30*(2-3), 79-98.

Molina-Rodríguez, S., Ros-León, A., & Pellicer-Porcar, O. (2021). Characterizing the executive functioning associated with dispositional mindfulness. *Current Psychology*, 1-8.

Moore, R. C., Depp, C. A., Wetherell, J. L., & Lenze, E. J. (2016). Ecological momentary assessment versus standard assessment instruments for measuring mindfulness, depressed mood, and anxiety among older adults. *Journal of Psychiatric Research*, *75*, 116-123.

Mothes, H., Klaperski, S., Seelig, H., Schmidt, S., & Fuchs, R. (2014). Regular aerobic exercise increases dispositional mindfulness in men: A randomized controlled trial. *Mental Health and Physical Activity*, *7*(2), 111-119.

O'Bryan, E. M., Luberto, C. M., Kraemer, K. M., & McLeish, A. C. (2018). An examination of mindfulness skills in terms of affect tolerance among individuals with elevated levels of health anxiety. *Anxiety, Stress, & Coping*, *31*(6), 702-713.

Ortner, C. N., Kilner, S. J., & Zelazo, P. D. (2007). Mindfulness meditation and reduced emotional interference on a cognitive task. *Motivation and Emotion*, *31*(4), 271-283.

Osman, A., Lamis, D. A., Bagge, C. L., Freedenthal, S., & Barnes, S. M. (2016). The mindful attention awareness scale: Further examination of dimensionality, reliability, and concurrent validity estimates. *Journal of Personality Assessment*, *98*(2), 189-199.

Page, M., Cumming, N., Norris, D., Hitch, G. J., & McNeil, A. M. (2006). Repetition learning in the immediate serial recall of visual and auditory materials. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*(4), 716-733.

Paolillo, E. W., Obermeit, L. C., Tang, B., Depp, C. A., Vaida, F., Moore, D. J., & Moore, R. C. (2018). Smartphone-based ecological momentary assessment (EMA) of alcohol and cannabis use in older adults with and without HIV infection. *Addictive Behaviors*, *83*, 102-108.

Parmentier, F. B., García-Toro, M., García-Campayo, J., Yañez, A. M., Andrés, P., & Gili, M. (2019). Mindfulness and symptoms of depression and anxiety in the general population:

The mediating roles of worry, rumination, reappraisal and suppression. *Frontiers in Psychology*, *10*, 1-10.

Petter, M., Chambers, C. T., McGrath, P. J., & Dick, B. D. (2013). The role of trait mindfulness in the pain experience of adolescents. *The Journal of Pain*, *14*(12), 1709-1718.

Quach, D., Mano, K. E. J., & Alexander, K. (2016). A randomized controlled trial examining the effect of mindfulness meditation on working memory capacity in adolescents. *Journal of Adolescent Health*, *58*(5), 489-496.

Quaglia, J. T., Braun, S. E., Freeman, S. P., McDaniel, M. A., & Brown, K. W. (2016). Meta-analytic evidence for effects of mindfulness training on dimensions of self-reported dispositional mindfulness. *Psychological Assessment*, *28*(7), 803-818.

Rau, H. K., & Williams, P. G. (2016). Dispositional mindfulness: A critical review of construct validation research. *Personality and Individual Differences*, *93*, 32-43.

Reangsing, C., Rittiwong, T., & Schneider, J. K. (2021). Effects of mindfulness meditation interventions on depression in older adults: A meta-analysis. *Aging & Mental Health*, *25*(7), 1181-1190.

Rehfeld, K., Lüders, A., Hökelmann, A., Lessmann, V., Kaufmann, J., Brigadski, T., ... & Müller, N. G. (2018). Dance training is superior to repetitive physical exercise in inducing brain plasticity in the elderly. *PloS One*, *13*(7), e0196636.

Reis, N. A., Waldhauser, K. J., Hives, B. A., Hulteen, R. M., Ruissen, G. R., Wierts, C. M., ... & Beauchamp, M. R. (2023). Effects of older adults' social identification on psychological flourishing and exercise program adherence. *Psychology & Health*, 1-13.

Riggs, N. R., Black, D. S., & Ritt-Olson, A. (2015). Associations between dispositional mindfulness and executive function in early adolescence. *Journal of Child and Family Studies*, *24*(9), 2745-2751.

Robert-McComb, J. J., Cisneros, A., Tacón, A., Panike, R., Norman, R., Qian, X. P., & McGlone, J. (2015). The effects of mindfulness-based movement on parameters of stress. *International Journal of Yoga Therapy*, *25*(1), 79-88.

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). 'Oops!': Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*(6), 747-758.

Robson, D. A., Allen, M. S., & Howard, S. J. (2020). Self-regulation in childhood as a predictor of future outcomes: A meta-analytic review. *Psychological Bulletin*, *146*(4), 324-354.

Rodriguez Vega, B., Melero-Llorente, J., Bayon Perez, C., Cebolla, S., Mira, J., Valverde, C., & Fernández-Liria, A. (2014). Impact of mindfulness training on attentional control and anger regulation processes for psychotherapists in training. *Psychotherapy Research*, *24*(2), 202-213.

Rosenbaum, E. (2017). *The heart of mindfulness-based stress reduction: A MBSR guide for clinicians and clients*. Retrieved from https://ebookcentral.proquest.com/lib/uvic/detail.action?docID=4915368#goto_toc

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology*, *28*(2), 573-594.

Ruocco, A. C., & Wonders, E. (2013). Delineating the contributions of sustained attention and working memory to individual differences in mindfulness. *Personality and Individual Differences*, *54*(2), 226-230.

Runyan, J. D., Steenbergh, T. A., Bainbridge, C., Daugherty, D. A., Oke, L., & Fry, B. N. (2013). A smartphone ecological momentary assessment/intervention "app" for collecting real-time data and promoting self-awareness. *PloS One*, *8*(8), e71325.

Runyan, J. D., & Steinke, E. G. (2015). Virtues, ecological momentary assessment/intervention and smartphone technology. *Frontiers in Psychology*, *6*, 1-24.

Russell, M. A., & Gajos, J. M. (2020). Annual research review: Ecological momentary assessment studies in child psychology and psychiatry. *Journal of Child Psychology and Psychiatry*, *61*(3), 376-394.

Ryff, C. D., & Almeida, D. M. (2009). *National Survey of Midlife in the United States (MIDUS II): Daily Stress Project, 2004-2009*. Inter-university Consortium for Political and Social Research.

Sahdra, B. K., Shaver, P. R., & Brown, K. W. (2010). A scale to measure nonattachment: A Buddhist complement to Western research on attachment and adaptive functioning. *Journal of Personality Assessment*, *92*(2), 116-127.

Sala, M., Rochefort, C., Lui, P. P., & Baldwin, A. S. (2020). Trait mindfulness and health behaviours: A meta-analysis. *Health Psychology Review, 14*(3), 345-393.

Sandstrom, G. M., Lathia, N., Mascolo, C., & Rentfrow, P. J. (2017). Putting mood in context: Using smartphones to examine how people feel in different locations. *Journal of Research in Personality*, *69*, 96-101.

Schneider, J., Malinowski, P., Watson, P. M., & Lattimore, P. (2019). The role of mindfulness in physical activity: a systematic review. *Obesity Reviews*, *20*(3), 448-463.

Scott-Sheldon, L. A., Gathright, E. C., Donahue, M. L., Balletto, B., Feulner, M. M., DeCosta, J., ... & Salmoirago-Blotcher, E. (2020). Mindfulness-based interventions for adults with cardiovascular disease: A systematic review and meta-analysis. *Annals of Behavioral Medicine*, *54*(1), 67-73.

Segal, Z. V., Williams, M., & Teasdale, J. (2018). *Mindfulness-based cognitive therapy for depression*. Guilford Publications.

Semple, R. J., & Burke, C. (2019). State of the research: Physical and mental health benefits of mindfulness-based interventions for children and adolescents. *OBM Integrative and Complementary Medicine*, *4*(1), 1-31.

Seshadri, A., Orth, S. S., Adaji, A., Singh, B., Clark, M. M., Frye, M. A., ... & Fuller-Tyszkiewicz, M. (2021). Mindfulness-based cognitive therapy, acceptance and commitment therapy, and positive psychotherapy for major depression. *American Journal of Psychotherapy*, *74*(1), 4-12.

Shapiro, S. L., Brown, K. W., Thoresen, C., & Plante, T. G. (2011). The moderation of mindfulness-based stress reduction effects by trait mindfulness: results from a randomized controlled trial. *Journal of Clinical Psychology*, *67*(3), 267-277.

Sheikh, J. I., & Yesavage, J. A. (1986). Geriatric Depression Scale (GDS): Recent evidence and development of a shorter version. *Clinical Gerontologist: The Journal of Aging and Mental Health*, *5*(1-2), 165-173.

Shiffman, S. (2009). Ecological momentary assessment (EMA) in studies of substance use. *Psychological Assessment*, *21*(4), 486-497.

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual Review of Clinical Psychology*, *4*, 1-32.

Shonin, E., Van Gordon, W., & Singh, N. N. (2015). *Buddhist foundations of mindfulness*. Springer International Publishing.

Short, M. M., Mazmanian, D., Oinonen, K., & Mushquash, C. J. (2016). Executive function and self-regulation mediate dispositional mindfulness and well-being. *Personality and Individual Differences*, *93*, 97-103.

Simon, J. R. (1969). Reactions toward the source of stimulation. *Journal of Experimental Psychology*, *81*(1), 174-176.

Sipe, W. E., & Eisendrath, S. J. (2012). Mindfulness-based cognitive therapy: theory and practice. *The Canadian Journal of Psychiatry*, *57*(2), 63-69.

Spinella, M. (2005). Self-rated executive function: Development of the executive function index. *International Journal of Neuroscience*, *115*(5), 649-667.

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: the GAD-7. *Archives of Internal Medicine*, *166*(10), 1092-1097.

Strehli, I., Burns, R. D., Bai, Y., Ziegenfuss, D. H., Block, M. E., & Brusseau, T. A. (2021). Mind–body physical activity interventions and stress-related physiological markers in educational settings: A systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, *18*(1), 224.

Sutton, A. (2016). Measuring the effects of self-awareness: Construction of the self-awareness outcomes questionnaire. *Europe's Journal of Psychology*, *12*(4), 645-658.

Szeto, E. H., Schoenmakers, T. M., van de Mheen, D., Snelleman, M., & Waters, A. J. (2019). Associations between dispositional mindfulness, craving, and drinking in alcohol-dependent patients: An ecological momentary assessment study. *Psychology of Addictive Behaviors*, *33*(5), 431-441.

Tang, Y. Y. (2017). *The neuroscience of mindfulness meditation: How the body and mind work together to change our behaviour*. Springer.

Tang, Y. Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews Neuroscience*, *16*(4), 213-225.

Teasdale, J. D., Moore, R. G., Hayhurst, H., Pope, M., Williams, S., & Segal, Z. V. (2002). Metacognitive awareness and prevention of relapse in depression: empirical evidence. *Journal of Consulting and Clinical Psychology*, *70*(2), 275-287.

Tomlinson, E. R., Yousaf, O., Vittersø, A. D., & Jones, L. (2018). Dispositional mindfulness and psychological health: A systematic review. *Mindfulness*, *9*(1), 23-43.

Tsafou, K. E., De Ridder, D. T., van Ee, R., & Lacroix, J. P. (2016). Mindfulness and satisfaction in physical activity: A cross-sectional study in the Dutch population. *Journal of Health Psychology, 21*(9), 1817-1827.

Tsafou, K. E., Lacroix, J. P., Van Ee, R., Vinkers, C. D., & De Ridder, D. T. (2017). The relation of trait and state mindfulness with satisfaction and physical activity: A cross-sectional study in 305 Dutch participants. *Journal of Health Psychology*, *22*(10), 1221-1232.

Tsering, G. T. (2004). Lamrim Chenmo module 3, teaching 12. *Eudlo, Australia: Chenrezig Institute Buddhist Studies Program*.

Tugade, M. M., Fredrickson, B. L., & Feldman Barrett, L. (2004). Psychological resilience and positive emotional granularity: Examining the benefits of positive emotions on coping and health. *Journal of Personality, 72*(6), 1161-1190.

Tulving, E., & Craik, F. I. (Eds.). (2000). *The Oxford handbook of memory*. Oxford University Press.

Turna, J., Zhang, J., Lamberti, N., Patterson, B., Simpson, W., Francisco, A. P., ... & Van Ameringen, M. (2021). Anxiety, depression and stress during the COVID-19 pandemic: Results from a cross-sectional survey. *Journal of Psychiatric Research*, *137*, 96-103.

Ueberholz, R. Y., & Fiocco, A. J. (2022). The effect of a brief mindfulness practice on perceived stress and sustained attention: Does priming matter?. *Mindfulness, 13*(7), 1757-1768.

Ulmer, C. S., Stetson, B. A., & Salmon, P. G. (2010). Mindfulness and acceptance are associated with exercise maintenance in YMCA exercisers. *Behaviour Research and Therapy*, *48*(8), 805-809.

Van Buuren, S. (2018). *Flexible imputation of missing data*. CRC press.

Van Buuren. S. & Groothuis-Oudshoorn, K. (2011). Mice: Multivariate imputation by chained equations in R. *Journal of Statistical Software*, *45*(3), 1-67.

Van der Stouwe, E. C. D., Van Busschbach, J. T., De Vries, B., Cahn, W., Aleman, A., & Pijnenborg, G. H. M. (2018). Neural correlates of exercise training in individuals with schizophrenia and in healthy individuals: a systematic review. *NeuroImage: Clinical, 19*, 287-301.

Verhaeghen, P. (2021). Mindfulness as attention training: Meta-analyses on the links between attention performance and mindfulness interventions, long-term meditation practice, and trait mindfulness. *Mindfulness*, *12*, 564-581.

Vohra, S., Punja, S., Sibinga, E., Baydala, L., Wikman, E., Singhal, A., ... & Van Vliet, K. J. (2019). Mindfulness-based stress reduction for mental health in youth: A cluster randomized controlled trial. *Child and Adolescent Mental Health*, *24*(1), 29-35.

Volanen, S. M., Lassander, M., Hankonen, N., Santalahti, P., Hintsanen, M., Simonsen, N., ... & Suominen, S. (2020). Healthy learning mind–Effectiveness of a mindfulness program on mental health compared to a relaxation program and teaching as usual in schools: A cluster-randomised controlled trial. *Journal of Affective Disorders*, *260*, 660-669.

Walach, H., Buchheld, N., Buttenmuller, V., Kleinknecht, N., & Schmidt, S. (2006). Measuring mindfulness–The Freiburg Mindfulness Inventory (FMI). *Personality and Individual Differences, 40*, 1543–1555.

Wassenaar, T. M., Yaffe, K., van der Werf, Y. D., & Sexton, C. E. (2019). Associations between modifiable risk factors and white matter of the aging brain: insights from diffusion tensor imaging studies. *Neurobiology of Aging*, *80*, 56-70.

Wen, C. K. F., Liao, Y., Maher, J. P., Huh, J., Belcher, B. R., Dzubur, E., & Dunton, G. F. (2018). Relationships among affective states, physical activity, and sedentary behavior in children: Moderation by perceived stress. *Health Psychology*, *37*(10), 904-914.

Whalen, C. K., Henker, B., Jamner, L. D., Ishikawa, S. S., Floro, J. N., Swindle, R., ... & Johnston, J. A. (2006). Toward mapping daily challenges of living with ADHD: Maternal and child perspectives using electronic diaries. *Journal of Abnormal Child Psychology*, *34*(1), 111-126.

Whitmoyer, P., Fountain-Zaragoza, S., Andridge, R., Bredemeier, K., Londeree, A., Kaye, L., & Prakash, R. S. (2020). Mindfulness training and attentional control in older adults: A randomized controlled trial. *Mindfulness*, *11*(1), 203-218.

Wood, C. J., Clow, A., Hucklebridge, F., Law, R., & Smyth, N. (2018). Physical fitness and prior physical activity are both associated with less cortisol secretion during psychosocial stress. *Anxiety, Stress, & Coping*, *31*(2), 135-145.

Wood, L., Roach, A. T., Kearney, M. A., & Zabek, F. (2018). Enhancing executive function skills in preschoolers through a mindfulness-based intervention: A randomized, controlled pilot study. *Psychology in the Schools*, *55*(6), 644-660.

Yang, C. H., & Conroy, D. E. (2020). Mindfulness and physical activity: a systematic review and hierarchical model of mindfulness. *International Journal of Sport and Exercise Psychology*, *18*(6), 794-817.

Yu, J., Rawtaer, I., Feng, L., Fam, J., Kumar, A. P., Cheah, I. K. M., ... & Mahendran, R. (2021). Mindfulness intervention for mild cognitive impairment led to attention-related improvements and neuroplastic changes: Results from a 9-month randomized control trial. *Journal of Psychiatric Research*, *135*, 203-211.

Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training. *Consciousness and Cognition*, *19*(2), 597-605.

Zhaoyang, R., Martire, L. M., & Darnall, B. D. (2020). Daily pain catastrophizing predicts less physical activity and more sedentary behavior in older adults with osteoarthritis. *Pain*, *161*(11), 2603-2610.

APPENDIX A

Baseline History Questionnaire

What is your age?

How much do you weigh (in lbs)?

What is your height (in feet and inches)?

What is your current heart rate (beats/minute)? Please use the following instructions for accurate measurement (from Michigan Medicine, University of Michigan).

You can easily check your pulse on the inside of your wrist, below your thumb.

- Gently place 2 fingers of your other hand on this artery.
- Do not use your thumb because it has its own pulse that you may feel.
- Count the beats for 30 seconds; then double the result to get the number of beats per minute.

You can also check your pulse in the carotid artery. This is located in your neck, on either side of your windpipe. Be careful when checking your pulse in this location. If you press too hard, you may become lightheaded and fall.

Handedness: Right Left **Country of Origin:** __________________

What sex were you assigned at birth (i.e., on your original birth certificate)?

____Male
____Female

Which best describes your current gender identity?

_____Male
_____Female
_____Transgender Male
_____Transgender Female
_____Indigenous two spirit
_____Other (e.g., gender fluid, non-binary): _____________________

What are your preferred pronouns?

_____He/his
_____She/her
_____They/their
_____Other: ________________

With which ethnic group do you identify the most (okay to choose more than one)?

_____ Black
_____ East Asian (e.g., Chinese, Korean, Japanese, Taiwanese, Mongolian)
_____ Filipino
_____ Indigenous Person, First Nations, Metis, Inuit or Aboriginal persons
_____ Latinx/Hispanic (e.g., Mexican, Argentinian, Cuban)
_____ South Asian (e.g., Indian from India or Uganda, Pakistani, Punjabi, Tamil)
_____ South East Asian (e.g., Vietnamese, Thai, Laotion)
_____ West Asian or North African (e.g., Armenian, Syrian, Moroccan, Saudi)
_____ Middle Eastern (e.g., Syrian, Egyptian, Saudi Arabian, etc.)

_____ White (e.g., British, French, North or South American or European background)
_____ Other (specify): _________________________________

Which province or territory do you live in?

a. Alberta
b. British Columbia
c. Manitoba
d. New Brunswick
e. Newfoundland and Labrador
f. Northwest Territories
g. Nova Scotia
h. Nunavut
i. Ontario
j. Prince Edward Island
k. Quebec
l. Saskatchewan
m. Yukon

Which best describes the area in which you live?

1. Urban
2. Rural

What is your highest level of education achieved? (Choose one)

_____Grade 8
_____High School
_____Some College/University (did not complete)
_____College/University
_____Master's Degree (MA, MBA, MPH, etc.)
_____Doctoral Degree (Ph.D., J.D., M.D.)
_____Other: _________________________

What is your gross family income?

1. $19, 999 or less
2. $20, 000 – 39, 999
3. $40, 000 – 59, 999
4. $60, 000 – 79, 999
5. $80, 000 – 99, 999
6. $100, 000 – 119, 000
7. $120, 000 – 139, 999
8. $140, 000 – 159, 999
9. $160, 000 – 179, 999
10. $180, 000 – 199, 999
11. $200, 000 or greater

Have you ever been diagnosed with high cholesterol? Yes No

- If yes, do you take medication or supplements to control your cholesterol? Yes No

Do you have any severe headaches or migraines? Yes No
Do you have normal/corrected vision? Yes No

Do you have normal/corrected hearing? Yes No

Do you have any problems with your ability to smell? Yes No

Do you have a tremor or other motor control issues? Yes No

Do you have any problems with walking or balance? Yes No

Do you have any chronic sleep problems? Yes No

How satisfied are you with your appetite? {1-5 likert scale; 1 = Extremely dissatisfied, 5 = Extremely satisfied}

Do you smoke? Yes No
- If yes, how often do you smoke? {drop down menu with options}

Do you vape? Yes No
- If yes, how often do you vape? {drop down menu with options}

Do you have a family history of dementia or other neurodegenerative disorders (e.g., Alzheimer's disease, Parkinson's disease, Multiple Sclerosis, etc.)? Yes No

Do you have any problems with incontinence? Yes No
- If yes, for how long? {drop down menu}

Do you play an instrument or sing? Yes No
- If yes…

What instrument do you play (write "sing" if you sing)? _________
How many years have you been actively playing or singing? ________
At what age did you start playing or singing? _______
What type of training did you receive? {drop down menu}

Do you practice mindfulness meditation? Yes No
- If yes, how frequently? {drop down menu}

Before the pandemic of COVID-19 got serious in Canada and when things were normal, how stressful was your life in general?
1-7 Likert scale (1. Not at all stressful, 2. Slightly stressful, 3. Somewhat stressful, 4. Neutral, 5. Moderately stressful, 6. Very stressful, 7. Extremely stressful)
After the social distancing policies were implemented by the Canadian government to cope with the COVID-19, how stressful was your life in general?
1-7 Likert scale (1. Not at all stressful, 2. Slightly stressful, 3. Somewhat stressful, 4. Neutral, 5. Moderately stressful, 6. Very stressful, 7. Extremely stressful)

APPENDIX B

EMA Burst Morning Survey (~8:30 AM)

SLEEP/ WAKEFULNESS

How long have you been awake?

Options: Scroll with hours and minutes (in 30-min increments)

The next questions ask about your sleep last night.

1. How would you rate the quality of your sleep? (Slider: 1 Very poor to 10 Very good)
2. Was your sleep refreshing? (Slider: 1 Not at all to 10 Very much)
3. How many hours of sleep did you get last night?
   Options: Scroll from 0 to 12+ hours and minutes in 30-min. increments
4. What is your current level of **sleepiness** (i.e., desire to fall asleep)? (slider: 1 Not sleepy to 10 very sleepy)

MOOD

The next questions ask about your feelings during the past 15 minutes.

To what extent were you feeling… (slider: 1= not at all to 5 = very much)

National Study of Daily Experiences (NSDE)—Positive Affect (Ryff & Almeida, 2009***)***

1. In good spirits
2. Cheerful
3. Extremely happy
4. Calm and peaceful

PROMIS Item Bank v1.0—Emotional Distress—Anxiety Short Form 4a (adapted EMA momentary wording from Moore et al., 2016)

5. Fearful
6. That it was hard to focus on anything other than your anxiety
7. Overwhelmed by your worries
8. Uneasy

PROMIS Emotional Distress—Depression—Short-Form 4a (adapted from Moore et al., 2016)

9. Worthless
10. Helpless
11. Depressed
12. Hopeless

Medical Outcome Study SF-36—Vitality subscale, Busija et al., 2011

13. Full of pep
14. A lot of energy
15. Worn out
16. Tired

***PROMIS- Social Isolation—Short Form* (adapted)**

17. Left out
18. That people barely know you
19. Isolated from others
20. That people are around you but not with you

STRESS

1. Please rate your current level of **stress**. (slider: 1 Not at all stressed to 10 Extremely stressed)
2. Right now, how stressed are you about COVID-19? (slider: 1 Not at all stressed to 10 Extremely stressed)
    a.

HEALTH

Please rate your current level of **pain**. (slider: 1 No pain to 10 Severe pain)
Please rate your current level of **fatigue** (i.e., exhaustion, low energy). (slider: 1 Not at all fatigued to 10 Extremely fatigued)
In the last 7 days, have you been diagnosed with COVID-19 by a medical professional? (Y/N)

Health Symptoms Checklist

Please indicate if you have experienced any of the following health related concerns since awakening. Select all that apply:

- Aches/ pains (e.g., muscle pain, headaches, etc.)
- Gastrointestinal symptoms (e.g., upset stomach, constipation, diarrhea)
- Discomfort, tightness in your chest, or dizziness
- Flu like symptoms
- Physical feelings of discomfort
- None of the Above

Medication

The next question asks about your use of medication, both prescription and over the counter.

Since awakening, have you taken any of the following (select all that apply):

- I have not used any medications
- Pain relievers such as Aspirin or Tylenol
- Tranquilizers such as Vallum or Ativan
- Anti-depressants such as Prozac, Paxil, or Effexor
- Codeine, Demerol, or morphine
- Diet pills such as Ponderal, Dexatrim, or Fastin
- Allergy medication such as Reactine or Allegra
- Cough or cold remedies
- Penicillin or other antibiotics
- Blood pressure medication

- Diuretics or water pills
- Steroids
- Stomach remedies
- Laxatives
- Thyroid medication
- Other: ______________________

Since awakening…

1. How much caffeine have you consumed (e.g., coffee, soda, energy drinks)? [1 serving = 12 oz coffee [1 cup], 1 energy drink, 2 cups of teas or canned pops] (slider: 0 none to 5+ servings in .5 increments?)
2. How many joints worth of cannabis (marijuana or hashish) have you consumed? [1 joints-worth = 10 puffs, 5 bong or pipe hits, or ½ gram] (slider: 0 none to 5+ joints-worth in .5 increments?)

CONTEXT/ ENVIRONMENT

The next few questions ask about your current environment.

1. How many people are in the same in the same room as you? (1 = yourself, 2 = yourself + one other, etc.; slider: 1 to 10+)
2. Who is with you right now? Select all that apply:
   a. No one
   b. Spouse/ partner
   c. Child(ren)
   d. Other family member(s)
   e. Friend(s)
   f. Neighbour(s)
   g. Acquaintance(s)
   h. Colleague(s)
   i. Stranger(s)
   j. Pet(s)
   k. Other
3. Where are you right now? Select all that apply:
   a. Outdoors
   b. Indoors
   c. At home
   d. At school or work
   e. Socializing
   f. Running errands
   g. Commuting
   h. Other

Thank you for completing the survey.

<u>EMA Burst Evening Survey</u>

Note: some questions from the morning survey are repeated in the end of day survey.
In the last 7-days, have you been diagnosed with COVID-19 by a medical professional? (asked once per week)

- Yes, I have been diagnosed and understand that I need to contact the project coordinator [and/ or a medical professional] to discuss my continuation in this study
- No, I have not been diagnosed with COVID-19

MOOD

The next questions ask about your feelings during the past 15 minutes.
To what extent were you feeling… (slider: 1= not at all to 5 = very much)

<u>National Study of Daily Experiences—Positive Affect (Almeida)</u>

1. In good spirits
2. Cheerful
3. Extremely happy
4. Calm and peaceful

<u>PROMIS Item Bank v1.0—Emotional Distress—Anxiety Short Form 4a (Bjorner et al., 2013; adapted EMA momentary wording from Moore et al., 2016)</u>

5. Fearful
6. That it was hard to focus on anything other than your anxiety
7. Overwhelmed by your worries
8. Uneasy

<u>PROMIS Emotional Distress—Depression—Short-Form 4a (adapted from Moore et al., 2016)</u>

9. Worthless
10. Helpless
11. Depressed
12. Hopeless

<u>Medical Outcome Study SF-36—Vitality subscale, Busija et al., 2011</u>

13. Full of pep
14. A lot of energy
15. Worn out
16. Tired

<u>PROMIS- Social Isolation—Short Form</u> **<u>(adapted)</u>**

17. Left out
18. That people barely know you
19. Isolated from others
20. That people are around you but not with you

STRESS

1. Please rate your current level of **stress**. (slider: 1 Not at all stressed to 10 Extremely stressed)
2. Right now, how stressed are you about COVID-19? (slider: 1 Not at all stressed to 10 Extremely stressed)

HEALTH

Please rate your current level of **pain**. (slider: 1 No pain to 10 Severe pain)
Please rate your current level of **fatigue** (i.e., exhaustion, low energy). (slider: 1 Not at all fatigued to 10 Extremely fatigued)

Health Symptoms Checklist

Since your last survey, please indicate if you have experienced any of the following health related concerns over the course of the day. Select all that apply:

- Aches/ pains (e.g., muscle pain, headaches, etc.)
- Gastrointestinal symptoms (e.g., upset stomach, constipation, diarrhea)
- Discomfort, tightness in your chest, or dizziness
- Flu like symptoms
- Physical feelings of discomfort
- None of the Above

Medication

The next question asks about your use of medication, both prescription and over the counter.

Since your last survey, have you taken any of the following (select all that apply):

- I have not used any medications
- Pain relievers such as Aspirin or Tylenol
- Tranquilizers such as Vallum or Ativan
- Anti-depressants such as Prozac, Paxil, or Effexor
- Codeine, Demerol, or morphine
- Diet pills such as Ponderal, Dexatrim, or Fastin
- Allergy medication such as Reactine or Allegra
- Cough or cold remedies
- Penicillin or other antibiotics
- Blood pressure medication
- Diuretics or water pills
- Steroids
- Stomach remedies
- Laxatives
- Thyroid medication
- Other: ______________________

The next few questions ask about your consumption over the course of the day…

1. How much caffeine have you consumed today (e.g., coffee, soda, energy drinks)? [1 serving= 12 oz coffee, 1 energy drink, 2 teas or pops] (slider: 0 to 5+ servings in .5 increments?)
2. How many joints worth of cannabis (marijuana or hashish) have you consumed today? [1 joints-worth = 10 puffs, 5 bong or pipe hits, or ½ gram] (slider: 0 to 5+ joints-worth in .5 increments?)
3. How many cigarettes have you smoked today? (slider: 0 to 10+)
4. How many puffs of an e-cigarette/ vape have you taken today? (enter amount)
5. How many alcoholic drinks have you consumed today? [1 drink = 1 bottle of beer, 5 ounces of wine, 1.5 ounces of liquor)? (enter amount)

NUTRITION

6. How healthy/ nutritious has your food intake been?
    - Not at all healthy/ nutritious
    - Somewhat healthy/ nutritious
    - Mostly healthy/ nutritious
    - Completely healthy/ nutritious
7. Did you take a multivitamin today? Y/ N

PHYSICAL ACTIVITY

What type of physical activity have you participated in today? Select all that apply:

- None
- Walking
- Hiking
- Running/ jogging
- Cycling
- Weight training/ resistance exercise
- Yoga/ Pilates
- Stretching
- Sports (e.g., basketball, golf, tennis, soccer)
- Other

The next few questions are interested in your activity over the course of the day. To the best of your memory, approximately how much time did you spend participating in sedentary, light, moderate, or hard activities over the course of your day? (in 30-min. increments)

Please answer all four activity levels. Enter '0' if you spent no time participating in one of the four activity levels.

Over the course of the day, approximately how much time was spent participating in each one of the following activity levels …

Sedentary activity (e.g., no effort, such as watching TV, sitting, reading a book)

Light activity (e.g., minimal effort with normal breathing and regular movement, such as walking, golfing, cleaning, etc.)

Moderate activity (e.g., moderate effort with increased breathing and quicker movements, such as fast walking, casual biking, etc.)

Hard activity (e.g., effortful, with heard breathing and quick, fast movements such as running, fast-paced sports, aerobic classes, etc.)

CONTEXT/ ENVIRONMENT

The next few questions ask about your current environment.

4. How many people are in the same in the same room as you? (1 = yourself, 2 = yourself + one other, etc.; slider: 1 to 10+)
5. Who is with you right now? Select all that apply:
    a. No one
    b. Spouse/ partner
    c. Child(ren)
    d. Other family member(s)
    e. Friend(s)
    f. Neighbour(s)
    g. Acquaintance(s)
    h. Colleague(s)
    i. Stranger(s)
    j. Pet(s)
    k. Other
6. Where are you right now? Select all that apply:
    i. Outdoors
    j. Indoors
    k. At home
    l. At school or work
    m. Socializing
    n. Running errands
    o. Commuting
    p. Other

APPENDIX C

EMA Non-burst Evening Surveys

The next questions ask about your <u>physical activity</u> over the course of your day…

What type of physical activity have you participated in today? Select all that apply:

- None
- Walking
- Hiking
- Running/ jogging
- Cycling
- Weight training/ resistance exercise
- Yoga/ Pilates
- Stretching
- Sports
- Other

The next few questions are interested in your activity over the course of the day. To the best of your memory, approximately how much time did you spend participating in sedentary, light, moderate, or hard activities over the course of your day? [in HOURS]

Please answer all four activity levels. Enter '0' if you spent no time participating in one of the four activity levels.

Over the course of the day, approximately how much time was spent participating in each one of the following activity levels …

Sedentary activity (e.g., no effort, such as watching TV, sitting, reading a book)

Light activity (e.g., minimal effort with normal breathing and regular movement, such as walking, golfing, cleaning, etc.)
Moderate activity (e.g., moderate effort with increased breathing and quicker movements, such as fast walking, casual biking, etc.; talking is possible but not singing)

Hard activity (e.g., effortful, with heard breathing and quick, fast movements such as running, fast-paced sports, aerobic classes, etc.; few words can be said without pausing for breath)