Exploration of psychological and psychophysiological change mechanisms modulated by mindfulness training

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I, Hana Villar, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

A surfeit of clinical studies validates the salutary effects of mindfulness training, yet our knowledge of change mechanisms and corresponding biomarkers remain poorly understood. To address these gaps, this doctoral study investigated psychological and psychophysiological processes underpinning mindfulness-induced emotion regulation and mental health, responding to calls for NIH-defined Stage 3 community efficacy trials and pragmatic real-world process evaluation research. Novel exploration was undertaken of the mediational influences of interoceptive (bodily) awareness, acceptance and attention, alongside objective psychophysiological biomarkers including skin conductance responses and cardioceptive interoceptive accuracy.

In line with the Mindfulness Based Stress Reduction (MBSR) literature, the mindfulness condition reported significant improvements across all primary outcomes (stress, distress and anxiety), as well as secondary outcomes of mindfulness and interoceptive awareness skills. Promising evidence emerged that mindfulness promotes emotion regulation via an objective implicit biomarker. The MBSR group demonstrated a small but significant reduction in sympathetic arousal during an emotion-eliciting behavioural task, while the control group trended toward increased arousal, suggesting enhanced implicit emotional regulation. While interoceptive accuracy via heartbeat counting was not improved, significant enhancement of interoceptive metacognition was found, contributing to previous findings that heartbeat counting may not adequately capture adaptive interoceptive awareness cultivated through mind-body therapies.

Multiple mediation analyses revealed that acceptance uniquely mediated distress attenuation, outperforming attention, while both processes independently mediated stress reduction. Neither uniquely mediated anxiety. Global mindfulness skills overrode global interoceptive awareness in mediating primary mental health outcomes, though interoceptive awareness uniquely mediated alexithymia reduction, suggesting that alexithymia may represent a transdiagnostic marker of poor interoception and emotion regulation rather than a fixed personality trait.

These findings isolate specific change mechanisms in mindfulness-induced wellbeing, highlighting interoceptive awareness dimensions, acceptance and attention as critical mediators and biomarkers warranting further investigation in mindfulness-based, real world intervention research.

Acknowledgements

This PhD could not have been achieved without the expertise, generosity, encouragement and understanding of my doctoral supervisors, Professor Bettina Forster and Dr. Paul Flaxman. Tina and Paul are amazing educators and I know this sentiment is widely shared by their students, supervisees and colleagues.

I am so grateful for their guidance and input throughout this long and challenging process. Their willingness to share their vast knowledge of the fields of cognitive neuroscience, applied psychology and third wave mindfulness and acceptance-based therapies made it possible for me to begin and finally complete this ambitious study. I also benefitted from the interdisciplinary nature of this project, enabling me to collaborate with other students at City who were interested in mindfulness research and Dr. Sebastian Gaigg who influenced the emotion regulation chapter of this thesis.

I would like to thank my husband, Ellis Farrell, for his support and unwavering belief in my ability to finally complete this thesis, despite many moments of self-doubt. My mother, Keiko, and mother-in-law, Sue, have been key supporters throughout this long process. I was also encouraged by many colleagues at Mind, especially Miia Chambers, Kornilia Givissi, Lenora Fitzpatrick and Nichola Lauder.

A special expression of gratitude to Professor Forster is warranted. Without her acceptance, reassurance and persistent support, I would not have finished this thesis and to a standard I can be pleased with, despite life events presenting many challenges along the way.

Finally, I am refreshed in my belief in the value of mindfulness meditation (and its various iterations) for the fields of clinical research and practice and for its applicability as a powerful tool in daily life.

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Chapter 1 PhD Thesis Introduction

Exploration of psychological and psychophysiological change mechanisms modulated by mindfulness training

Background and context

There is an explosion of research interest into the salutary effects, change mechanisms and therapeutic applicability of mindfulness meditation in the psychological and neurobiological literature, though at times with differing methods, conceptualizations and findings (Lao et al., 2016; Schuman-Olivier et al., 2020). A plethora of studies have shown health benefits of mindfulness training on psychological and physical wellbeing in both clinical and healthy populations (Basso et al., 2019; Bohmeijer et al., 2010; Boyd et al., 2018; Burton et al., 2017; Carmona i Farres et al., 2019; de Vibe et al., 2017; Fjorback et al., 2011; Galante et al., 2021; Garland & Fredrickson, 2019; Gawande et al., 2019; Goldberg et al., 2018; Gotink et al., 2015; Goyal et al., 2014; Heckenberg et al., 2018; Keng et al., 2011; Kuyken et al., 2016; Li & Bressington, 2019; Lomas et al., 2019; Rosenkranz et al., 2019; Shankland et el., 2020; Shapero et al., 2018; Singh et al., 2019; Sousa et al., 2021; Tang, 2018; Veehof et al., 2016; Vollestad et al., 2012; Walsh et al., 2019; Yu et al., 2019; Zollars et al., 2019). Given the multifaceted conceptual and methodological elements of mindfulness and inconsistent results in the literature with regard to the correspondence of 'objective' and subjective measurements (see a review by Grossman et al., 2019; Van Dam et al., 2017), an argument has been made for research to be aimed at investigating the specific mechanisms and 'ingredients' constituting mindfulness practice and its putative psychological benefits (Grossman, 2019).

Stress is considered a worldwide public health concern, contributing to adverse mental health and physical health issues such as anxiety, depression, heart disease and suicidality (WHO, 2019). There is strong evidence that prolonged stress exposure, even at mild to moderate ranges, increases the risk of psychological and physiological impairments (Yaribeygi et al., 2017). If unaddressed, psychological distress experienced during the transition to adulthood and to university life may forecast later chronic health problems (Emmerton et al., 2024). Stress and psychological distress have been shown to negatively affect the working population, affecting health and mental health, social functioning and performance (LaMontagne et al., 2014; Holden et al., 2011). Much of the global burden of disability is correlated with subclinical symptomology, with depression and anxiety found to be the most disabling psychiatric disorders (for a systematic analysis, see GBD Study 2019; 2020; Kessler et al., 2009). Beyond the personal impact, stress-related issues, anxiety and depression present colossal economic load such as mounting costs in health care (The World Health Organization, 2017; Alsubaie et al., 2017; Vasiliadis et al., 2013). Chronic stress, when not addressed, is linked to prolonged sickness absence and presenteeism, as well as to workers' compensation claims (Jarman et al., 2014). According to Kessler and colleagues (2005), emotional distress may indicate employee stress and predict common mental health conditions such as anxiety and depression. Furthermore, there is significant and growing psychological distress in the general population that is not addressed due to lack of formal diagnoses and barriers to help-

seeking (Querstat et al., 2020). Stress and common mental health issues such as anxiety and depression are significant areas of interest in public health, and clearly point to a need for efficacious real world treatments and accessible preventative/early intervention strategies (Juul et al., 2020).

A plethora of studies have shown health benefits of mindfulness training on psychological and physical wellbeing in both clinical and healthy populations (Basso et al., 2019; Bohmeijer et al., 2010; Boyd et al., 2018; Burton et al., 2017; Carmona i Farres et al., 2019; de Vibe et al., 2017; Fjorback et al., 2011; Galante et al., 2021; Garland & Fredrickson, 2019; Gawande et al., 2019; Goldberg et al., 2018; Gotink et al., 2015; Goyal et al., 2014; Heckenberg et al., 2018; Keng et al., 2011; Kuyken et al., 2016; Li & Bressington, 2019; Lomas et al., 2019; Rosenkranz et al., 2019; Shankland et el., 2020; Shapero et al., 2018; Singh et al., 2019; Sousa et al., 2021; Tang, 2018; Veehof et al., 2016; Vollestad et al., 2012; Walsh et al., 2019; Yu et al., 2019; Zollars et al., 2019). The literature on stress research has increasingly become associated with favourable outcomes for mindfulness studies, validated by a (Jong et al., 2016; Fazia, 2021; Loucks et al., 2022). For subclinical populations, MBSR results are consistent, with strongest outcomes for stress reduction and moderate effects for common mental health symptoms (Khoury et al., 2015). In a meta-analytic review conducted by Chiesa and Serretti (2009), MBSR was found to significantly reduces stress among nonclinical participants. More recent workplace research indicates that MBSR can decrease emotional and physical exhaustion (a burnout component), stress, psychological distress, depression, anxiety, and work-induced stress (Janssen et al., 2018). Within the literature on MBSR and employee wellbeing, healthcare professionals constitute the most frequently studied group (Janssen et al., 2018). Additionally, many reviews and meta-analyses draw from occupations such as teaching or health and social care (Lomas et al., 2019; Virgili, 2015) or concentrate on a single MBP (e.g., MBSR) (Jayawardene et al., 2017; Khoury et al., 2015; Ebert & Sedlmeier, 2012; Chiesa & Serretti, 2009).

Mindfulness-Based Interventions (MBIs) may be well-placed to serve a distinctive preventative or early intervention role in addressing the significant health burdens confronting the United Kingdom (Mindful Nation UK, 2015). The UK National Health Service (NHS) has been experiencing unprecedented demand, and there is a need for more universally accessible, psychologically-informed care, with less emphasis on exclusion criteria and specialised treatments. There is considerable interest in mindfulness among healthcare stakeholders, with 72% of general practitioners (GPs) expressing willingness to refer patients to mindfulness interventions (Halliwell, 2010). However, only 20% of GPs report access to mindfulness courses in their localities (Crane & Kuyken, 2012). In fact, the salutary outcomes of MBSR and other MBIs may not be explained by their effects on specific clinical diagnoses (Davis et al., 2024) but may instead be transdiagnostic with several processes underlying a range of symptoms and issues (Goldberg, 2022).

Mental ill health is among the leading global health-related burdens. The Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2019 found that the most disabling psychiatric disorders are depression and anxiety, ranking amongst the leading causes of global burden (for a systematic analysis, see GBD Study 2019; 2020; Kessler et al., 2009). Beyond the negative individual experiences of people affected, anxiety and depression present colossal economic load such as mounting costs in health care (The World Health Organization, 2017; Alsubaie et al., 2017; Vasiliadis et al., 2013), clearly pointing to a need for efficacious and targeted treatments and preventative strategies. Dimidjian & Segal (2015) highlight the paucity of ecologically valid, high quality RCT research conducted in real world settings, defined by the NIH framework of 'clinical psychological science' as Step 3 intervention research (Onken et al., 2014). Efficacy studies are overrepresented in the literature, yet an essential research priority is the optimization of interventions, which rely on understanding and utilizing key change mechanisms (Holmes et al., 2018; Kazdin & Blase, 2011). Longitudinal and experimental evidence is limited, with most investigations into the 'ingredients' of mindfulness being cross sectional (for systematic reviews and meta-analyses, see Burton et al., 2017; Galante et al., 2023; Gu et al., 2015; Dimidjian & Segal, 2015; Van Dam et al., 2017).

Since 2010, seminal neuroscience frameworks have outlined core interrelated neurocognitive mechanisms that underpin the effects of mindfulness via a broad self-regulation system, including *attentional and cognitive control*, *emotion regulation*, and *self-related processes* (Holzel et al., 2011; Tang et al., 2015; Vago & Silbersweig, 2012; Schuman-Olivier et al., 2020), how they interact with and are informed by *bodily awareness* (interoception) (Farb et al., 2013, 2015; Gibson, 2019; Hanley et al., 2017; Holzel et al., 2011; Khalsa et al., 2018; Kerr et al., 2013; Mehling et al., 2012), and more recently with memory and learning (Schuman-Olivier et al., 2020). In the psychological literature, attentional processes, such as executive attention, are also recognized as central to the salutary benefits of mindfulness (Prakash et al., 2020), however less as a standalone mechanism and more as enabling experiential awareness and the cultivation of the *attitudinal components* of mindfulness (Burzler et al., 2019; Kabat-Zinn, 1990; Keng et al., 2011; Lindsay & Creswell, 2017; Malinowski, 2013; Rogge & Daks, 2021).

The attitudinal mechanisms, alongside interoceptive awareness, are highlighted as particular to mindfulness (compared with cognitive behavioural traditions), and can be broadly referred to as *acceptance* processes such as receptivity and willingness, as well as nonjudging and nonreactivity (Bergomi et al., 2013; Kabat-Zinn, 1990; 1994; Lindsay & Creswell, 2017), corresponding with 'psychological self-distancing' capacities (Desbordes et al., 2015) of decentering, defusion, equanimity, metacognition, meta-awareness, non-striving or nonattachment (Bernstein et al., 2015; Creswell et al., 2019; Desbordes et al., 2015; Guendelman et al., 2017; Johansenn et al., 2022; Schuman-Olivier et al., 2020; Shapiro et al., 2006; Soler et al., 2021). The acceptance literature is not fully explicit about the extent to which acceptance involves taking a self-immersed (receptivity and willingness) versus self-detached (nonreactivity and nonjudging) relationship to internal phenomena (Dunn et al., 2009; Kross & Ayduk, 2009). Acceptance-oriented mechanisms

are often contrasted with effortful control, reappraisal and suppression strategies associated with traditional emotion regulation conceptualisations (Gross, 2014; 2015; Ochsner & Gross, 2008) that have been hypothesised to be more costly and less sustainable than flexible responding (Aldao et al., 2010) and 'mindful' or 'embodied' forms of emotional self-regulation (Guendelman et al., 2017; Iani et al., 2019). Mindful and embodied forms of attention and acceptance may work together and differentially to represent an adaptive emotion regulation function that mediates mindfulness-induced psychological wellbeing and resilience (Baer et al., 2003; Lindsay & Creswell, 2017; Rogge & Daks, 2021).

NIH and MRC research frameworks

NIH experts are calling for 'hypothesis-driven mechanisms research' into areas such as self-regulation, executive function, interoceptive awareness, and emotion regulation, with analysis of mechanisms at the social, psychological and neurobiological levels (Nielsen et al., 2018). Dimidjian & Segal (2015) assert that Stage 3 real world efficacy research makes up less than 1% of the total mindfulness-based intervention research, (ie., Mindfulness Based Stress Reduction (MBSR) and Mindfulness Based Cognitive Therapy (MBCT)), whilst mechanisms research makes up less than 30% of NIH-funded clinical research (Nielsen et al., 2018). Onken and colleagues (2014) define a Stage III study is "a well-controlled, internally valid study in a community setting with community therapists/providers" (page 29). These studies also focus on testing efficacy and identifying mechanisms of change (Dimidjian & Segal, 2015).

Based on these two interrelated frameworks, this study can be identified as 1. an evaluation study from the perspective of MRC guidance, with additional focus on change mechanisms (process evaluation) and objective psychophysiological measurement (Skivington et al., 2021) and 2. Stage III efficacy trail conducted in a community setting using a community provider, with emphasis on external validity and mechanisms of change (Dimidjian & Segal, 2015).

Complex intervention research may use efficacy, effectiveness, theory-based, or systems perspectives, chosen by prior knowledge and the evidence that would most advance understanding. It asks beyond whether an intervention works to its broader questions: other impacts, value compared with cost, mechanisms, contextual interactions, contribution to system change, and how evidence informs real-world decisions. This approach aligns with the UK Medical Research Council's updated Framework for Developing and Evaluating Complex Interventions (2021), which is particularly relevant to this PhD study given its real-world pragmatic RCT design with a small sample size and resource constraints. In line with a broader conception of complexity, the scope of complex intervention research needs to include the development, identification, and evaluation of whole system interventions and the assessment of how interventions contribute to system change (Rutter et al., 2017; Kessler & Glasgow, 2011).

A complex intervention research design is warranted to interrogate the multifaceted processes through which mindfulness-based stress reduction (MBSR) exerts salutary effects on wellbeing. By transcending a singular efficacy assessment, this approach enables simultaneous examination of multiple causal pathways, including mediational mechanisms, contextual contingencies, and resource-related constraints, that collectively shape observed outcomes. Specifically, the design permits testing of hypothesized mediators (e.g., attentional control, present-moment awareness, regulatory reactivity) and their temporal sequencing within realistic settings, thereby elucidating how changes in mindfulness processes translate into improvements in affect, stress appraisal, and functional wellbeing. Moreover, the complex-intervention framework accommodates heterogeneity in implementation and context (Skivington et al., 2021), allowing for an integrated appraisal of mechanisms, effect sizes, and their interaction with ecological factors. In sum, this rationale preserves theoretical precision while embracing methodological pluralism essential for delineating the substantive and practical implications of MBSR for wellbeing in everyday life.

Taken together, there is evidence of the applicability of these change mechanisms in clinical research and practice, however there remains a lack of consensus and a compelling theoretical model explaining the influences of mindfulness practice on psychological wellbeing (Lima-Araujo, 2023), as such greater understanding of the specificity of these processes is crucial (Alsubaie et al., 2017; Burzler et al., 2019; Heeren et al., 2009). In addition to a lack of coherence of understanding and evidence concerning mindfulness processes modulating treatment effects, there is limited evidence as to the correspondence between subjective and 'objective' (implicit, indirect, neurophysiological), biomarkers implicated in mindfulness-based interventions (Treves et al., 2019; Prakash et al., 2020).

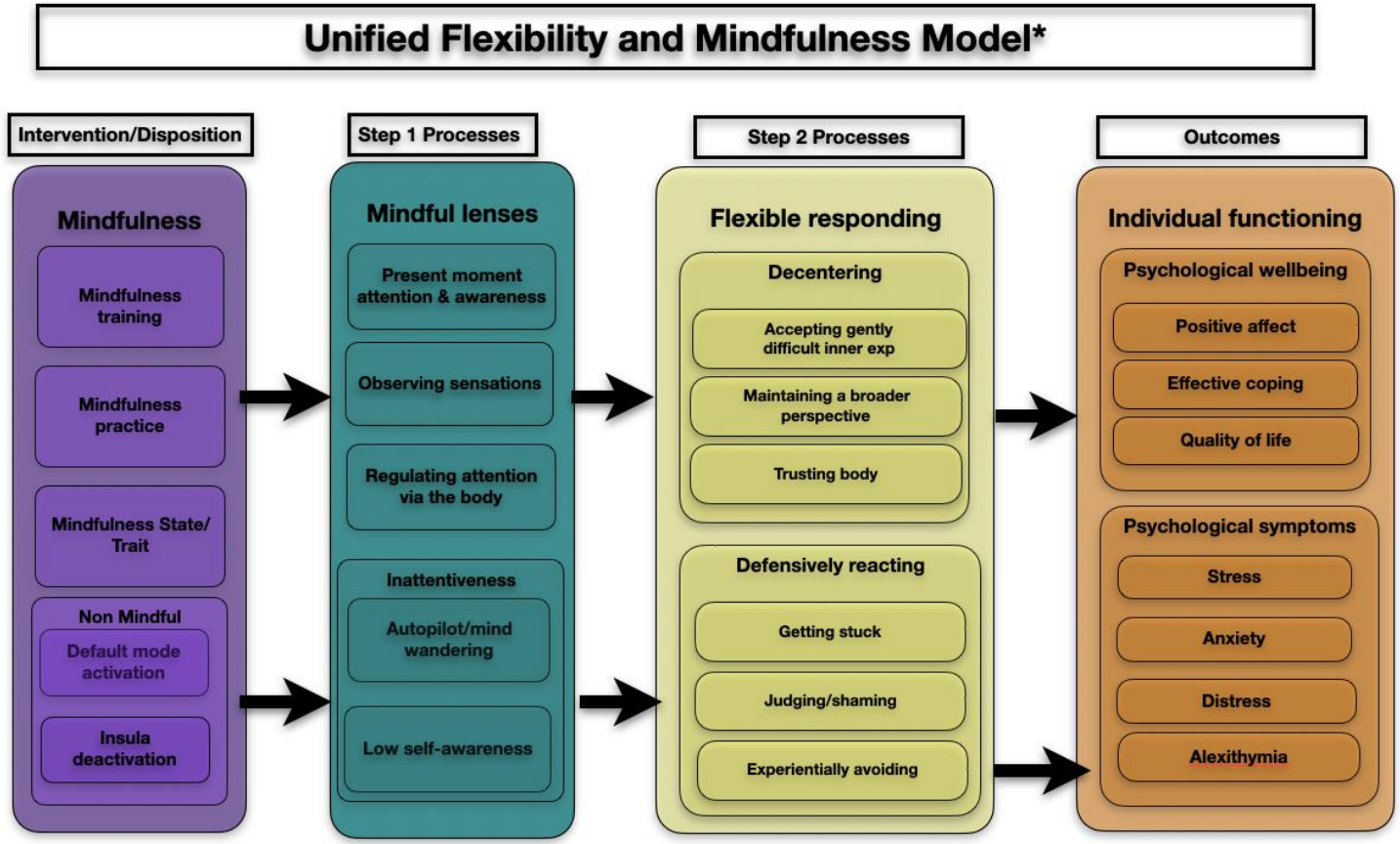
Due to these complex challenges regarding definitions and research methodologies, this doctoral study has selected an ecologically valid RCT design, using psychological and psychophysiological outcome and mechanism measures to explore the effects and processes mediating psychological wellbeing induced by standardized mindfulness training in formal practices.

In this doctoral study, change mechanisms of interest are those associated with mindfulness and emotion regulation including interoceptive awareness, attentional processes and acceptance (decentering). There is evidence that mindfulness mechanisms do not act on their own, but in conjunction with other psychological processes, giving a rationale for using multiple mediation models (Perez-Pena et al., 2022). As such, this study will explore multiple mediation analyses, informed by the multi-process, sequential UFM model (Rogge & Daks, 2021). The UFM organizes its process model into three sequential axes comprising attentional processes (mindful lenses), flexible responding to difficult experience (acceptance and decentering), values-led behaviours, leading to psychological wellbeing (Rogge & Daks, 2021).

The Unified Flexibility and Mindfulness (UFM) model was chosen as the guiding theoretical framework due to the correspondence between mindfulness practice to clinically relevant outcomes through cooperating yet independent key mediators of mindful attention and acceptance. To address a gap in the clinical literature, I have integrated two interoceptive awareness subscales into a modified UFM model and removed Step 3 values-based actions that are not relevant to MBSR, rather processes relevant to Acceptance and Commitment Therapy (Hayes et al., 2006; Parker et al., 2024). See Figure 1 for the unified framework of core mindfulness processes (UFM) and their sequential mediational influences on mental health outcomes achieved via mindfulness training.

Figure 1

*Unified Flexibility and Mindfulness (UFM) Sequential Mediation Model**



Note. *An adapted UFM sequential mediation model that incorporates interoceptive processes into Step 1 (attention) and Step 2 (acceptance), removing Step 3 (values-based actions) which are not relevant for mindfulness-based interventions but relevant for Acceptance and Commitment Therapy (Hayes et al., 2006)

Conceptualising mindfulness

A shortcoming in the mindfulness literature is the lack of specificity and accord related to its definition, methodology and measurement. Mindfulness is often used as an overarching designation to describe a variety of practices, processes, and qualities and there is no universally agreed upon technical definition to date (Van Dam et al., 2017). Though mindfulness has its origins rooted in Buddhism, it has expanded into the sciences and Western contemporary milieu. Grossman (2019) argues that the integration of mindfulness into secular culture is challenging in that mindfulness practice is intended to cultivate personal, embodied wisdom that can be elusive and difficult to operationalize and empirically measure. These contexts have contributed to a paucity of methodologically stringent mindfulness research (Grossman, 2019; Van Dam et al., 2017). In the research literature, several definitions have been proposed. Kabat-Zinn (2003) defined mindfulness as the awareness that emerges through 'paying attention 'on purpose', in the present moment, and non-judgmentally to the unfolding of experience, which includes moment-to moment sensations, thoughts, and emotions and urges. Updated definitions include moment-to-moment awareness, cultivated by paying attention in a specific way, in the present moment, as non-reactively, non-judgmentally, and open-heartedly as possible (Kabat-Zinn, 2011) and awareness of present-moment experiences, including thoughts, emotions, and bodily sensations, with a gentle and accepting attitude towards oneself (Bishop et al., 2004). Brown and Ryan (2003) suggested that attention to the moment is the single most critical aspect of mindfulness, supplanting acceptance and non-reactivity. Shapiro et al (2006), assert that 'attention, intention, and attitude' are the essential components of mindfulness, and that noticing one's experience can result in changes in self-reference and perspective, or decentering (Bernstein et al., 2019; King & Fresco, 2019).

How mindfulness is conceptualized influences what is measured and by what methods, which can vary by scale, orientation and discipline (Grossman, 2019). Essential facets of mindfulness that are routinely referenced in the scientific literature include present-moment awareness, beginner's mind, non-judging, non-reactivity, and acceptance (Mehling et al., 2017). Mindfulness has been described as a mental faculty for being consciously aware or present in a particular moment (Kabat-Zinn, 2013). Mindfulness may also refer to a particular meditation practice, such as an attention to the breath, body scan or open-monitoring meditation (Fox et al., 2014; Lutz et al., 2015; Van Dam et al., 2017). Mindfulness has also been defined as a psychological capacity relating to terms capturing the Pali word *sati*, such as 'attention, awareness, retention, or discernment' (Davidson & Kaszniak, 2015). Mindfulness has also been proposed as a pathway to mental and physical wellbeing (Grossman, 2019). Mindfulness disposition is described as a stable personality trait whereas a state of mindfulness corresponds to a momentary condition of nonelaborative, present moment awareness (Chambers et al., 2009; Davidson, 2010; Tomlinson et al., 2018) which can fluctuate across time and individuals. Mindfulness as practice refers to the specific intentional practice of mindfulness meditation, the cultivation and training of a decentered or metacognitive faculty and a curious, accepting orientation

towards present moment attention and awareness that leads to an experiential rather than narrative experience of self-consciousness and self-reference (Chambers et al., 2009; Davy et al., 2016; Farb et al., 2007; Hamilton et al., 2015; Tang et al., 2015).

Mindfulness and mental health

Systematic reviews and meta-analyses provide evidence for the effectiveness of mindfulness and acceptance-based therapies on both mental health and bodily symptoms (Johannsen et al., 2022; A-Tjak et al., 2015; Grossman et al., 2004; Khoury et al., 2013; Leaviss & Uttley, 2015; Swain et al., 2013). Meta-analyses and RCTs demonstrate that the positive outcomes of mindfulness and acceptance-based therapies are on par with cognitive behavioural therapy (CBT) (Arch et al., 2012; Arch et al., 2013; Craske et al., 2014; Forman et al., 2007; Kuyken et al., 2016; Twohig & Levin, 2017; Wetherell et al., 2011). Mindfulness training has been shown to increase dispositional (trait) mindfulness which is proposed to explain positive effects on mental health (for meta-analytic evidence and reviews, see Gu et al. 2015). Similarly, meditation practice is linked with higher dispositional mindfulness as measured with the Five Factor Mindfulness Questionnaire (FFMQ) (Baer et al. 2008; Tran et al. 2014). Mindfulness training (MT) has been associated with significant improvements in cognitive functioning and mood as well as improvements in attentional skills and reduction of stress markers, depressive symptoms, and anxiety-related conditions (Farb et al., 2012; Lao et al., 2016; Pascoe et al., 2017; Tang et al., 2015). Studies suggest that elevated trait mindfulness corresponds to improved self-care (Slonim et al., 2015) and fewer medical issues and health-related behaviours in people with developmental trauma, or who have experienced childhood adverse events (Whitaker et al., 2014).

Mindfulness based interventions, particularly MBSR, have been found to alleviate psychological distress (e.g., stress, anxiety, mood symptoms) with medium effect sizes compared to waitlist controls and active treatment controls (Hofmann et al., 2010; Khoury et al., 2013; 2015; Ma et al., 2018; Chiesa & Serretti, 2009). Wellbeing, the inverse of psychological distress, is proposed as a protective factor against recurrent psychiatric disorders (Keyes et al., 2010; Lamers et al., 2015). A systematic review found psychological wellbeing to be a core emotional outcome significantly associated with mindfulness (Tomlinson et al., 2018). Thirteen studies found positive correlations between psychological wellbeing and mindfulness skills (Bodenlos et al., 2015; Short et al., 2016). Research on mindfulness-based programmes reveals a strengthened facility to experience unpleasant, ruminative thoughts and emotions with less negative arousal (Raes & Williams, 2010; Feldman et al., 2011; Coffey et al., 2010; Segal et al., 2002). The capacity to shift attention away from negative rumination is suggested to relate to remission from depressive recurrence (Segal et al., 2002; Labelle et al., 2010). This shifting and redeployment of attention is a skill trained implicitly in MBSR and explicitly in MBCT. Sustained mindfulness practice may contribute to depressive symptom remediation via a modulating process whereby negative ruminative patterns are interrupted or neutralized

(Heeren and Philippot, 2011; Labelle et al., 2010; Raes and Williams, 2010, Shamini et al., 2007).

Stress

Notwithstanding the research interest in the suitability of mindfulness therapies for specific and diverse clinical populations, less consideration is afforded to the demonstrated preventative benefits of MBIs for healthy stressed populations (Khoury et al., 2015; Nyklicek & Kuijpers, 2008; Zollars et al., 2019). Stress is a multifaceted response to psychological or biological overwhelm and perceived or actual threat. A systematic review has shown that various meditation practices influence physiological markers of stress reactivity yet there is limited understanding of the neurobiological mechanisms via which mindfulness attenuates stress (Pascoe & Crewther, 2016). Daily life stressors cause pathological arousal and psychological stress resulting in persistent activation of the sympathetic nervous system (SNS) and hypothalamic pituitary adrenal (HPA) axis (Nesse et al., 2016). Acute, sustained stress exposure can be deleterious to mental and physical health, with adverse effects to interpersonal relationships (Cordon et al., 2009). There is a recognition that certain levels of stress can be tolerable and even motivational, however harmful stress has been found to contribute to a range of somatic issues and affects the body's cardiovascular, respiratory, musculoskeletal, gastrointestinal, nervous and reproductive systems (Fogelman & Canli, 2018; Yaribeygi et al., 2017). Unhealthy stress can also be exacerbated by unhelpful coping styles such as worry and rumination, leading to risk elevation for depression and other mental health conditions (Watkins & Roberts, 2020). Stress has been proposed as a mechanism for depression and anxiety (Dantzer, 2012; Juruena et al., 2020; Pariante & Lightman, 2008).

There is some evidence that emotional acceptance is associated with psychological health in part by lessening affective reactivity to stress (Ford et al., 2017; Lindsay et al., 2018), and that this improvement in psychological wellbeing and stress biology, via acceptance, can be achieved by engagement with brief mindfulness training (Lindsay et al., 2018). In a systematic review of mindfulness and measures of psychological health (Tomlinson et al. 2018), most of the twenty-one studies examined focused on how mindfulness is inversely related to experiential avoidance (Na et al., 2022), which in turn is associated with non-acceptance (Johansenn et al., 2022; Hayes et al., 2006), negative thinking patterns affecting emotional health (Kiken & Shook, 2012), procrastination (Sirois & Tosti, 2012) and rumination (Tomlinson et al., 2018). Johansson et al. (2022) assert that negative, aversive thoughts and emotions are not intrinsically problematic in themselves, but that one's maladaptive, negative reactivity to these unpleasant inner experiences are what drive psychopathology.

Anxiety and depression

According to Tran et al. (2014), there are differing mindfulness mechanisms mediating anxiety versus depression. Body awareness was found to be a specific mediator for the effects of dispositional mindfulness on anxiety conditions and for depression the mediator was nonattachment, defined as a general absence of inner pressures to hold on to, change or avoid specific experiences and the absence of a fixation on ideas, images and sensory experiences (Sahdra et al., 2017). In a mediational study using the FFMQ, with over a hundred psychiatric patients receiving either MBCT/MBSR or CBT, researchers found that the *nonreactivity* and *acting with awareness* facets (acceptance and attention components respectively) predicted longitudinal amelioration of depression and anxiety, and not the other facets (Webb et al., 2019). Most significantly, these FFMQ facets mediated depression and anxiety and outperformed CBT. These findings were validated by mainly cross-sectional studies reporting significant associations between enhanced acting with awareness and lower depressive and anxiety symptoms (Branstrom et al., 2011; Curtiss & Clemanski, 2014; de Bruin et al., 2012; Royuela-Colomer & Calvete, 2016). The study by (Royuela-Colomer & Calavete, 2016) found that elevated acting with awareness and nonreactivity scores in over 450 adolescents over time (4 months later) mediated reduced depressive symptoms four months after initial assessment, while the observing facet predicted increased depression via rumination.

Emotional dysregulation (alexithymia)

Alexithymia is considered a transdiagnostic risk factor for a variety of emotion-based disorders, including depression, anxiety and stress (Preece et al., 2024). Alexithymia, translated as having no language for emotions, is described as an impairment in the capacity to identify, describe, and regulate one's emotions (Luminet et al., 2018). Alexithymia is proposed an emotional regulation deficit, rather than an attentional impairment, due to reduced ability to recognize one's own feelings (emotional awareness) and in others (Edwards & Lowe, 2021). Alexithymia may be an earlier indicator of emotional regulation difficulties, given that the ability to clearly identify emotions is a primary skill of emotional regulation (Goetz et al., 2020; Preece et al., 2017). Conversely it has been argued that alexithymia may more accurately relate to a general impairment in interoceptive capacities (Brewer et al., 2016; Herbert et al., 2011). Alexithymia is normally distributed in the general population, with around ten percent struggling with high alexithymia (Parker et al., 2008), while in clinical populations up to half meet criteria for significant alexithymic symptoms (McGillivray et al., 2017). Mindfulness and alexithymia have been shown to be related constructs, with high alexithymia significantly correlated with low levels of mindfulness (Baer et al., 2006; Teixeira et al., 2015) and poor interoception (Trevis et al., 2019; Santarnecchi et al., 2014). Alexithymia had originally been conceived of as a fixed personality trait, however more recent evidence has indicated that it can be modified.

Mindfulness-based approaches have been found to be effective in attenuating the symptoms of alexithymia and associated emotion dysregulation (Edwards & Lowe, 2021; Van Bael et al., 2024; Gross, 2015; Preece et al, 2022) and psychological distress (Honkalampi et al., 2000; Margalit et al., 2014; Tominga et al., 2014). Mindfulness improves both body and emotional awareness and regulation (Norman et al., 2019), which are both found to be deficits in alexithymia (Santarnecchi et al., 2014). Despite this known association, a systematic review of alexithymia and psychological interventions did not find any study specifically examining mindfulness training's effects on alexithymia (Cameron et al., 2014). Since then, there has only been one study explicitly analyzing the effects of mindfulness-based interventions on alexithymia (see Norman et al., 2018 for a systematic review with meta-analyses). Two studies have suggested that MBIs may ameliorate alexithymic deficits in interoceptive (bodily) awareness (Byrne et al., 2016; Haase et al., 2015). There have been mixed results with respect to intervention-induced change to trait mindfulness scores on alexithymia, with only one of the four RCT studies assessed (Norman et al., 2018) to measure trait mindfulness (Santarnecchi et al., 2014) and reporting no significant improvement in mindfulness scores as a result of the MBI. This is contrary to other evidence (Khoury et al., 2013) and this discrepancy has been attributed to the use of the Mindful Attention Awareness Scale (MAAS: Brown & Ryan, 2003) which does not capture the emotional and attitudinal elements present in other mindfulness instruments (Norman et al., 2018). A study of the effects of long-term mindfulness training found increases in interoceptive accuracy that may be directly related to improvement in alexithymic symptoms (Bornemann & Singer, 2017).

Neuroscience of mindfulness

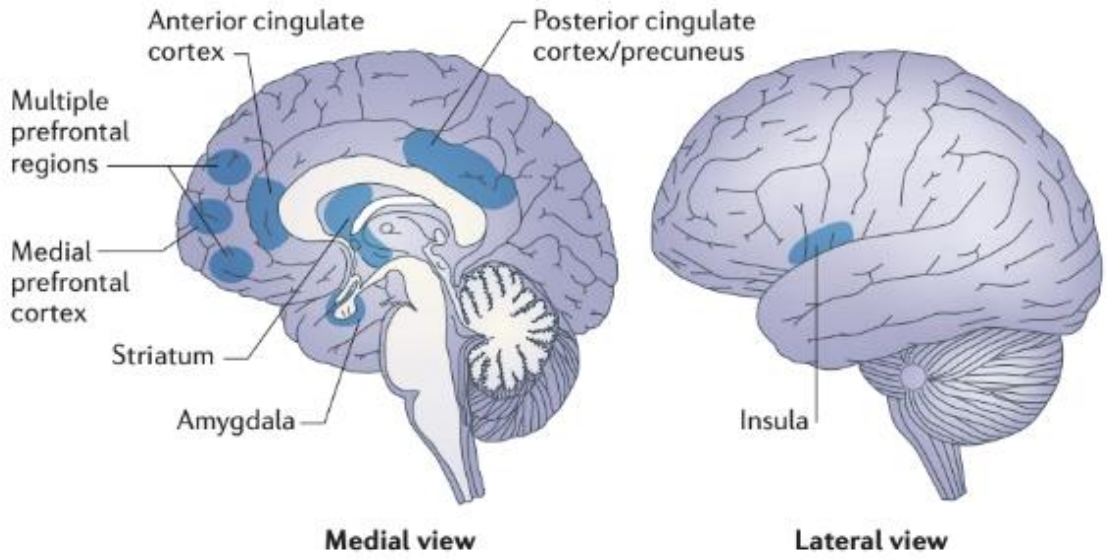
Mindfulness has demonstrated effects on neuroplasticity in a range of neural regions, particularly the default mode, salience (comprising interoceptive and exteroceptive networks), and central executive networks (Feruglio et al., 2021). A recent meta-analytic review suggests that the insular cortex is the neural region routinely activated by both interoceptive processes and mindfulness (Casals-Gutiérrez & Abbey, 2020). In addition, a systematic review reveals that regions of the default mode network are active when not mindful (ie., during mind wandering) and that mindfulness can alter DMN functional connectivity and deactivate DMN signatures associated with ruminative depression and mind wandering tendencies (Feruglio et al., 2021; Tabibnia, 2020; Vago & Zeidan, 2016; Melis et al., 2023). Melis and colleagues (2023) indicate that mindfulness interventions, training attention to present moment internal and external experience, have been found to strengthen attentional control over mind wandering, negative self-reflection and rumination which is evidenced by enhanced DMN functional connectivity with the central executive network (frontoparietal) and frontoparietal down-regulation of the DMN (Bremer et al., 2021; Chou et al., 2023).

The interoceptive network, a node of the salience network coupled with the anterior cingulate cortex, spans various brain regions, which include the insular cortex, cingulate cortex, inferior frontal gyrus, and the sensorimotor cortex (Craig, 2002; 2009; Critchley et al., 2004; Farb et al., 2007; 2013; Friedel et al., 2015; García-Cordero et al., 2016; Haase et al., 2016; Pollatos et al., 2007a). Wang et al. (2019b) found that focused attention on exogenous (external) stimuli and endogenous (internal) sensations produced distinctive neural signatures and mindfulness practitioners who brought sustained attention to inner experience, such as the breath, produced a lowering of self-referential activity which corresponded with associated neural regions such as the medial prefrontal cortex and the default mode network (DMN). The network of brain regions implicated in self-referential processing is known as the default mode network (DMN), of which the primary midline nodes are the precuneus cingulate cortex and the dorsal and medial prefrontal cortex (Bremer et al., 2022; Brewer et al., 2011; Guendelman et al., 2017; Holzel et al., 2011; Tabibnia et al., 2020). Feruglio and colleagues (2021) indicate that when mindfulness practitioners experience mind wandering during a focused attention meditation, regions of the DMN appear to be active such as the precuneus cingulate cortex, medial prefrontal cortex, posterior parietal or temporal cortex and parahippocampal gyrus. Conversely when mindfulness practitioners notice their mind is wandering, an activation of the salience network occurs, which is associated with the detection of internal and external salient signals (Tabibnia, 2020; Feruglio et al., 2021).

Neural effects of mindfulness become more pronounced, depending on level of experience or ‘dose’ exposure to prolonged meditation practice. Indeed, experienced meditators demonstrate more attentional focus on ‘bottom up’ nociceptive signals that are associated with the posterior insula with dampening of the more ‘top down’ evaluative, cognitive appraisal activity represented in the dorsomedial prefrontal cortex (DMPFC). Meditation, with its attending to the body, lessens DMPFC activity which in turn contributes to the anterior insula focusing more deeply on information from the posterior insula, to where the body signals are transmitted. This process leads to simultaneous effects including: 1. neuroplasticity changes in the posterior, mid, and anterior insula (Damasio & Carvalho, 2013; Farb et al., 2015) and 2. a decoupling of the insula from the DMN and the DMFPC (Farb et al., 2007; 2013; Wang et al., 2019b). To that effect, researchers have found that higher traits of mindfulness are associated with dampened connectivity between the DMN nodes, but greater connectivity between the DMN and the somatosensory network (Harrison et al., 2019; Parkinson et al., 2019. See Figure 2 for a graphical representation of brain regions involved in the components of mindfulness meditation (Tang et al., 2015). See Figure 2 for diagramme of brain regions involved in mindfulness components of attention, emotion regulation and self-awareness.

Figure 2

Brain Regions Involved in Attention, Emotion Regulation and Self-Awareness



Note. graphical representation from Tang and colleagues (2015) of brain regions involved in the components of mindfulness meditation. Schematic view of some of the brain regions involved in attention control (anterior cingulate cortex, striatum), emotion regulation (multiple prefrontal regions, limbic regions, striatum) and self-awareness (insula, medial prefrontal cortex, posterior cingulate cortex, precuneus)

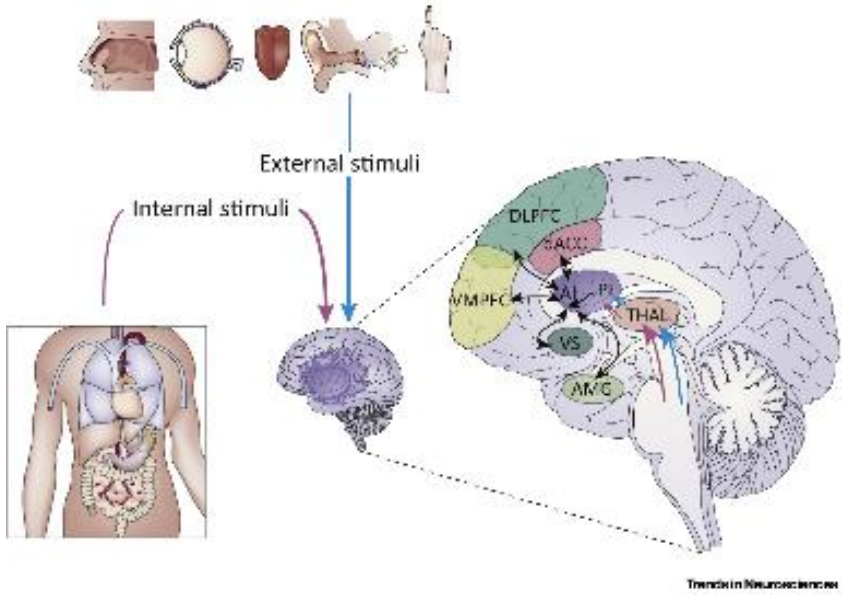
The DMN has been shown to be active during rest, spontaneous thinking, when thinking about self in relation to past and future and in relation to other people (Bremer et al., 2022; Tabibnia, 2020; Brewer et al., 2011; Chou et al., 2023). DMN overactivity has been linked to the tendency toward mind wandering, elevated focus on distressing emotional states and rumination associated with major depressive disorder (Chou et al., 2023; Zhou et al., 2020). The interruption of negative rumination is difficult, yet research indicates that mindfulness meditation training may alter baseline resting states, where the wandering mind tends to be active, which can then enable more adaptive functioning and less biased, self-referential cognitions (Vago & Zeidan, 2016). Key DMN regions are found to be less active in experienced meditators, which indicates that mindfulness meditation may produce an anti-depressant effect (Chou et al., 2023). DMN deactivations are also related to stronger connectivity between DMN regions and the anterior cingulate and prefrontal cortices. This indicates that reduced self-referential thinking may accompany increased attentional control over mind wandering (Brewer et al., 2011). According to Farb and colleagues (2013), a circuit involving the medial prefrontal cortex and posterior cingulate cortex (DMN) exerts a narrative type of self-referential cognitive activity when engaged. Narrative self-focus involves an emotionally-laden cognitive amplification of past and future thinking and is associated with rumination and mind wandering as previously stated. The authors also proposed an opposing DMN-inhibiting interoceptive network that enables a different type of self-awareness, termed experiential focus. Experiential focus inhibits the mental storytelling about self, in favour of present moment attending and open awareness, a sensing mode rather than a thinking mode. (Tabibnia, 2020) The authors argue that in the absence of cognitive interpretations about self, mentation less limited, and allowed to take in wider experience, or a metacognitive awareness (Farb et al., 2013).

The mindfulness literature indicates that mindfulness and meditation practices modulate the insula and interoceptive network (Fox et al., 2016). The insular, or interoceptive, network plays a significant role in attention (Craig, 2009; García-Cordero et al., 2017) and is involved in all bodily, emotional, and subjective experience. The insular cortex acts as a switch between the DMN and the central executive, with interdependent connections to the anterior cingulate cortex, thereby facilitating cognitive control (Cole & Schneider, 2007; Menon & Uddin, 2010). The interoceptive network covers a range of neural regions, involving the insular cortex, cingulate cortex, the inferior frontal gyrus, and the sensorimotor cortex (Craig 2002; 2009; Critchley et al., 2004; Pollatos et al., 2007a; García-Cordero et al., 2017). Of note is that the interoceptive network also connects to the amygdala, hypothalamus, hippocampus, and brainstem (Craig, 2009; Becker et al., 2015; Khalsa et al., 2018) and appears to function as an interdependent and interconnected cognitive control and sensory processing system (Tabibnia, 2020; Cole & Schneider, 2007). Sensory stimuli are transmitted from the body to the poster insula, the anterior insula, then to the prefrontal cortex which facilitates a gradual conscious awareness of bodily signals and experience (Farb et al., 2015), forming the overall functional activity of the interoceptive network.

Mindfulness researchers assert that interoceptive awareness plays a powerful role in self-regulatory capacities and maintenance and provides a measurable neurological imprint within the insula (Friedel et al., 2015). The insula and interoceptive network provide an experiential mode of self-awareness, distinguished from the narrative self-referential mode associated with the DMN. The experiential orientation views bodily sensations, emotional experience and cognitions as an integrated part of selfhood and facilitates psychological distancing where these mental events do not need to be identified with and are recognized as transient (Farb et al., 2007). There is evidence for enhanced activation in the insula (Khalsa et al., 2018; Craig, 2003; Young et al., 2018) using a mindfulness-based programme in a nonclinical population (Farb et al., 2007) as well as in experienced meditators (Grant et al., 2010). A systematic review validates the activation of the insular cortex via mindfulness and interoception (Casals-Gutierrez & Abbey, 2020). See Figure 3 for diagramme of interoceptive information activating cortical and subcortical regions corresponding to emotional, cognitive and motivational signals.

Figure 3

Interoception and Neural Activation Related to Emotions and Cognition.



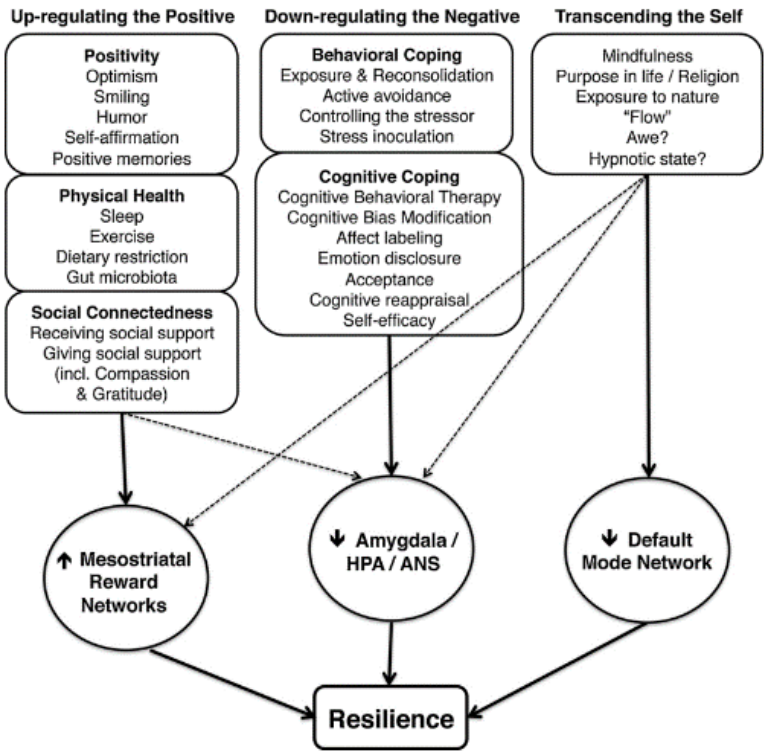
Note. Interoceptive information activating emotional, cognitive and motivational signals corresponding to a range of cortical and subcortical regions (Namkung et al., 2018)

As discussed, neural mechanisms of emotional regulation implicated in mindfulness training tend to differ based on the individual's 'dose' of meditation experience. Meditation naive populations, exposed to brief mindfulness training in the laboratory, exhibited 'top down' control by prefrontal cortex regions on par with individuals who deploy cognitive reappraisal strategies (Lutz et al., 2013). Experienced meditators, on the other hand, downregulate emotional reactivity which involves deactivation of the DMN without deactivation of the amygdala (Taylor et al., 2011). According to Kral et al. (208), MBSR participants exhibited reduced reactivity of the amygdala which was followed by increased amygdala-ventromedial prefrontal cortex functional coupling, in line with evidence that symptom improvement in anxiety patients correlates with the same increased neural coupling after MBSR (Hozel et al., 2013). Experienced meditators, as opposed to eight-week MBSR participants, appeared to deploy 'bottom up', or implicit, emotion regulation functions implicating the insula and ventromedial prefrontal cortex to modulate emotional reactivity (Kral et al., 2018). Together the evidence suggests that more extensive meditation practice enhances greater awareness and acceptance of aversive emotional experience, reducing the need for more effortful suppression and top down inhibitory control of emotional experience (Guendelman et al., 2017; Lutz et al., 2013; Kral et al., 2018; Taylor & Bagby, 2013).

A recent affective neuroscience paper proposes a tripartite model of resilience and wellbeing (Tabibnia, 2020), in which mindfulness activates a 'self-transcendence' pathway toward enhanced resilience and wellbeing, differentiated from (though interrelated to) two other pathways referred to as 'downregulating the negative' and 'upregulating the positive' (Yaden et al., 2017). The mindful pathway to enhanced resilience and wellbeing is via self-transcendence, which involves engaging in present moment attention via mindfulness practice or being in the flow of personally meaningful experiences also involves disengagement from the default mode network (DMN) and its self-focus and mind wandering modalities (Yaden et al., 2017). There is also evidence that mindfulness acts on some of the strategies within the other two pathways, namely exposure, acceptance, affect labelling in the 'downregulative the negative' pathway which reduces amydgala and nervous system stress/threat activation (Tabibnia, 2020). This pathway has significant associations with anxiety. Additionally, prosociality in the 'upregulating the positive' pathway activates the mesostriatal reward networks. Missing from this model is the role of interoceptive or bodily awareness, with its associated modulatory activity in the insular cortex, or 'interoceptive network' (Fox et al., 2016; Khalsa et al., 2018), though it is implicated in all three pathways, particularly the self-transcendence pathway. See Figure 4 for a diagramme of the tripartite model of wellbeing and resilience (Tabibnia, 2020).

Figure 4

*Tripartite Model of Wellbeing and Resilience**



Note. *Tripartite Model of Wellbeing and Resilience (Tabibnia, 2020). In this model, mindfulness acts as a 'transcending the self' strategy, with some upregulation of the positive associated with reward networks and downregulation of the negative associated with stress and threat activation. Missing from this model is the significant neuroscience evidence of the role of interoceptive awareness in mediating the mental health benefits of mindfulness (Hozel et al., 2011)

An understanding of the brain's interoceptive and default mode networks, and their facilitation of a less self-referential orientation toward an experiential self-focus, may provide an explanatory framework that can advance our understanding of mindfulness, interoception, attentional and cognitive process, and mental health issues associated with maladaptive self-referential experience. Overall, evidence exists of the salutary benefits of mindfulness training and skills on interoceptive and default mode networks (Schuman-Olivier et al., 2020). Guendelman and colleagues (2017) describe an embodied form of emotion regulation as a multistage model to explain the neurobiological changes produced by mindfulness training. Embodied emotion regulation strategies distinguish top-down from bottom-up emotion regulation functions. This offers a theoretical framework for the concept of 'mindful' emotion regulation which the researchers state is not adequately decoupled in the clinical literature from other emotion regulation strategies, such as suppression and problem-solving (Guendelman et al., 2017).

Psychophysiological measurements

Some studies have found that mindfulness interventions may not always be evidenced by increases in self-reported mindfulness traits (Quaglia et al., 2016; Bergomi et al., 2013). This, alongside the interest in interoception as a core and understudied mindfulness change mechanism, was the justification for including a multidimensional measure of interoceptive awareness (MAIA: Mehling et al., 2012) in this doctoral study. In addition, the limitations of self-report measures in general provided the rationale for exploring implicit, psychophysiological measures of interoception and emotion regulation.

Psychophysiological emotional elicitation and regulation

Psychophysiological measures, such as electrodermal activity, may be a powerful biomarker of unconscious emotional arousal and remediate the limitations of self-report instruments (Jadhav et al., 2017). Electrodermal activity (EDA) is an electrophysiological signal that reveals the electrical properties of the skin, which are modulated by sweat production (van der Mee et al., 2021). The activity of sweat glands and corresponding skin conductance are entirely under the domain of the sympathetic nervous system (SNS) that enables the body to handle stressors via the fight or flight threat response (Christopoulos et al., 2019; Wallin, 1981). According to van der Mee and colleagues (2021), this makes EDA a relevant measure to assess SNS activity (van der Mee et al., 2021). Patterns of skin conductance response (SCR) have been associated with anxiety, emotional responses, and responses to threat (Craske et al., 2008). Analysis of EDA activity, particularly elicited by an emotionally-laden stimulus, enables researchers to investigate a participant's emotional reaction to a selected stimulus (Sequeira et al., 2009; Sharma et al., 2019). The sympathetic nervous system is a central component of emotional experience and, by extension, cognitive activity and behavior (Christopoulos et al., 2019).

Preliminary findings reveal that MBSR can attenuate the degree of unconscious, implicit emotional arousal to visual affective stimuli via EDA measurement which can represent changes to emotional reactivity and regulation (Correira et al., 2023). Some studies have found a relationship between mindfulness practice and psychophysiological benefits such as a dampening of emotion arousal via skin conductance and changes to heart and respiratory rates (Correira et al., 2023; Jadhav et al., 2017; Tang et al., 2009). Other studies have found an inverse relation between mindfulness and reactivity to external stimuli (Brady et al., 2021; Ortner et al., 2007; Ostafin et al., 2014). There is significant evidence that mindfulness improves emotional regulation and inhibits impulsive reactions to negative stimuli (Sobolewski et al., 2011; Tang et al., 2014). The cultivation of these emotional skills, enhanced by mindfulness training, is argued to evoke physiological alterations at the level of the autonomic nervous system which is represented by alternations to volume and magnitude of electrodermal responses (Correira et al., 2023; Moore et al., 2012).

In order to study emotions in a systematic and controlled manner, Standardized Emotion Elicitation Databases (SEEDs) are recommended (Bradley et al., 2008). SEEDs are sets of databases used for emotion elicitation that replicate real world emotional provocations yet in a controlled laboratory environment. The International Affective Picture system (IAPS) (Lang & Bradley, 2007) is considered a gold-standard collection of visual stimuli (pictures) used to elicit positive, negative and neutral emotions. The validation methods of SEEDs involve both self-report and physiological data such as skin conductance response. Studies using IAPS and physiological measurements demonstrated a congruency between the self-report and physiological data, solidifying it as a reliable tool for emotion elicitation (Bradley et al., 2008). There is limited evidence of a relationship between EDA and self-reported depression and anxiety (Correira et al., 2023), pointing to a need to explore correlations between psychological states and psychophysiological measures.

Psychophysiological interoception

Interoceptive accuracy is defined as the capacity to accurately detect signals from within the body and is considered a skill that can be measured objectively (Critchley et al., 2004). The preferred method for measuring interoceptive accuracy in the research literature has been the heartbeat detection, or heartbeat counting task (Schandry, 1981). Other physiological tests have been used to measure interoception such as the water load test based on the sensation of gastrointestinal signals (Herbert et al., 2012). Although the heartbeat detection task has come under some scrutiny (Brener & Ring, 2016), the heartbeat counting task is still considered the standard and preferred way to assess interoceptive accuracy (Bornemann et al., 2015; Critchley et al., 2004; Dunn et al., 2007; Fisher et al., 2017; Fustos et al., 2012). In Garfinkel et al.'s (2015) three-dimensional model of interoception, the third dimension is a metacognitive ability represented by the accordance between confidence and accuracy of interoceptive abilities (Fischer et al., 2017; Suksasilp & Garfinkel, 2022).

There is inconsistent evidence of a relationship between mindfulness and interoceptive accuracy (Khalsa et al., 2020; Treves et al., 2019). This contradictory evidence may hinge on the type of mindfulness practice used and the depth and length of mindfulness 'dosage' (Todd & Aspell, 2022). To that effect interoceptive accuracy has been observed in mindfulness programmes emphasizing the body scan meditation over an eight-week period (Fischer et al., 2017) or across a nine-month period of meditation training (Bornemann & Singer, 2017). Studies indicate that psychophysiological measures of interoceptive accuracy such as the heartbeat counting task are unaffected in short-term meditators and after eight session mindfulness interventions (Melloni et al., 2013; Parkin et al., 2014). A large-scale longitudinal intervention study, named the ReSource project, found that improvements in training-related heartbeat perception only emerged after six and nine months, with trainings including attention-based mindfulness, socio-emotional and socio-cognitive practices (Singer et al., 2017). This evidence implies that suggest that increases in objective accuracy measures are enhanced over time. Of interest, Bornemann & Singer (2017) also found that interoceptive accuracy improvement were directly linked to amelioration of alexithymic symptoms. It has been argued that increased accuracy in the perception of bodily cues can be associated with improved coping strategies for stress (Bornemann et al., 2015, healthier eating behaviours (Herbert et al., 2013), pain tolerance and management (Villemure et al., 2014), and interpersonal effectiveness (Porges, 2011; Gibson, 2014).

Recent studies indicate that objective interoceptive measures may not strongly overlap, and that different physiological sensations and systems elicit divergent neural effects (Wang et al., 2019b). Two longitudinal studies of heartbeat detection found conflicting results. Fischer et al. (2017) demonstrated modest improvements in accurately detecting heartbeats in a longitudinal study, while the second study did not find improvements in cardioceptive accuracy (Parkin et al., 2014). Neuroimaging results suggest that improved interoceptive accuracy, 'interoceptive learning', relies on neuroplasticity changes elicited by mindfulness and other mind-body contemplative practices (García-Cordero et al., 2016). Of note, García-Cordero and colleagues (2017) conducted another study examining heartbeat counting accuracy and found that when participants focused on exteroceptive stimuli, not internal bodily sensations, their performance improved. The authors propose that interoception and exteroception employ distinct neural mechanisms and that exteroception may require less exertion due to already well developed sensory capacities (García-Cordero et al., 2017). Additionally, the somatosensory cortex, involved in processing exteroceptive stimuli, is generally included as a part of the interoceptive network (Farb et al., 2007; 2013). In short, the clinical, behavioral, and neuroscientific literature converge to indicate that neural areas associated with interoceptive (insula) and exteroceptive (somatosensory cortext) bodily awareness are highly activated in participants of the MBSR programme and in experienced meditators (Chiesa et al., 2013; Holzel et al., 2011; Lutz et al., 2008).

Mediators (change mechanisms)

According to Johansenn et al. (2022), an understanding of change mechanisms, or mediators, is crucial to optimizing mindfulness and acceptance-based treatments for anxiety and depression. In their systematic review and meta-analysis, the authors selected primary mediators of mindfulness-induced psychological wellbeing to include *mindful attention, decentering and acceptance* (Fresco & Mennin, 2019; Hayes et al., 2006; Mennin et al., 2013). Secondary mediators were identified such as rumination, worry, emotion regulation, and general maladaptive thinking styles (Johansenn et al., 2022), and were designated as secondary due to their applicability to other modalities such as to CBT (Berking et al., 2013; Lemmens et al., 2017; Goldberg, 2022). A theory that has emerged in the past decade explaining the processes involved in mindfulness-induced psychological health are the Mindfulness to Meaning Theory (MMT) (Garland et al., 2015). Mindfulness to Meaning Theory is a process model suggesting multiple drivers that mediate mindfulness-induced psychological wellbeing. Its core tenet is the mindful reappraisal hypothesis, which suggests that mindfulness-based interventions enhance mental wellbeing by enabling reappraisal of negative stimuli. MMT's core sequential processes involve attentional control, decentering, broadened awareness, positive reappraisal leading to positive emotion regulation.

Gu and colleagues (2015) conducted a systematic review and meta-analysis of MBSR and MBCT longitudinal studies, with further criteria of only including studies with mediation analyses. Starting from 169 trials and ending with 20 studies meeting inclusion criterion for further analysis, the authors found consistent and strong evidence of emotional and cognitive reactivity, repetitive negative thinking (such as rumination and worry), and mindfulness itself as change mechanism implicated in MBSR and MBCT. With the aim of examining change mechanisms implicated in MBCT for recurrent depression, Van der Velde et al. (2015) assessed twenty-three mediation studies via systematic review, of which twelve concluded that mindfulness skills, worry, rumination, self-compassion and meta-awareness modulated MBCT treatment effects (Van der Velde et al., 2015). This evidence is concordant with the work of Aldao et al. (2010) in which *avoidance, rumination*, and *suppression* as maladaptive emotion regulation strategies were correlated to anxiety, depression, and eating disorders (Aldao et al., 2010). Fissler and colleagues (2016) found evidence of an interrelated mediation relationship between interoceptive awareness and decentering mediating depressive symptoms following a brief mindfulness induction. Alsubaie and colleagues (2017) integrated the literature on hypothesized mechanisms of MBSR/MBCT, describing a process whereby one initially learns to cultivate a specific form of attentional capacity to focus and stabilize attention in the body (Williams & Kabat-Zinn, 2013), which may be a prerequisite to becoming aware of emotional and cognitive reactivity and later decentering from negative thinking (an emotion regulation strategy). Synthesizing these findings, key adaptive mediators of mindfulness-induced psychological health may be non-reactivity, acceptance, decentering, interoceptive awareness and attentional meta-awareness and regulation.

Attention

Regulation of attention has been proposed as the essential foundation of all meditation practices and may be a priori mechanism enabling other salutary mechanisms to emerge (Farb et al., 2015; Hozel et al., 2011; ref). Furthermore, attention may stand out as an ontological prerequisite for other cognitive functions to exist (McGilchrist, 2012). Seminal theories have implied that attention is the most important component of mindfulness (Brown & Ryan, 2003), and that mindful attention can determine the quality of subjective experience and perspective (Shapiro et al, 2006). A methodological challenge is how to measure attentional processes cultivated by mindfulness meditation. Mindfulness does not necessarily differentiate between attention to bodily sensations (interoceptive), attention to mental events such as thoughts and emotions, and attention toward exteroceptive stimuli via the five senses. Some studies suggest that different attentional styles elicit disparate 'neural signatures' (Fox et al., 2016; Wang et al., 2019b).

Formal mindfulness practices are taught in MBIs, along an attentional spectrum that ranges from *focused attention* to *open monitoring* processes (Lutz et al., 2008; Schuman-Olivier et al., 2020). *Focused attention* involves: 1. deploying and sustaining attention to an object of attention, such as a breath sensation; 2. noticing and disentangling from mind wandering (e.g., distractors); and 3. returning attention to the selected object, again and again, when mind wandering is noticed. *Open monitoring* involves: 1. a wider awareness of endogenous experience with no explicit object focus; 2. cultivating metacognitive monitoring, or an observing-self capacity; and 3. a nonreactive awareness of the coming and going of mental phenomena ie., thoughts, emotions, urges and sensations (Lutz et al., 2008; Schuman-Olivier et al., 2020). Focused attention meditations have a cyclical quality, where meditators experience a circuit of disparate mental states (Hasenkamp et al., 2012, Malinowski, 2013) including focused attention on the object of meditation, followed by unconscious mind wandering, then becoming aware that the mind has wandered, and finally escorting attention back to the object of focus such as the breath (Delorme & Brandmeyer, 2019). These types of mindfulness practices can be categorized as specific mental training of attentional self-regulation (Jha et al., 2007; Tang et al., 2015). Meditation practitioners develop the capacity to monitor and perceive naturally occurring mental events, disengage from inner preoccupations and thoughts and shift their attentional focus to a selected object whenever they notice the mind on autopilot, or wandering off into thinking mode (Delorme & Brandmeyer, 2019).

Qualitative different from focused attention meditations is the open monitoring style of meditation. In open monitoring, the scope of attention is not limited to a distinct object and instead treats all experience as equally relevant and available to awareness (Lutz et al., 2008). Open monitoring enables the attitudinal orientation of mindfulness, viewing thoughts, feelings, urges and sensations as simply transitory mental events that can be noticed with a receptive, accepting stance. Receptivity, and equanimity, allow for practitioners to experience nonvolitional mental phenomena without resisting, holding onto, or fusing with thoughts and feelings. Meditators can simply notice mental events as they

emerge, receive them and watch them pass. Together, FA and OM practices are hypothesized to reduce the arousal associated with mind wandering, helping to eliminate the automatic reinforcing of emotional reactivity, or hyperarousal, toward unpleasant or anxiety-provoking thoughts and sensations (Delorme & Brandmeyer, 2019; Hanley et al., 2017). Being nonreactive involves deploying intentional styles of attention that reduce emotional interference, rather than being nonresponsive to experience. See Table 1 for an attentional schema of focused attention versus open monitoring styles found it meditation practices (Lutz et al., 2008).

Table 1

*Attentional Schema of Meditation**

Attentional Style	Attentional Process
Focused Attention	Directing and sustaining attention on a selected object (e.g., breath sensation).
Focused Attention	Detecting mind wandering and distractors (e.g., thoughts).
Focused Attention	Disengagement of attention from distractors and shifting of attention back to the selected object.
Focused Attention	Non attentional: receptive reappraisal of distractor (e.g., 'just a thought', 'just a mental event'
Open Monitoring	No explicit focus on objects of attention - wider attention/awareness
Open Monitoring	Nonreactive metacognitive monitoring (e.g., for early meditators, labelling of experience).
Open Monitoring	Nonreactive awareness of automatic interpretations (cognitive and emotional) of sensory, perceptual and internal stimuli

Note. *Buddhist tradition considers FA meditation to produce a calming effect on the mind and OM meditation to induce some physiological arousal and energy (Lutz et al., 2008; Brown & Ryan, 2004)

A central aspect of mindfulness is paying attention to the present moment (Carmody, 2009). In contrast, mind-wandering is when attention drifts away from the primary task at hand, with individuals often not being aware that their attention has drifted (Schooler, 2002; Smallwood & Schooler, 2006). Studies have reported that people spend approximately 30-50% of their waking hours in mind wandering thoughts unrelated to their current activities (Killingsworth & Gilbert, 2010). Because mind wandering entails a partial disconnection from the external environment, it is usually associated with an increased number of errors and other performance impairments in activities that require focused attention (Delorme & Brandmeyer, 2019). As such, mind wandering has been proposed as being functionally the opposite of mindfulness, particularly mindful attention and associated with a range of negative consequences such as work-related injuries, accidents and poor mental health (Liu et al., 2023). Mindfulness meditation reduces mind-wandering (e.g., Cantone et al., 2021; Feruglio et al., 2021; Rahl et al, 2017; Giannandrea et al., 2019). Empirically, meta-analyses support biased attention as a core feature of anxiety and depressive disorders (Peckham et al., 2010).

Studies have found that high attentional control is associated with lower levels of anxiety and depression (Olafsson et al., 2011; Reinholdt-Dunne et al., 2013), thereby highlighting attentional control as a relevant therapeutic target. In a recent scoping review of the contemplative sciences literature examining the impact of mindfulness meditation for components of attention, researchers found the most robust evidence for mindfulness training to impact executive control of attention (Prakash et al., 2020). Reductions in mind-wandering propensity, negatively correlating with mindful attention, are validated by clinical trials (see Feruglio et al., 2021 for a systematic review), provide preliminary support that training in mindfulness meditation may enhance one's ability to prioritize task-relevant representations, and to filter out irrelevant, internal thoughts or external stimuli in the environment. Taken together, there is a growing recognition for the potential for mindfulness practices to improve attentional control.

The potential of increasing mindful attention seems particularly relevant in the context of anxiety and depression, as it may enable patients to pay attention to and notice patterns of maladaptive self-referential processing (e.g., rumination and worry) inherent to these disorders (Mennin et al., 2013; Nolen-Hoeksema et al., 2005). This unhelpful tendency toward 'narrative' self-reference is found in the neuroscience literature with neural correlates in the default mode network, which is contrasted with more adaptive self-orientational style, an 'experiential' self-referencing associated with mindfulness-induced default mode deactivation.

Orienting, alerting, and executive attention receive and send information along the frontal lobe and the anterior cingulate cortex (ACC) (Botvinick et al., 2001; Kolling et al., 2016; Petersen & Posner, 2012). The interpreting of this information and the adjustments employed from the interpretation of that information is known as attention regulation (Botvinick et al., 2001; Kolling et al., 2016). When information between the attentional networks conflict, Tang and colleagues propose that two outcomes are possible,

investigation of the stimulus or attention to the body (Tang et al., 2015). Investigation of the stimulus occurs when the level of conflict in the ACC is alarming enough to warrant attention (Petersen & Posner, 2012; Tang et al., 2015) and information is transferred to the lateral frontal lobe associated with executive attention and language. Orientation of attention toward the body occurs when ACC conflict or threat is low and control is passed to the temporoparietal junction and insula cortex, associated with emotion regulation, consciousness and bodily homeostasis.

As summarized in Figure 1.5, the UFM model asserts that mindfulness interventions initially train attentional processes, or 'mindful lenses' and consider attentional processes as sequentially a priori to cultivating the attitudinal qualities promoted in both mindfulness and acceptance-based literatures, though with different treatment components and targets (Rogge & Daks, 2021). The attitudinal constellation of decentering capacities comprise acceptance, which is defined in the mindfulness literature as either nonreactivity or nonjudging of endogenous experience.

Acceptance

An accepting orientation to one's experience, despite its emotional valence, is described in the mindfulness and contemplative literatures as a powerful, unique change mechanism (Mennin et al, 2013), yet there are limited intervention studies investigating the attitudinal component of acceptance which is proposed to be cultivated in mindfulness-based training programmes. An orientation of receptivity and nonreactivity to emotionally-laden endogenous stimuli is achieved by permitting emotionally valent (pleasant/unpleasant) experiences to come and go without interference (Creswell et al., 2017). Lindsay and Creswell (2019) use the concept of acceptance to refer to an orientation of receptivity and noninterference with present-moment endogenous experiences (Desbordes et al., 2015; Young, 2016), distinct from human tendencies to control, suppress, change or fuse with unwanted stimuli. Hadash et al. (2016) suggest that rather than grasping for wanted experiences (craving) and avoiding unwanted experiences (aversion), acceptance interrupts the quintessential association between desire (wanting and not wanting) and the emotional valence of experience (pleasant or unpleasant). Acceptance-based emotional regulation strategies have been found to lessen negative affect (Campbell-Sills et al., 2006) and to attenuate anxiety and avoidance tendencies (Levitt et al., 2004). Researchers found that after a prolonged mindfulness training of three months, acceptance (nonreactivity) outperformed present-moment attention in mediating reduction in mood symptoms compared with a progressive muscle relaxation control group (Gao et al., 2018). It has been suggested that mind/body interventions that facilitate the experiencing of internal stimuli (bodily sensations, feelings, thoughts, urges) without modifying or distracting from them can cultivate acceptance skills (Hayes et al., 1999), however not enough is understood about how mindfulness fosters acceptance and to what extent acceptance mediates its beneficial outcomes (Lindsay & Creswell, 2017). Acceptance, contrasted with experiential avoidance, is put forward as primary component of mindfulness-based interventions according to the Monitoring and Acceptance Theory

(MAT) (Lindsay & Creswell, 2017). Based on theory and correlational research, MAT asserts that acceptance is the essential emotion regulation mechanism, with preliminary evidence from dismantling studies validating this assertion (Lindsay & Creswell, 2019). Some evidence from experimental studies indicate that prolonged practice in attention monitoring, conceptualized as observing inner experience and present moment awareness, may lead to adaptive attentional control strategies that offer greater emotional awareness and clarity associated with emotion regulation, however that these gains may only be achieved over time (Lindsay & Creswell, 2017; O'Brien et al., 2017). In the earlier phases of mindfulness training and practice, the authors posit that increased attentional awareness on its own, without acceptance, does not provide the essential mechanism to ameliorate stress (Inzlicht & Legault, 2014; Barnes & Lynn, 2010). Studies assessing the relationship between attention and acceptance found that present moment attention drives improved mental health and reduced clinical symptoms only when accompanied by high levels of acceptance (Pearson et al., 2015; Desrosiers et al., 2014). As a new theory, there is some criticism of MAT (Simione & Saldarini, 2023). Traits of mindful attention, absent of acceptance traits, have been associated with positive affect, life satisfaction and purpose (Sahdra et al., 2017; Felsman et al., 2017; Iani et al., 2017). As such, the trait mindfulness literature suggests that attention skills alone may be sufficient to heighten positive experiences (Lindsay & Creswell, 2015).

Nevertheless, Mutch and colleagues (2021) found a significant mediational effect of acceptance in the relationship between mindfulness training and wellbeing in a nonclinical population undergoing an eight-week-long mindfulness-based stress reduction intervention. Studies suggest that mindfulness and acceptance attenuate psychotic phenomena (Cramer et al., 2016; Jansen et al., 2019), disordered eating (Prefit et al., 2019), addictive behaviours (Bowen et al., 2011), self-harm and suicidality (Tighe et al., 2018) and other psychopathologies (Aldao et al., 2010). Two experimental studies appear to provide evidence that cultivating an attitude of acceptance towards present moment experiences is a central driver via which mindfulness training exerts its positive emotional effects (Lindsay et al., 2018; Rahl et al, 2017). Rahl et al. (2017) conducted an RCT study where reductions in mind wandering was found to be mediated by specific targeting of acceptance. A study has also highlighted that the relationship between mindfulness traits and 'peace of mind' is mediated by acceptance (Xu et al., 2015), and the positive association between subjective psychological wellbeing and mindfulness was significantly mediated by self-acceptance only (Xu et al., 2016). Further, acceptance of nociceptive stimuli promoted pain tolerance and endurance as a result of mindfulness training, as opposed to simplify focusing attention on the pain without an accepting orientation (Wang et al., 2019a). Ford et al. (2017) reviewed systematic cross-sectional, experimental, and longitudinal studies and found that habitual acceptance of difficult emotions is linked to emotional wellbeing, to some extent by neutralizing negative reactivity to stress (Ford et al., 2017; Creswell et al., 2017).

In a study by Iani and colleagues (2019), acceptance emerged as the prominent mechanism in 'mindful' emotion regulation function, differentiated from traditional cognitive

and behavioural strategies of suppression and avoidance. The association between acceptance and nonreactivity, measured by the Five Factor Mindfulness Questionnaire (FFMQ) nonreactivity facet, indicates that disrupting automatic negative emotional reactivity to challenging experiences, via nonreactivity skills, is a prerequisite to being able to flexibility accept one's experience, however aversive. Accordingly, a mindful approach to emotion regulation consists of developing the skills to become aware of all aspects of one's experience, including difficult experience, and in turn practicing equanimity and willingness to experience the stimuli while resisting the urge to react (Hill & Updegraff, 2012). Iani et al. (2019) found that habitually accepting unpleasant experience and emotions resulted in a strengthening of other adaptive strategies such as reappraisal, coping and problem-solving. The relationship between acceptance, nonreactivity, and adaptive reappraisal can be elucidated by the mindfulness-to-meaning theory (Garland et al., 2015). Mindfulness is thought to lead to positive reappraisal through a process of decentering that induces a metacognitive state of awareness (Iani et al., 2019).

Studies suggest that nonreactivity, related to acceptance, may serve as a potent mindfulness mechanism (Zou et al., 2020; Malinowski, 2013; Makowski et al., 2019; Heeren et al., 2015). Lutz et al (2015) found that for external stimuli, nonreactivity modified the association between the experience of the stimuli and its cognitive appraisal or interpretation. Contrary to prevailing concepts of mindfulness mechanisms, non-judging may not exert a significant mediational influence on the relationship between standardized mindfulness interventions and psychological wellbeing (Zou et al., 2020). There is growing evidence that reduced reactivity to emotion leads to beneficial mental health effects (Gao et al., 2018; Malinowski, 2013; Malinowski & Lim, 2015), with the suggestion that nonreactivity supports disengagement from habitual cognitive and behavioural control strategies. There is also evidence that higher capacity to not react impulsively to aversive experience enables the space to engage in emotion regulation strategies such as inhibiting habitual responses, switching mental modes more intentionally and generating less negative appraisals, leading to different options for coping and responding (Malinowski, 2013; Malinowski & Lim, 2015). Some neurobiological evidence exists to support a nonreactivity hypothesis concerning mindfulness processes (Rosenkrantz et al., 2013; Goldin & Gross, 2010; Taren et al., 2015), whereby nonreactivity plays an axiomatic role in inducing the salutary outcomes (Mayer et al., 2019). Finally, mindfulness was found to consist of two axes of a higher-order, overarching emotion regulation structure that mediates improvements to depression and anxiety and which can be applied to both clinical and general populations. These two axes comprise an acceptance-based 'orientation to experience' factor and a 'self-regulating of attention' factor (Burzler et al., 2019).

Interoceptive (bodily) awareness

Interoception concerns the body, the perception of the body's physiologic state and a range of neural functions and correlates (Khalsa et al., 2018; Tabibnia, 2020). As previously stated, interoception plays a central role in the maintenance of self-regulatory functions which is a distinctive element in the mindfulness literature, offering an identifiable neurobiological imprint within the insula (Casals-Gutierrez & Abbey, 2020; Friedel et al., 2015). The body, via interoceptors (receptors located in the gut area of the body: Furness et al., 2013), transmits data to the temporoparietal junction and insular cortex. These neural regions process and interpret the endogenous somatic cues and provide an internal bodily 'map' at both conscious and unconscious levels (Mehling et al., 2018). The overriding function of interoception is to maintain bodily homeostasis and when homeostatic, the endogenous signals remain unconscious (Furness et al., 2013). Once homeostasis is disrupted, conscious awareness of interoceptive activity is instantiated (Ceunen et al., 2016; Mehling et al., 2018). This conscious discernment of interoceptive activity is referred to as interoceptive awareness (Mehling et al., 2018), with particular interest from the field of mindfulness research in the interceptive phenomena that correspond to the bodily representation and expression of emotions (Ceunen et al., 2016; Garfinkel et al., 2015). Interoceptive signals can influence one's emotional and psychological condition at an unconscious level, however the evidence suggests that there is a greater effect on thinking, feeling, perceiving and behaviour when interoceptive cues reach conscious awareness (Cameron, 2001; Dunne et al., 2007; Craig, 2009).

Interoceptive awareness (IA) has long been linked to mindfulness and other contemplative therapies (Mehling et al., 2012; Farb et al., 2015; Yang et al., 2015; Holzel et al., 2011) and has been purported to be coupled, both functionally and theoretically (Farb et al., 2015; Holzel et al., 2011). Many formal mindfulness practices such as the body scan and yoga element in Mindfulness-Based Stress Reduction (MBSR), promote focused attending to bodily sensations though not exclusively (Kabat-Zinn, 2013). From the neuroscience literature, IA has put forward as of the core change mechanisms implicated in mindfulness and other mind/body therapies (Bornemann & Singer, 2017; Farb et al., 2015; Guendelman et al., 2017; Holzel et al., 2011). Essentially, IA and mindfulness are both oriented to take inner, endogenous experience as the object of attention, with self-reflective capacities underpinning both. Although IA and overall mindfulness both capture attentional processes, the divergence is that mindfulness does not differentiate between attention directed to exteroception, interoception, thoughts or emotional valence.

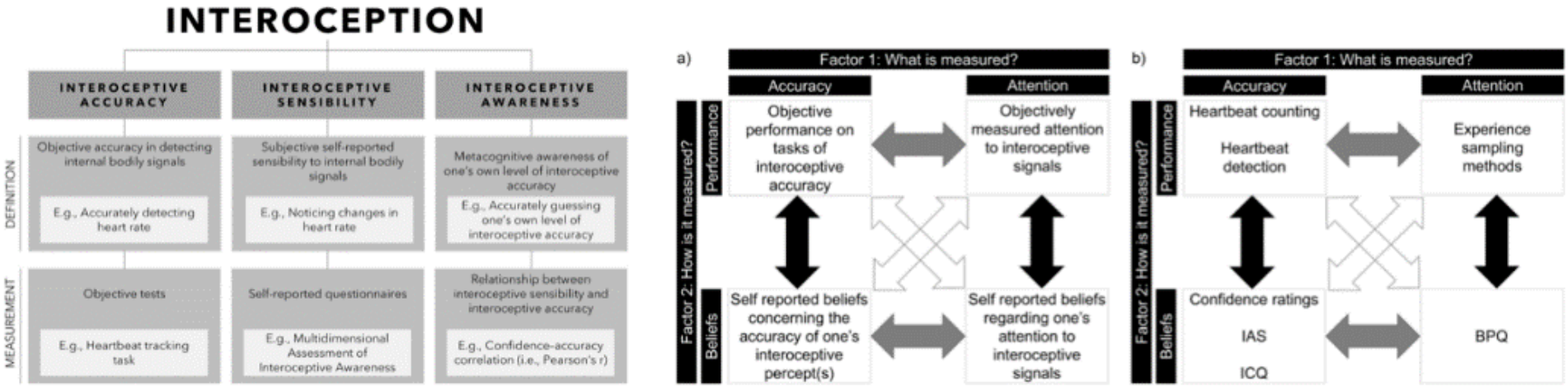
A growing body of evidence has linked interoceptive deficits to depression, anxiety disorders, eating disorders, chronic pain, alexithymia and other psychopathologies (Brewer et al., 2016; Ardizzi et al. 2016; Di Lernia et al., 2016; Herbert & Pallatos, 2014; Paulus & Stein, 2010). Interoceptive cues are not considered intrinsically positive or negative, however the style of relating to bodily signals may determine between adaptive and maladaptive responses to interoceptive cues (Mehling et al., 2016). According to Garfinkel et al. (2016b), anxiety symptoms may be generated by interpretations of bodily stimuli as

threatening or nociceptive, leading to a heightened sensitivity and vulnerability when contrasted with more mindful attentional orientation. Adaptive IA can be characterized by qualities of mindful attention as well as the capacity to regulate one's emotional experience via attending to the body. IA can thus be used to disengage from maladaptive thoughts and improve clinical symptoms, such as with pain and depression (Michalak et al., 2012; de Jong et al., 2016). There is an increased recognition of the importance of interoceptive awareness, with the correspondence between interoceptive accuracy and interoceptive confidence/insight emerging as potentially relevant for a range of somatic and psychological conditions (Garfinkel et al. 2016a; Nord & Garfinkel, 2022; Quadt et al., 2018; Paulus & Stein, 2006; 2010; Rae et al., 2018) and potentially mediating certain transdiagnostic features (Ewing et al., 2017; Murphy et al., 2019). Interoceptive awareness focuses primarily on somatically-grounded conscious experience, with intersections to attention, emotion and psychological fields. This more encompassing notion of IA, it can be argued, is a departure from traditional conceptualizations of body or somatic awareness. Much of the body and somatic awareness literature is directed at clinical populations, where a heightened sensitivity to or amplification of bodily symptoms and sensations has been linked to anxiety, medically unexplained symptoms and other somatic conditions (Mehling et al., 2009; Barrett et al., 2004; Herbert & Pollatos, 2014; Mallorquí-Bagué et al., 2014; Fischer et al., 2017; Pollatos et al., 2007b).

To address the diversity of interoception concepts, researchers developed a multidimensional construct of IA, the Multidimensional Assessment of Interoceptive Awareness (MAIA) which enables a discernment between mindful versus maladaptive (ie, anxiety-driven) attentional styles towards internal experience (Mehling et al., 2012). In an attempt to operationalise interoception by integrating definitions and methodologies (both 'objective' and subjective measurements), Garfinkel and colleagues (2015) proposed a three-dimensional model comprising: 1. interoceptive accuracy, or sensitivity; 2. interoceptive sensibility, or self-reported confidence and 3. interoceptive metacognitive insight/awareness, the correspondence between accuracy and confidence. Murphy and colleagues (2019) extended the three-dimensional model to a model of interoceptive ability. The authors use a 2x2 factorial model of interoceptive abilities, which deviates from the literature related to mindfulness and interoceptive awareness with its focus on interceptive attention/ability rather than a more psychological aspect of interoceptive awareness. The first factor specifies whether accuracy or attention is the target of measurement and the second factor specifies what type of measurement used and whether it takes the form of an objective or subjective instrument (Murphy et al., 2019). See Figure 5 for a graphical representation of the 3-Dimensional Interoception Model (Garfinkel et al., 2015) and the 2x2 factorial interoception model (Murphy et al., 2019). Of these dimensional and factorial models, interoceptive sensibility can be understood as the closest, conceptual parallel to IA as defined by the developers of the self-report measure used in this study (Mehling, 2016).

Figure 5

*Dimensional Models of Interoception**



Note. *The 3-Dimensional Model of Interoception (Garfinkel et al., 2015) and 2x2 Factorial Model of Interoception (Murphy et al., 2019) both define 'objective' and subjective measurements of interoceptive processes. According to Garfinkel and colleagues (2015), *interoceptive accuracy* is measured by the heartbeat counting task, *interoceptive sensibility* is measured by the Multidimensional Assessment of Interoceptive Awareness questionnaire (Mehling et al., 2012) and *interoceptive awareness* is measured by metacognitive awareness, or accuracy is estimating one's own level of interoceptive accuracy.

The capacity to shift attention to the body has been hypothesised to enhance focused attention, reduce stress, and obtain awareness of one's emotional and cognitive state (Bornemann et al., 2015; Fissler et al., 2016). The interoceptive network in the brain plays a key role in disentangling from self-referential cognitive activity, which has been associated with clinical gains related to psychological flexibility (Baer, 2003; Wang et al., 2019a) and is a central element of the mindfulness traditions (Mehling et al., 2012; Bornemann et al., 2015; de Jong et al., 2016). Regulating one's attention to the body enables the anchoring of the mind in the here and now and away from ruminative 'time traveling' (Farb et al., 2015) and other markers of poor mental health. Researchers are settling on interoceptive awareness as the scientific concept representing the mechanism of change cultivated within the mind body therapies and investigations (Craig, 2002; Mehling et al., 2012; 2016), while integrating views from many disciplines. Mehling and colleagues (2012; 2016) propose two overarching factors encompassing multiple dimensions of IA in their MAIA self-report instrument including: 1. awareness of one's physiological state (Critchley & Garfinkel, 2017) and 2. the evaluations and interpretations affiliated with said bodily awareness (Mehling, 2016). Despite the clinical significance of IA for mind/body investigations and psychological and physical health, limited intervention research has been undertaken to understand the impact of mindfulness on IA (Perez-Pena et al., 2022) and the influence of IA as a mindfulness change mechanism.

To date a limited number of studies have explored the impact of mindfulness-based interventions on IA (de Jong et al., 2016; Bornemann et al., 2016). Interoceptive awareness and its relationship to mindfulness and its outcomes have primarily been limited to cross-sectional and neuroscience studies. Some evidence suggests that mindfulness training improves self-reported interoceptive awareness (de Jong et al., 2016; Bornemann et al., 2015; 2016, which appears to produce psychological benefits (Perez-Pena et al., 2022), including for depression (Fissler et al., 2016), chronic pain and comorbid depression (de Jong et al., 2016), pregnant women (Duncan et al., 2017). Data from (Hanley et al., 2017) seem to validate evidence that the use of bodily awareness to enhance adaptive behaviour is cultivated by mindfulness (Tsur et al., 2016). Bornemann et al. (2016), in a nonrandomized study, reported that a mindfulness-based intervention specifically focused on bodily awareness improved the regulatory subscales of the MAIA (self-regulation of distress, attention regulation, listening to the body for insight, using the body for emotional awareness, trusting the body and not distracting from unwanted experience) compared to a retest control group. Particularly strong effects were found for the regulatory strategies of interoceptive awareness: (1) regulating distress by attending to body sensations (self-regulation), (2) regulating attention to and from bodily sensations (attention regulation) and (3) listening to the body for important information (body listening) (Bornemann et al., 2014). Self-reported interoceptive capacities have improved following 8 weeks of mindfulness-based training (Parkin et al., 2014), and even after a brief mindfulness exposure of a few days (de Lima-Araujo et al., 2022). Taken together, findings imply that embodied forms of emotion regulation are improved by mindfulness training while IA elements such as noticing bodily signals may not be associated with mindfulness benefits (Bornemann et al., 2015; de Lima-Araujo et al., 2022).

It is important to highlight that while mindfulness training may improve interoceptive awareness as measured by self-report, mixed results have been observed regarding more objective measures of interoceptive accuracy, such as heartbeat detection, following mindfulness training (Khalsa et al., 2020; Melloni et al., 2013; Parkin et al., 2014; Treves et al., 2019). In fact, there is evidence that no coherent relationship exists between objective interoceptive accuracy and interoceptive sensibility (Garfinkel et al. 2015). Some studies have found weak or no association between mindfulness and interoceptive accuracy or detection (Khalsa et al., 2020; Treves et al., 2019). Existing data suggest that the relationship between 'objective' interoceptive accuracy measures and self-report measures of interoception may differ according to whether the self-report instrument measures accuracy or attention. Interoceptive accuracy has been linked to one's confidence/belief regarding the accuracy (Garfinkel et al., 2015), yet not with self-reported attention to interoceptive cues (Murphy et al., 2018).

There are multiple processes involved in interoception, which is reflected in the discipline-dependent variation in interoceptive conceptualizations (Khasa & Lapidus, 2016; Khalsa et al., 2018) as well as the scientific developments in interoceptive investigations, concepts and methodologies (Farb et al, 2015; Khalsa et al., 2018). As interoceptive stimuli contribute to emotional experience, mindfulness-based investigations may offer insights into how neural signals trigger bodily responses, emotional reactions, and cognitive appraisals, which can then be used to develop adaptive strategies to regulate stress and enhance wellbeing (Farb et al., 2015). Some studies have demonstrated that becoming more aware of bodily sensations and signals via mind/body interventions direct facilitates emotional awareness, a prerequisite for emotional regulation (Villemure et al., 2014; Bornemann et al., 2015; Bornemann & Singer, 2017; García-Cordero et al., 2017). As such IA and mindfulness have been integrated to form concepts such as embodied or 'mindful' styles of emotion regulation (Guendelman et al., 2017). Conversely, a recent review of the effect of mindfulness interventions on self-related processes found mixed results for embodiment and interoception (Britton et al., 2021). As the science is emergent, there is a need for further longitudinal and mechanism-focused intervention research into adaptive interoceptive awareness implicated in mindfulness therapies.

Emotion regulation

Emotions are psychological states that are influenced by and manifest via 3 forms of arousal (1) cognitive (2) behavioural manifestations such as facial expressions, muscle tensions, verbal tone, (3) and physiological such as heart rate, breathing, etc (Gross & Barrett, 2011; Jerath et al., 2015; Norman et al., 2014). Emotions are shorter in duration than moods, with emotions involving a triggering stimulus and moods not requiring a trigger (Jerath et al., 2015). Once the valence of an emotion is assessed, emotional responses are monitored and modulated via an emotion regulation system (Braunstein et al., 2017; Holzel et al., 2011; Oscher & Gross, 2005). According to the mindfulness literature, emotion regulation may involve appraisal/reappraisal then exposure, extinction, and reconsolidation (Braunstein et al., 2017; Oscher & Gross, 2005), though other

perspectives on more implicit, bottom up forms of embodied/mindful emotion regulation exist (Guendelman et al., 2017; Iani et al., 2019) and there is mixed evidence with regard to mindfulness and reappraisal (Iani et al, 2019).

Wielgosz and colleagues (2019) propose that the activity of being mindful facilitates the capacity to adaptively cope with emotions and that mindfulness practice cultivates the skills required to effectively regulate challenging emotional activation. Mindfulness and emotion regulation are interrelated, with evidence pointing to mindfulness improving overall emotion regulation (Chiesa et al., 2013; Roemer et al., 2015; Schuman-Olivier et al., 2020). It is suggested that training in mindfulness offers dose-dependent effects, with shorter term meditators exercising top-down control and experienced practitioners with the capacity to deploy bottom-up regulation of emotional experience (Chiesa et al., 2013). Research has indicated that mindfulness is antithetical to presumed 'maladaptive' or taxing emotion regulation strategies, such as experiential avoidance, suppression of emotional experience, and emotional dysregulation (Guendelman et al., 2017; Hayes & Feldman, 2004). One line of thinking suggests that a mindfulness approach counteracts the need to reappraise or change aversive experiences and situations, with emotions and thoughts being recognized as temporary mental events that can be observed, rather than identified with (Iani et al., 2019). This can extend to the noticing of physical sensations, representing an overall metacognitive monitoring capacity (Garland & Fredrickson, 2013). Internal experiences, especially difficult emotions, are deemed come and go like waves in the ocean and the attitudinal orientation of mindfulness, with its receptivity and acceptance of all experiences, neutralizes the tendency or impulse to actively change or dissociate from unwanted emotions (Chambers et al., 2009; Nyklíček, 2013). Other authors have argued that mindfulness might be better understood as a mental state that promotes reappraisal of the emotional interpretation or valence, which in turn may produce a sense of wellbeing (Garland et al., 2010; 2015). Indeed, Goldin et al. (2016) found that mindfulness-based stress reduction increased reappraisal as effectively as cognitive behavioral therapy. A synthesis of these two positions is that mindfulness promotes acceptance and flexibility in the generation of positive reappraisal (Iani et al., 2019).

Mindfulness practices may cultivate more sustainable, adaptive emotion regulation, described by Iani and colleagues (2019) in their research as 'mindful' emotion regulation. Mindfulness facilitates deployment of attention and metacognitive awareness, which inhibits and eventually interrupts habitual appraisals (Corcoran et al. 2009; Farb et al., 2015), thereby activating different regulatory processes. These regulatory strategies may involve new evaluations and responses to emotional triggers, as well as a receptivity and expression of emotional experience rather than the putative strategies of avoidance, suppression and rumination. Mindful acceptance of emotional experience can be regarded as transforming one's relationship to difficult emotional stimuli, viewing emotions as transient phenomena rather than a problem to be solved (Chambers et al., 2009; Schuman-Olivier et al., 2020). Accordingly, both the clinical and neurobiological evidence broadly supports this view (Gu et al. 2015; Guendelman et al. 2017). Mindfulness has been found to increase awareness of how emotions influence decisions and behaviour

which in turn can influence problem-solving and coping (Werner & Gross, 2010). Research into chronic illness in primary care revealed that patients engaging in an eight-week mindfulness-based intervention increased emotion regulation and demonstrated health-oriented behavior change (Gawande et al., 2019). A meta-analysis by Britton et al. (2016) found that participants in a mindfulness-based programme, compared to controls, significantly improved on emotion-regulation measures, suggesting that mindfulness may engage emotion-regulation processes that can improve behavioral outcomes (Loucks et al., 2015; Schuman-Olivier et al., 2020; Werner & Gross, 2010).

The mindfulness-to-meaning theory was validated by a longitudinal study, indicating that increases in decentering capacities contributed to a widening of awareness that in turn predicted positive reappraisal (Garland et al. 2017). Mindfulness-to-meaning theory asserts that mindfulness pauses automatic appraisal and stress reactivity (Garland et al. 2015), allowing for the space to generate new appraisals and behavioural choices. Moreover, mindfulness is seen to facilitate forms of psychological distance such as a metacognitive activity of decentering (Grenucci et al. 2015) from the elaborative mental contents made up mainly of emotions and thoughts. Mindfulness can promote shifts of attention toward self-reflection, broadened to encompass previously unnoticed (less negative) aspects of self and experience which can become available for reframing (reappraisal), and finally leading to a capacity to flexibly select more adaptive responses (Grenucci et al., 2015). Another process by which mindfulness can influence emotion regulation is that of noticing one's emotions and describing the internal experience via words, known to be a deficit of alexithymia (Preece et al., 2023). With greater emotional awareness and clarity via mindfulness training, an overall adaptive emotion regulation strategy can be cultivated which facilitates the awareness that emotions and thoughts are transient events which can be approached with receptivity and noninterference (Gratz & Tull 2010; Iani & Didonna 2017). Finally, models specific to interoception and stress reactivity (Shulz & Vogele, 2015), neurobiology (Paulus, 2007) and physiology (Craig, 2002) come together in recognition of interoception, information from the body, as central to emotion experience and regulation (Critchley & Garfinkel, 2017).

Guendelman and colleagues (2017) reviewed the neuroscience literature of longitudinal MBSR studies on and found that MBSR induces neuroplastic changes in emotional reactivity (amygdala, insula), body/interoceptive awareness (insula, somatosensory cortex), self-awareness (posterior cingulate cortex, pons), and memory systems (hippocampus, cerebellum) (Holzel et al., 2009; 2011; Santarecchi et al., 2014; Singleton et al., 2014). Of interest, these studies did not find changes in prefrontal cortex regions involved in top-down control emotion regulation. Previous findings of MBSR participants found increased gray matter density in the hippocampus, posterior cingulate cortex , temporoparietal junction, cerebellum, and brainstem (Holzel et al., 2011) and increased gray matter volume in the left caudate (Farb et al., 2013). Research on meditation found regional increases in cortical thickness including in the insula (Zeidan et al., 2013). According to Guendelman et al. (2017), this provides a rationale for a hypothesis that the salutary effects of MBI, particularly MBSR, might be mediated primarily by changes in

relevant subcortical and cortical regions related to bottom-up emotion regulation systems. This is the overarching basis for which Guendelman and colleagues (2017) propose a bottom-up 'mindful' emotion regulation mechanism differentiating mindfulness mechanisms from other modalities.

Critical appraisal of seminal mindfulness models

Despite a lack of consensus in mindfulness conceptualisation and operationalisation across disciplinary fields, there is some agreement in the literature that mindfulness comprises both *attention regulation* and an *orientation toward experience* that is accepting or equanimous (Bishop et al., 2004; Burzler et al., 2019; Lindsay & Creswell, 2017) Depending on theoretical and research interests, studies have a wide range of foci, on related mechanisms such as decentring, acceptance, equanimity, rumination, mind-wandering, nonstriving, metacognition, reperceiving, defusion, emotion regulation. Recognising the divergence of mindfulness psychological research from its Buddhist origins, Chems-Maarif et al. (2025) acknowledge that both traditions share in the conceptualization of present-centred awareness. Buddhism diverges with additional emphases on ethics and memory, whilst psychology hinges on aspects such as attention, acceptance, and nonjudgment (for a literature review, see Chems-Maarif et al., 2025).

A useful model for mindfulness has been found to consist of two axes of a higher-order, overarching emotion regulation structure that mediates improvements to depression and anxiety and which can be applied to both clinical and general populations. These two axes comprise an acceptance-based 'orientation to experience' factor and a 'self-regulating of attention' factor (Burzler et al., 2019). For some psychological conceptions of mindfulness, however, the influence of Buddhist thought still holds significant importance. Many researchers advocate a practice of mindfulness that incorporates attitudes and qualities originating from Buddhism, including compassion toward oneself and others (Germer & Neff, 2013) and loving-kindness (Petrovic et al., 2024).

The Buddhist Psychological Model (BPM) (Grabovac et al., 2011) provides a useful grounding and context for mindfulness theory and practice. The primary reasons it was not selected for this doctoral study are its religious/spiritual affiliations, which are not appropriate for health-focused and secular environments. In addition, the attitudinal component of mindfulness is often integrated into 'attention regulation' rather than treated as distinct mechanisms, and in Buddhist conceptualizations interoceptive/body awareness is not clearly distinguished from awareness of thoughts, with both considered as 'mental events'. The primary mechanisms of interest in this study are acceptance and bodily processes.

Attentional paradigms

Within the attentional paradigm, two broad categories were proposed (Lutz et al., 2008). These are attention (FA) and open monitoring (OM) types of meditation. These categorisations are grounded in traditional meditation texts and contemporary neuroscientific conceptions. Travis and Shear (2010) have argued for self-transcendence

as mindfulness practice category beyond FA and OM, whereas Rao (2011) suggests diffused attention or 'inattention' as defining features of meditation. More recently, Mikulas (2011) has noted that mindfulness and concentration practices are often conflated in the literature. A frequent criticism is the lack of a clearly articulated attitudinal component or theory.

Clinical psychology and behavioural therapy

Bringing mindfulness into psychological science has required reframing its definition from its original Buddhist context (Schmidt, 2011). Consequently, contemporary definitions have distanced themselves from Buddhist precepts to align with academic, skills-based, and psychotherapeutic contexts (Ditrich, 2016). With particular emphasis on attentional, and more recently attitudinal processes, there exists a broad spectrum of influential and highly cited mindfulness theories and concepts drawn from clinical psychology and behavioural therapy. These conceptualisations and models trace their lineage to foundational work starting with the development of the MBSR programme (Kabat-Zinn, 1991, 1994, 2003; Brown and Ryan, 2003; Baer et al., 2006). Operationally, Bishop et al. (2004)) proposed a two-component definition of mindfulness consisting of self-regulation of attention and an orientation to experience marked by curiosity, openness, and acceptance.

Shapiro and colleagues distinguished three components: intention (doing it on purpose), attention (paying attention), and attitude (in a particular way; i.e., reperceiving), along with a meta-mechanism termed 'reperceiving' (Shapiro et al., 2006). These theoretical strands fostered the development of self-report mindfulness scales, though content and structure vary considerably. Some researchers advocate a single-factor instrument (e.g., the Mindfulness Attention and Awareness Scale, MAAS; Brown & Ryan, 2003) at trait (15-item) and state (5-item) levels, while others view mindfulness as multifaceted, comprising observing, describing, acting with awareness, nonjudging inner experience and nonreactivity to inner experience (FFMQ; Baer et al., 2006, 2008).

There are numerous mindfulness conceptions with differing corresponding measures, leading to fragmentation within the field. As a result, studies using different conceptualisations and assessments of mindfulness may yield results that are not readily comparable or synthesizable in meta-analyses, limiting generalisability (Bergomi et al., 2013). In psychological science, the choice of mindfulness definition influences a) how mindfulness is measured, b) the content and design of mindfulness-based interventions (MBIs/MBPs), c) the assessment of intervention efficacy, and d) research into mechanisms of change across outcomes. Presently, a major challenge remains that even well-specified definitions function primarily as operational tools rather than comprehensive theories of mindfulness.

Two-component model

Bishop et al. (2004) attempted to operationalise Kabat-Zinn's definition of mindfulness. They proposed that mindfulness comprises two distinct features: 1) the self-regulation of attention toward the present moment, and 2) an orientation marked by curiosity, openness, and acceptance. Mindfulness is considered a mental skill or state that emerges when an individual purposefully directs attention to present-moment experience, whereas the latter accounts for attitudinal components that are cultivated in mindfulness practices, with both

components interdependent (Bishop et al., 2004). Although this theoretical definition was designed to be applicable to contemporary research, it is worth noting that a psychometric scale designed to assess mindfulness according to Bishop and colleagues (20004) did not fully support their definition (Lau et al., 2006).The model underpinned the development of self-report measures such as the Five Facet Mindfulness Questionnaire (FFMQ), which has demonstrated psychometric properties and facilitated mechanistic research (Baer et al., 2006). A weakness is it not designed for multi-mediator longitudinal testing so there is limited causal chain specificity.

Intention, Attention and Attitude (IAA) model

Shapiro et al. (2006) proposed a three-component model of mindfulness to explain its salutary effects. In addition to attention and attitude, intention is defined as a crucial aspect of the personal motivation needed to be a practitioner of mindfulness. The claim is that the outcome of meditation practice may be determined by on practitioners' intentions. According to these authors, mindfulness training leads to a fundamental change in the relationship to experience (reperceiving), which in turn enables beneficial changes in self-regulation, values clarification, cognitive and behavioural flexibility, and exposure. A subsequent study testing the validity of this model reported partial support for the mediating influence of these four variables on measures of psychological distress when mindfulness and reperceiving were combined (Carmody et al., 2009). Unlike attention and attitude, that are measurable using FFMQ subscales of acting with awareness for attention and nonjudging and nonreacting for an accepting attitude (Baer et al., 2006), intention is a more challenging motivational factor that does not lend itself easily to psychometric measurement within the mindfulness landscape. Additional weaknesses may be an oversimplification of the concept of motivation, with IAA model asserting that intentionality can evolve from self-regulation up to self-transcendence.

Multidimensional Interoception

Alsubaie and colleagues (2017) integrated the literature on hypothesised mechanisms of MBSR/MBCT, describing a process whereby one initially learns to cultivate a specific form of attentional capacity to focus and stabilise attention in the body (Williams & Kabat-Zinn, 2013), which may be a prerequisite to becoming aware of emotional and cognitive reactivity and later decentring from negative thinking (an emotion regulation strategy). Synthesising these findings, key adaptive mediators of mindfulness-induced psychological health may be acceptance (nonreactivity, nonjudging, decentring), interoceptive awareness and attentional meta-awareness and regulation.

A key attentional focus in mindfulness practice is the body, in addition to awareness of thoughts, feelings, and other mental events. Despite the prominent role of bodily attention, the mindfulness literature often overlooks interoceptive (bodily) awareness as a powerful change mechanism. A strength of the neurobiological literature is the elucidation of the central role of interoception in mindfulness and mind/body therapies. Attentional processes explicitly train interoceptive awareness through attending to internal experiences and sensing the body (Holzel et al., 2011), with a small body of self-report research indicating increases in interoceptive awareness (IA) (Mehling et al., 2019). It is only in the past decade that a standardised, multidimensional self-report measure of interoceptive

awareness has been developed, with a particular focus on mind/body training and the corresponding operationalisation and measurement (Mehling et al., 2019).

Hanley and colleagues (2017) were among the first to examine the relationship between interoceptive awareness and psychological health. Considerable shared variance appears to exist between IA and dispositional mindfulness (DM) in predicting psychological well-being. Nonetheless, aspects of IA predicted wellbeing beyond DM in multivariate, hierarchical linear regression analyses. Specifically, two MAIA scales, Trusting and Attention Regulation, remained significant predictors of psychological wellbeing after controlling for DM. The MAIA Trusting scale appears to capture a component of interoception not reflected in the FFMQ. These results indicate that individuals who trust their bodies are more likely to report greater psychological well-being, irrespective of their dispositional mindfulness. While this relationship is intuitive, its nature warrants elaboration. Future research should clarify whether interoceptive awareness relates to higher-order eudaimonic processes such as meaning-making, personal growth, and environmental mastery (e.g., Mehling et al., 2019). A more robust understanding of translating momentary bodily sensations into durable wellbeing deserves continued investigation.

The MAIA Attention Regulation scale also remained a significant, yet negative, predictor of psychological wellbeing. Given that the bivariate correlation between Attention Regulation and wellbeing was positive, this counterintuitive finding may reflect statistical suppression. This pattern aligns with Mehling et al. (2019), who reported that Emotional Awareness, Attention Regulation, and Body Listening were positive predictors of trait anxiety when shared variance was removed but negative predictors in bivariate analyses. Moreover, IA is ambiguous and can be adaptive or maladaptive depending on context; excessive interoceptive attention has been linked with hypervigilance and heightened interoceptive amplification among patients with anxiety (e.g., Tsur et al, 2016). It can be asserted that the utility of body awareness for adaptive behaviour is conditioned by mindfulness (Mehling et al., 2017; Tsur et al., 2016). This complexity suggests that continued exploration is needed to delineate the individual contributions of IA elements to markers of psychological health.

Although the study offers novel analyses of the relationship between IA and DM, several limitations should be noted. First, there is ongoing debate about competing definitions of interoceptive awareness (e.g., Mehling et al.; Garfinkel et al., 2015), and this study aligned with both the MAIA and 3-Dimensional Models consistent with the measure's developer's rationale. The broader debate about interoception's operationalization remains open; however, applying the MAIA, one of the most widely used measure, was justified for the current empirical focus. The MAIA was deployed within the 3 Dimensional Model to measure the concept of 'Interoceptive Sensibility' (Garfinkel et al., 2015).

Consistent with prior literature reporting negative associations between IA (as measured by the MAIA) and markers of emotional distress (Mehling et al., 2012; Bornemann et al., 2015), bivariate analyses revealed that seven of the eight MAIA scales were positively associated with psychological wellbeing. This broad pattern suggests that IA, as assessed by the MAIA, may be linked with a holistic conception of wellbeing, one which encompasses self-acceptance, purpose in life, environmental mastery, positive relationships, personal growth, and autonomy. Notably, the MAIA Trusting scale exhibited the strongest zero-order correlation with psychological wellbeing. This finding resonates with theoretical and empirical evidence that uncertainty can engender distress (Carleton et

al., 2012; Hirsh et al., 2012). Taken together, these results imply that perceiving the body as a safe and predictable space may reduce uncertainty at an immediate, physiological level, with greater bodily certainty associated with lower anxiety and depressive symptoms and higher wellbeing (Carleton et al., 2012; Hirsh et al., 2012))

Neurocognitive Models

Seminal neuroscience frameworks have outlined core interrelated neurocognitive mechanisms that underpin the effects of mindfulness via broad self-regulation processes (Schuman-Olivier et al., 2020), including *attentional (cognitive) control*, *emotion regulation/attitudinal components*, and *self-related processes, such as interoception* (Holzel et al., 2011; Tang et al., 2015; Vago & Silbersweig, 2012; Schuman-Olivier et al., 2020), how they interact with and are informed by bodily (interoceptive) awareness (Farb et al., 2013; 2015; Gibson, 2019; Hanley et al., 2017; Holzel et al., 2011; Khalsa et al., 2018; Kerr et al., 2013; Mehling et al., 2012), and more recently with memory and learning (Schuman-Olivier et al., 2020). In the psychological literature, attentional processes, such as executive attention, are also recognized as central to the salutary benefits of mindfulness (Prakash et al., 2020), however less as a standalone mechanism and more as enabling experiential awareness and the cultivation of the *attitudinal components* of mindfulness (Burzler et al., 2019; Kabat-Zinn, 1990; Keng et al., 2011; Lindsay & Creswell, 2017; Malinowski, 2013; Rogge & Daks, 2021).

The NIH Science of Behaviour Change (NIH-SOBC) framework (Nielsen et al., 2018) designated the Mindfulness Research Collaborative project to first evaluate the Mindful Self-Regulation model (Schuman-Olivier et al., 2020) via meta-analytic syntheses across three domains: emotional regulation (Hoge et al., 2021), attentional control (Malinowski, 2013), and self-related processes including bodily awareness (Britton et al., 2021). The objective was to identify measurable experimental targets and subsequently test these targets in multiple concurrent mindfulness-based practice (MBP) trials. Mindful self-regulation integrates attentional/cognitive control, emotion regulation, and self-related processes in synergy with mechanisms of motivation and learning as mindfulness practice deepens. The process begins with attentional control and curiosity about present-moment experience, fostering interoceptive awareness and alternatives to self-critical rumination. Through reappraisal of mental content, decentring, and acceptance, autonomic reactivity is downregulated, enabling exposure to aversive internal stimuli and the eventual development of equanimity (Schuman-Olivier et al., 2020).

A more explicit emphasis could be placed on how mindfulness practitioners differ from practitioners of other approaches (e.g., relaxation training or concentrative meditation) in terms of: a) attentional measures (Chiesa et al., 2011) b) body awareness, including sensitivity to detect one's own physiological sensations in particular body areas, which has been linked to qualities emphasized by traditional mindfulness trainings such as empathy (Lutz et al., 2008); c) emotional regulation, including the potential to reduce emotional interference (Ortner et al., 2007); and d) shifts in self-perspective (for a more detailed review, see Hölzel et al., 2011). In line with this, recent investigations have identified a default mode network (DMN), a set of brain regions active when the brain is not engaged in task-specific activity, that is intimately connected with the sense of self (Davey et al.,

2016). An increasing number of studies indicate that meditators engaged in both concentration and mindfulness practices show reduced DMN activation during meditation (e.g., Brewer et al., 2011; Hasenkamp et al., 2012; Pagnoni et al., 2008). Consequently, a productive avenue for future inquiry into the neural correlates of mindfulness, or the absence thereof (i.e., mindlessness), is the examination of DMN activity in mindfulness practitioners relative to concentrative meditators and non-practitioners. Conversely, while neuro-scientific and neuro-psychological findings offer valuable complements to self-report measures, they should not be construed as replacements for subjective mindfulness reports; rather, they should complement the investigation of mindfulness practice.

These seminal theories have influenced the choice of mechanisms to investigate in this doctoral study and the insights from neuroscientific literature have additionally influenced a curiosity to engage in more objective, rigorous scientific methodology. I did not select any of these models due to the lack of focus on neuroscience methods in this study. The self-regulation mode, with its incorporation of learning and motivational systems, did not present a good fit for this current investigation.

MBSR/MBCT

Recent meta-analyses on a range of mindfulness meditations highlight that different formal meditation practices, and by extension different standards of training and 'doses' (Crane & Kuyken, 2019) produce diverse neurological and psychological outcomes (Fox et al., 2014; Fox et al., 2016). To address the quality of mindfulness practice, teaching and research, academic mindfulness centers have launched to disseminate best practice in mindfulness-based programmes including appropriate standards for formal teacher training and teacher competencies to ensure research integrity (Crane & Kuyken, 2019). Standardized mindfulness-based interventions, namely mindfulness-based stress reduction (MBSR) (Kabat-Zinn, 1982) and mindfulness-based cognitive therapy (MBCT) (Segal et al., 2002) are identified as the first generation of mindfulness-based interventions. Kabat-Zinn began developing MBSR, the first mindfulness-based intervention in the late 1970s, integrating Buddhist insight meditation (Vipassana) and other contemplative practices (e.g., Zen and yoga) (Kabat-Zinn, 2011), with modern psychological evidence on stress and stress coping for real world applicability to health care patients (Davidson, 2003; Kabat-Zinn 1983). MBCT replicates the formal mindfulness practices of MBSR, however it targets negative and ruminative thinking styles to treat recurrent depressive conditions (Segal et al., 2002).

Mindfulness-based interventions (MBIs), also referred to as mindfulness-based programs (MBPs) are differentiated from mindfulness-informed nterventions and practices, in that they employ systematic and sustained training in mindfulness meditation practice as the core methodology (Crane et al., 2017). Mindfulness-informed interventions (Shapero et al., 2018), or 'third wave' cognitive behavioural interventions (Hayes, 2004) (e.g., dialectical behavior therapy (DBT), acceptance and commitment therapy (ACT)) (Linehan et al., 1999; Hayes et al., 2012) identify mindfulness as an important component within a wider programme of other modalities and change mechanisms, and do not explicitly feature formal mindfulness meditation practice (Crane et al., 2017; Shapero et al., 2018). MBSR and MBCT, on the other hand, integrate Eastern mindfulness practices into a

Western cognitive-behavioural framework and follow an intensive eight-week group model to introduce 40-45 minutes of formal mindfulness practices each session (Kabat-Zinn, 2003; Segal et al., 2002). Mindfulness can be developed in formal meditation practices such as sitting meditation, walking meditation, or mindful movements but also with information practices such as the 3-minute breathing practice or mindfulness in everyday life. MBSR is the most intensive mindfulness modality and retains the Buddhist ethic of nonstriving (Kabat-Zinn, 1994).

Monitoring and Acceptance Theory (MAT) (Lindsay & Creswell, 2017).

MAT presents a strong framework by positing that mindfulness involves two skills, attention monitoring (awareness) and acceptance (regulation). MAT contends that attention monitoring can heighten emotional reactivity, while acceptance serves to modulate it, producing salutary effects such as stress reduction and increased positive affect. These claims are supported by dismantling studies showing combined training in attention and acceptance is superior to attention only training. MAT appears to contribute to enhanced understanding of mindfulness processes, intervention optimisation via dismantling studies and evidence from trials that have isolated the crucial role of acceptance in conferring health benefits while recognising the interrelatedness of attention and acceptance. Nevertheless, MAT was not selected as the theory guiding this research due to its emphasis on moderation analysis and dismantling work father than mediation. (Simione et al., 2021).

United Flexibility and Mindfulness Model (UFM)

Acceptance-based intervention literatures offer a useful conceptualization for understanding and investigating multiple change processes implicated in mindfulness therapies. Rogge and Daks (2021) propose a Unified Flexibility and Mindfulness (UFM) model in which multiple dimensions of mindfulness and psychological flexibility operate together within a multistage, process-oriented framework linking mindfulness to psychological wellbeing. In UFM, attentional processes (present-moment awareness, and attention to internal and external experience) are posited to precede and enable attitudinal processes (acceptance, decentring, and nonreactivity to difficult inner experience), which mediate mental health benefits. The model integrates insights from mindfulness and cognitive flexibility literatures to deconstruct the components of acceptance and decentring (Rogge & Daks, 2021).

A key proposition of UFM is that the attentional stage fosters more adaptive immediate responses to challenging thoughts and emotions via subsequent mindful emotion regulation stances in the attitudinal stage. This sequential architecture connects early mindfulness-oriented processes with later adaptive regulation, illustrating how present-moment skills pave the way for acceptance-based responses to inner experiences. The model also foregrounds the differential roles of interoceptive (bodily) awareness, arguing for analytic attention to how interoception contributes to mindfulness-related mental health benefits versus other mindful mechanisms.

The UFM framework provides a coherent, multistage account of how distinct but interrelated processes (attention, acceptance/decentring, and interoceptive awareness) interact to produce psychological wellbeing. It explicitly integrates mindfulness constructs with psychological flexibility, enabling examination of multiple mediators within a unified, process-oriented design. UFM accommodates both cognitive-behavioural and phenomenological aspects of mindfulness, supporting nuanced hypotheses about differential mediators (e.g., interoception vs. cognitive decentring) and their temporal sequencing.

The model aligns with contemporary emphasis on mechanism-focused research in mindfulness-based interventions and supports real-world, sequential mediation analyses in diverse settings (e.g., workplaces, communities). Evidence highlighting the role of interoceptive awareness in mindfulness-related benefits provides a strong rationale for examining unique and differential mediational influences of interoceptive versus higher-order mindful mechanisms. Integrating interoception within UFM enriches the mechanism map and clarifies potential targets for intervention enhancement.

This doctoral thesis

Research problem/gap

A surfeit of clinical studies validates the salutary effects of mindfulness training, yet our knowledge of change mechanisms and corresponding biomarkers remain poorly understood. To address these gaps in the literature, this doctoral study investigated psychological and psychophysiological processes underpinning and mediating mindfulness-induced emotion regulation and mental health, with novel exploration of the mediational influences of interoceptive (bodily) awareness, acceptance and attention.

According to Dimidjian and Segal (2015) situating mindfulness research into a broader framework of clinical psychological science can significantly improve its public health impact and address gaps in the literature. Dimidjian and Segal (2015) reviewed the existing evidence and recommended an integrated approach to key research questions and improvements to internal and ecological validity to enhance the potential of mindfulness interventions to offer real world benefits addressing the mental health needs of communities. In addition, Nielsen and colleagues (2018) found that there is a paucity of mechanisms research in the field of behaviour change and identified NIH priorities in the areas of emotion regulation and interoceptive awareness.

To ensure the mindfulness intervention is efficacious in real-world community settings and scalable to heterogenous and diverse populations, this study is designed in accordance with the updated Medical Research Council (MRC) framework for complex interventions. Building on the original MRC guidance (development, feasibility/piloting, evaluation, implementation) and the recent update on context, process evaluation, and external validity (Skivington et al., 2021), this study seeks to explore mechanisms and context while testing outcomes relevant for policy and practice. The design incorporates theory-driven

development of components and implementation outcomes (reach, adoption, sustainability) alongside resource limitations. By integrating mechanism-focused mediational analyses (attention, acceptance, interoception) with objective measurement and ecological data, the study aims to provide MHR evaluation phase and Stage 3-level evidence of efficacy in real-world community settings and an evidentiary basis for scalable implementation.

Aims

This exploratory doctoral thesis is theory-driven, informed by the UFM process model (Rogge & Daks, 2021) and seeking to address aforementioned gaps in the mindfulness literature via:

(1) an ecologically valid MRC-informed evaluation/NIH Stage 3 efficacy trial in the community.

(2) a hypothesis-driven investigation into the interactions and independent mediational roles of core mechanisms (interoception, acceptance and attention) modulating the treatment effects of mindfulness, using multiple mediation models for robustness

(3) examination of the correspondence of self-report instruments with relevant psychophysiological markers of interoception and emotion regulation.

Research hypotheses

Hypothesis 1: MBSR will lead to improved psychological health (reduced stress, distress and anxiety) and improved self-regulation skills (attention, acceptance and interoception)

Hypothesis 2: MBSR will lead to improved interoceptive ability (accuracy and metacognition) using a physiological measurement (heartbeat counting task)

Hypothesis 3: MBSR will lead to improved psychophysiological emotion regulation via reduced reactivity to emotionally charged visual stimuli, measured by reduced electrodermal arousal

Hypothesis 4: In a multiple mediation model analysing a Stage 1 and Stage 2 mindfulness mechanisms (attention and acceptance), acceptance will uniquely mediate the mindfulness-induced mental health outcomes

Hypothesis 5: In a multiple mediation model analysing a Stage 1 and Stage 2 interoception mechanisms (bodily attention regulation and bodily trusting), attention regulation will uniquely mediate the mindfulness-induced mental health outcomes

Hypothesis 6: In a multiple mediation model analysis mindfulness versus interoception, interoception will uniquely mediate anxiety alleviation and mindfulness will uniquely mediate distress and stress reduction outcomes

Significance/contribution

The study grounded in theory-driven hypotheses and guided primary by the UFM mediational framework (Rogge & Daks, 2021), which posits that core mindfulness processes of attention and acceptance work sequentially and interdependently as mediators influencing the salutary outcomes produced by mindfulness-based interventions. These mediators can be analyses in a parallel to examine which processes exert a unique indirect mediational influence on mental health outcomes.

The Unified Flexibility and Mindfulness (UFM) model was adopted as the guiding theoretical framework because it cohesively links mindfulness practice to clinically meaningful outcomes through key mediators of mindful attention and acceptance. To address a gap in the clinical literature, I have included two interoceptive awareness subscales into a modified UFM model and removed Step 3 values-based actions that are not relevant to MBSR, rather processes relevant to Acceptance and Commitment Therapy (Parker et al., 2024).

Multiple mediation analyses

Mediation analysis is an important statistical tool for gaining insight into the mechanisms of exposure-outcome effects (MacKinnon, 2008) and is utilized in many research fields (Nguyen et al., 2020), including epidemiology. A recent review demonstrated that classical mediation analysis methodology remains consistently deployed to analyze data from randomized controlled trials (Vo et al., 2020). Classic mediation analysis involves estimating the indirect effect according to the 'product-of-coefficients' or the 'difference-in-coefficients' methods to ascertain the existence of a mediated effect (Hayes, 2017; MacKinnon, 2008). Mediation analysis is additionally the most frequently used statistical method to analyze change mechanisms in interventions (MacKinnon et al., 2007), providing insights into the efficacy of an intervention by estimating whether interventions produce effects on outcomes via mediating variables (mediators). Mediation analyses require longitudinal data as the timing between the exposure (treatment), mediator and outcome effects need to be determined. Comparison groups for the intervention are also needed because a causal inference requires the assessment of the difference between the intervention and the contrasting condition (MacKinnon et al., 2007). Randomized designs are best suited to causal inferences as they reduce the potential confounding of the intervention-mediator effects. Mediational analyses ultimately transform the total exposure-outcome relationship into a direct and indirect effect through mediator variable(s).

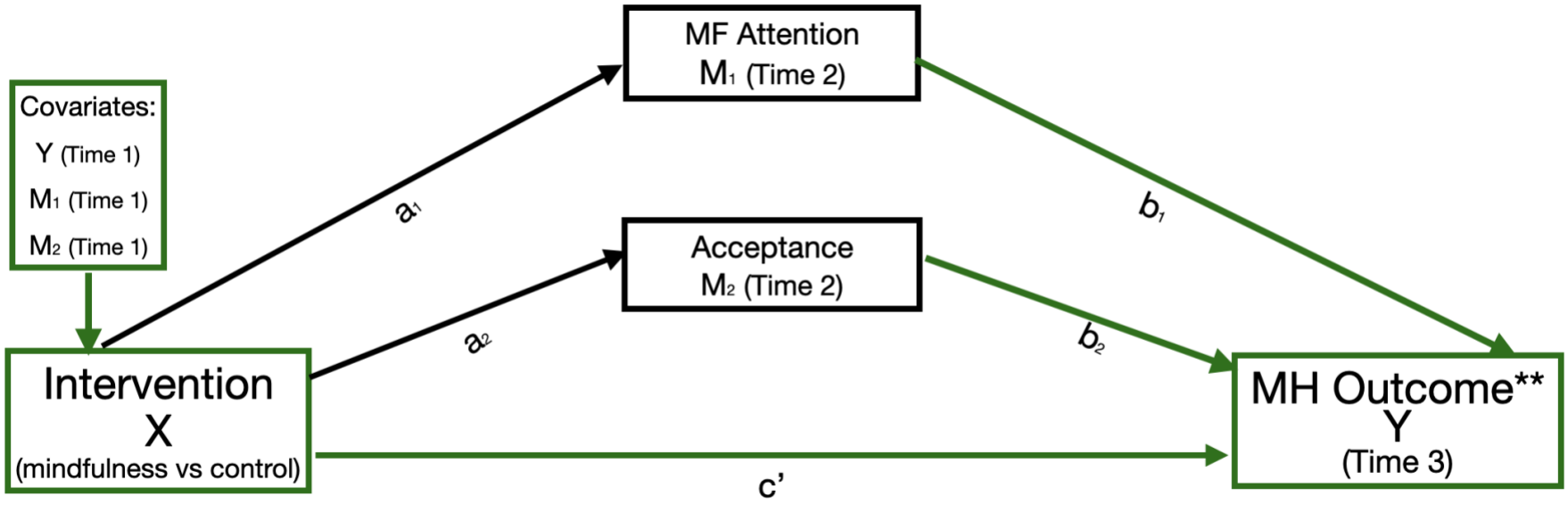
Hayes (2012) proposes using parallel multiple mediation model for a more robust mediation analysis whereby proposed mediators can covary in the model (Preacher & Hayes, 2008; MacKinnon, 2000; 2008). This offers an alternative to assuming a causal chain. An alternative to assuming a causal chain linking multiple mediators is to be

agnostic about the possibility of causal influence between mediators and simply allowing them to covary in the model (Hayes, 2012). PROCESS model 4 allows for multiple mediators between X and Y operating in parallel. Because a parallel mediation model is used to test the interventional indirect effects, confidence intervals, conveying the precision of the estimates with respect to sampling variability, may be construed using inferential procedures, such as a nonparametric bootstrap, or a Monte Carlo (or parametric bootstrap) method (MacKinnon et al., 2002; Preacher & Selig, 2012).

To make the findings of this study more robust, the bootstrap multiple mediation method that was employed assessed ‘temporal precedence’ so as to enable stronger inferences about change mechanisms across intervention time intervals (Labelle et al., 2010). Multiple parallel mediation analyses were conducted to examine total and specific (unique) indirect effects of mindfulness training on the study's mental health outcomes, via the proposed mediating variables (interoceptive awareness, acceptance, and attention). Mediating variables that significantly improved as a result of mindfulness training were included in the mediation analyses. See Figure 6 for a conceptual diagramme of a bootstrapped parallel multiple mediation analysis model using attention and acceptance as core mindfulness processes (Hayes, 2017).

Figure 6

Parallel Multiple Mediation Model of Attention and Acceptance Processes.*



Note. *Parallel multi-mediation model, using PROCESS macro model 4 (Preacher & Hayes, 2008), ***mental health outcomes = anxiety, psychological distress and stress, X = intervention group (mindfulness or control), M = mediators exerting indirect mediational effect on mindfulness-induced mental health outcomes; Y = mental health outcomes.

Thesis Outline

Study 1 Outline

The first study examines psychological health outcomes produced by intensive mindfulness training and further analyzed core underlying mechanisms in a multiple mediation model, including interoceptive awareness, due to its explicit attending to the body, and related dimensions of mindful attention and acceptance (emotion regulation skills). This study is interested in the differential or interdependent mediational influences of both mindful and interoceptive change mechanisms. The hypotheses of the first study are that 1. mindfulness training will significantly improve primary mental health outcomes (distress, anxiety, stress, alexithymia) for the mindfulness group over the control group; 2. MT will also improve mediator outcomes (interoceptive awareness and overall mindfulness, including the acceptance and attention facets) over the control group; 3. a parallel multiple subfacet analysis will find acceptance exerts an indirect mediation effect on mental health outcomes beyond the mediational influence of attention; and 4. a parallel multiple mediation analysis will find that overall interoceptive awareness exerts a specific indirect mediation effect on mental health outcomes above and beyond that of overall mindfulness.

Study 2 Outline

The second study focuses on a multidimensional exploration of interoception and mindfulness. This chapter examines the effects of mindfulness training on an implicit psychophysiological marker of interoceptive accuracy, a behavioural marker of exteroceptive sustained attention/mind wandering and corresponding dimensions of metacognitive ability and self-report dimensions of interoceptive awareness. Multiple mediation models are used to explore the unique mediational influences of key interoceptive facets of mind/body awareness and attention regulation. The hypotheses of this second study focusing on dimensions of interoceptive awareness are that 1. Mindfulness training will improve a psychophysiological measure of interoceptive sensitivity and related domains of confidence and metacognition; 2. MT will also improve IA subscales, particularly from the regulatory domains: mind/body awareness and attention regulation; 3. specific IA subscales from mind/body awareness and attention dimensions will exert differential mediational influences on anxiety, distress, stress and alexithymia and 4. attention regulation will emerge as a unique mediator of change in distress, anxiety, stress and alexithymia when compared with more attitudinal regulatory dimensions of mind/body awareness, which includes the IA subscales of self-regulation, body listening and emotional awareness. This hypothesis is in line with the UFM model of mindfulness-induced psychological wellbeing, whereby attentional processes are strengthened before the strengthening of attitudinal components to produce health outcomes (Rogge & Daks, 2021).

Study 3 Outline

Finally, the third study focuses on emotion regulation and mindfulness. This chapter explores the impact of mindfulness training on (implicit) physiological and (explicit) self-rated arousal and control induced by a visual emotion elicitation task, as well as on self-reported emotional dysregulation (alexithymia). This study explores the mediating roles of mindful versus interoceptive emotion regulation capacities using multiple mediation analyses. The hypotheses of this third study are therefore that 1. mindfulness training will improve specific subscales of alexithymia (identifying, verbalizing, analyzing) which correspond to the emotional awareness component of emotion regulation 2. mindfulness will result in improved implicit emotion regulation (psychophysiological measure of arousal) and self-rated arousal, valence and dominance during an emotion elicitation task; 3.interoceptive attention and mindful attention will emerge as a unique emotion regulation mediators of mindfulness-induced wellbeing, beyond the meditational effects of interoceptive mind/body awareness and mindful acceptance. This hypothesis is informed by the findings from study 1 and 2 and the UFM framework asserting that attentional processes will be strengthened before attitudinal processes (Rogge & Daks, 2021); and 4. mindful emotion regulation will emerge as a unique mediator beyond the mediational influence of ‘interoceptive’ emotion regulation. This hypothesis is yet again informed by the findings from the first two studies that mindfulness mechanisms exert stronger mediational effect on mental health outcomes than interoceptive mechanisms.

Chapter 2: Study 1

Exploring the role of interoceptive awareness, acceptance and attention (facets of emotion regulation) in mediating psychological wellbeing via intensive mindfulness training.

Abstract

An explosion of mindfulness intervention research in the past several decades has confirmed its salutary benefits, yet the underlying mechanisms remain debated. This study explored understudied mindfulness change mechanisms, including attention (present moment focus) and acceptance (an emotion regulation strategy), with a further novel exploration into whether bodily (interoceptive) awareness (IA) exerts a mediational influence beyond mindfulness.

Method: A randomized controlled 2x3 mixed design was employed, with 43 individuals from a healthy stressed community population allocated to the treatment group (n =21) which comprised an 8-week MBSR programme or waitlist control group (n =22). At three intervals (pre, mid, post), participants completed self-report measures on specific mental health outcomes (psychological distress, stress, anxiety and alexithymia), and on mediator variables (IA, acceptance and attention).

Results: The mindfulness training group demonstrated significant improvements in all mental health outcomes and mediator outcomes. Using bootstrapped parallel multiple mediation analysis, acceptance emerged as a specific indirect mediator of distress while both attention and acceptance exerted specific indirect mediational influences on anxiety and stress. In addition, overall mindfulness demonstrated specific indirect mediation effects overriding IA.

Conclusion: This RCT study adds to the body of literature that mindfulness training enhances psychological wellbeing in healthy, distressed populations and further isolated specific mechanisms of change mediating its beneficial outcomes. As predicted, mindful acceptance emerged as a unique mediator of distress reduction, while both attention and acceptance emerged as significant mediators of anxiety and stress. Overall mindfulness emerged as a unique mediator of psychological wellbeing, outperforming overall interoception. These preliminary findings provide a rationale for further exploration of multiple dimensions of interoception and emotion regulation exerting their mindfulness influence.

Introduction

Mindfulness can be defined as a state and practice of present moment awareness of internal experience (thought, feelings, bodily sensations, urges) with an orientation of openness, curiosity and equanimity (Kabat-Zinn, 2003). Despite an explosion of mindfulness research in the past several decades, there continues to exist significant research interest in the salutary effects of mindfulness meditation, its change mechanisms

and therapeutic applications. A plethora of studies have demonstrated beneficial mindfulness outcomes in emotional wellbeing among both clinical and healthy populations (Shankland et el., 2020; Singh et al., 2019; Bohlmeijer et al., 2010; Fjorback et al., 2011; Gotink et al., 2015). Neurobiological studies indicate that this form of mental and body-focused training may validate the notion of neuroplasticity, or changes to brain structure and functioning produced by training (Alvarez et al., 2023; Tomasino et al., 2013; Fox et al., 2014). Seminal neuroscience-based frameworks outline several synergistic neurocognitive systems that underlie the effects of mindfulness on a broad self-regulation system that includes *interoceptive (body) awareness* (Holzel et al., 2011), *attention, emotion regulation*, and *decentering* (Schuman-Olivier et al., 2020; Holzel et al., 2011; Tang et al., 2015; Vago et al., 2012). In the psychological and intervention literature, mindfulness has long been considered to comprise two main components: (1) self-regulation of *attention* and (2) an attitude of *acceptance* (Bishop et al., 2004; Lindsay & Creswell, 2017; Rogge & Daks, 2021). More recent evidence points to overlapping mechanisms of acceptance, decentering (Johannsen et al., 2022; Soler et al., 2021; Gecht et al., 2014), nonattachment, metacognition, (Bernstein et al., 2015) mediating the mental health benefits of mindfulness.

Mental health disorders are one of the leading causes of global health burden, with a pre-pandemic study (the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2019) highlighting that two of the more disabling mental health conditions are anxiety and depression, ranked in the top 25 leading causes of health burden worldwide (for a systematic analysis, see GBD Study 2019; 2020; Kessler et al., 2009). Mental health is now such a pressing issue that the World Health Organization (WHO) developed the Mental Health Action Plan 2013-2030, calling for strategies for 'promotion, prevention, treatment, and recovery' from mental ill health (WHO, 2021). In addition to the negative consequences experienced by the affected individuals, these disorders pose an enormous economic burden in terms of excessive health care expenses (The World Health Organization, 2017; Vasiliadis et al., 2013), highlighting a need for efficacious treatments. Dimidjian & Segal (2015) identify a lack of ecologically valid RCT mindfulness research in real world settings (making up less than 1% of the total mindfulness-based intervention research), referred to as Stage 3 research within the NIH framework of high quality 'clinical psychological science' (Onken et al., 2014).

Clinical research is dominated by efficacy studies, nevertheless an understudied research focus is the refinement of therapeutic interventions and modalities, which requires knowledge of treatment mechanisms (Holmes et al., 2018; Kazdin & Blase, 2011). To improve the quality of current behavioural change research, the NIH has implemented a 'Science of Behavior Change' programme (SOBC), proposing a 'unified science of behavior' protocol (Nielsen et al., 2018). The first phase of SOBC calls for coordinated efforts to focus on hypothesis-driven, mechanisms-foicused behaviour change research, or an 'Experimental Medicine Approach.' From 2009-14, the NIH funded 505 efficacy studies, of which only 29% investigated mechanisms of change. According to Nielsen and colleagues (2018), mechanisms of interest include those that may play a role in initiating or

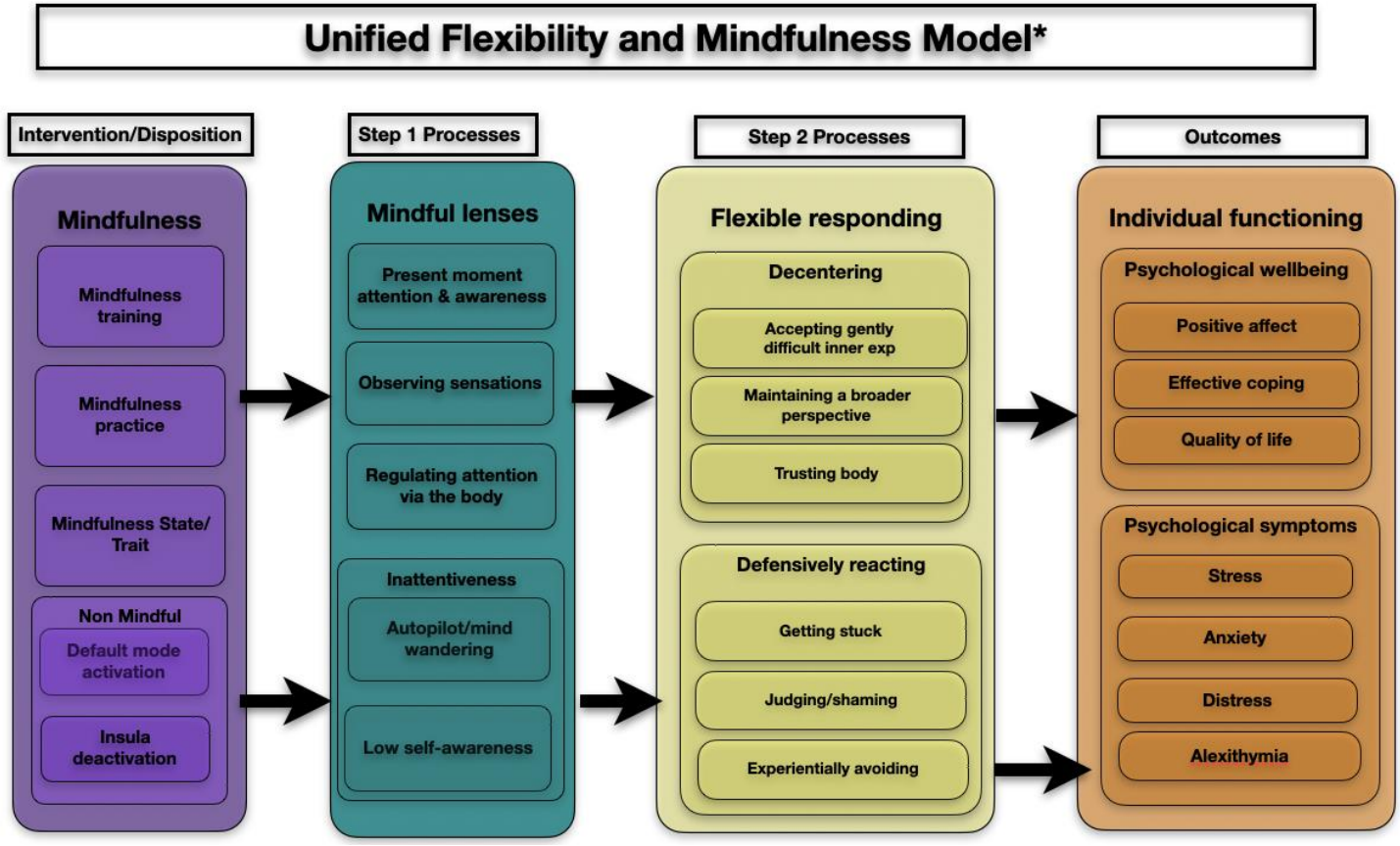
sustaining behaviour change such as mechanisms of self-regulation, executive function, interoceptive awareness, and emotion regulation, and involves the analysis of mechanisms at the social, psychological and neurobiological levels.

There is an argument for investigating multiple-mediator mechanisms in order to better understand how mechanisms cooperate or work differentially to mediate the salutary outcomes of mindfulness-based interventions (Gu et al., 2015). To optimize treatment, uncovering the interrelated and differentiated mediational influences of multiple psychological variables (i.e., acceptance, decentering, attentional processes) can facilitate a greater insight into which processes achieve the therapeutic effects. Most research into mindfulness processes have been cross−sectional (Carpenter et al., 2019), and longitudinal and experimental studies are limited (for systematic reviews and meta−analyses, see Burton et al., 2017; Galante et al., 2023; Gu et al., 2015; Dimidjian & Segal, 2015; Van Dam et al., 2017). To improve the impact of mindfulness−based interventions, there is a need for high quality longitudinal and experimental RCTs and for a better understanding of the core processes responsible for the health benefits of mindfulness.

This study thus explored hypothesized ‘change mechanisms’ mediating mindfulness-induced psychological wellbeing, including attention (present moment focus versus mind wandering), acceptance (a decentering and emotion regulation strategy), and interoceptive awareness (with its explicit attending to the body for emotional regulation). These specific psychological variables were selected because prior reviews and studies have documented their mediating role in explaining the effects of mindfulness-based practices (Schuman-Olivier et al., 2020; Holzel et al., 2011; Gu et al., 2015; Luberto et al., 2015). This study also addressed a gap in the field by conducting an ecologically valid MRC evaluation or NIH Stage 3 efficacy trial, delivering a programme of standard mindfulness-based therapy with a healthy stressed community population, rather than a student population. The multiple mediation models employed in this study were informed by the sequential Unified Flexibility and Mindfulness model (Rogge & Daks), where Step 1 attentional processes are strengthened a priori to cultivating Step 2 processes of acceptance/decentering. See Figure 2.1 for an adapted UFM model to include interoceptive awareness processes.

Figure 7

*Unified Flexibility and Mindfulness Sequential Process Model**



Note. *United Flexibility and Mindfulness (UFM) model. The UFM is a sequential model of processes (ie, attention, acceptance, values-driven behaviours) that drive (mediate) an outcome of psychological wellbeing cultivated by mindfulness practice. *This adapted model focuses on Step 1 and Step 2 processes and incorporates interoceptive mechanisms.

Mindfulness and Mental Health

Standardized mindfulness-based interventions have long been selected in clinical practice for their accessibility and affordability, and for the large body of evidence demonstrating the health benefits of MBIs for a range of emotional and somatic symptoms, including anxiety (Galante et al., 2021; Gu et al., 2015; Hoffman & Gomez, 2017; Shapero et al., 2018; Zollars et al., 2019). A growing number of experimental and neuroscience studies have investigated the impact of mindfulness on psychological and physical wellbeing with further examination of their neurological correlates (Lomas et al., 2019; Fox et al., 2014; 2016; Tang et al., 2015; Sedlmeier et al., 2012; de Vibe et al., 2012). Substantial evidence demonstrates the efficaciousness of mindfulness-based interventions (MBIs) or mindfulness-based programmes (MBPs) in improving a range of physical and psychological conditions as well as quality of life in clinical and non-clinical populations (Fisher et al., 2023; Lasso et al., 2019; Boyd et al., 2018; Burton et al., 2017; Carmona i Farres et al., 2019; de Vibe et al., 2017; Galante et al., 2021; Goldberg et al., 2022; Goldberg et al., 2018; Gotink et al., 2015; Goyal et al., 2014; Kuyken et al., 2016; Li & Bressington, 2019; Rosenkranz et al., 2019; Shankland et el., 2020; Shapero et al., 2018; Singh et al., 2019; Sousa et al., 2021; Tang, 2018; Vollestad et al., 2012; Walsh et al., 2019; Wielgosz et al., 2019; Yu et al., 2019; Zollars et al., 2019). Studies have found that mindfulness training is effective in improving psychological wellbeing via reduced psychological distress (Khoury et al., 2013; 2015; Ma et al., 2018; Grossman et al., 2004; Baer et al., 2012; Carmody & Baer, 2008; Sedlmeier et al., 2012; Shapiro et al., 2006; Sauer et al., 2013; Labelle et al., 2012).

Perceived stress and anxiety have also been found to be attenuated by mindfulness training modalities (Burton et al., 2017; Khoury et al., 2015; Chiesa & Serretti, 2009; Zollars et al., 2019) as well as overall mental wellbeing (Hoffman & Gomez, 2017; Hoge et al., 2023; Goldberg et al., 2018). According to a recent systematic review and aggregate-data (AD) meta-analysis of randomized controlled trials (RCTs) evaluating mindfulness based interventions across healthy stressed populations (Galante et al., 2021), mindfulness training ameliorated psychological distress when compared with waitlist controls. Goyal and colleagues (2014) conducted a meta-analysis of mindfulness training programmes (e.g., mindfulness-based stress reduction (MBSR) and mindfulness based cognitive therapy (MBCT)) and found mindfulness to be a significant mediator of reduced psychological distress, including anxiety and depression. This has been further confirmed by systematic reviews that have found promising evidence of mindfulness effects on anxiety symptoms in the general population (Gotink et al., 2015; Gillaume et al., 2017; Li & Bressington, 2019). Prolonged periods of stress and anxiety can elicit a wide range of mental health and physical health conditions (Cohen et al., 2007), negatively affecting cognitive performance on mechanisms such as attention (Girotti et al., 2018; Liu et al., 2020; e et al., 2013).

Mediators (change mechanisms)

The research focus of therapeutic interventions targeting wellbeing has moved from efficacy studies to more complex investigations, assessing whether the treatment effects can be attributed to the mediational influence of distinct change mechanisms (Falkenström et al., 2020). According to Johansenn et al. (2022), an understanding of change mechanisms, or mediators, is crucial to optimizing mindfulness and acceptance-based treatments for anxiety and depression. In the field of mindfulness intervention research, change processes responsible for therapeutic effects can be indicated by mediators as an important first step to understanding mechanisms (Kazdin, 2007). Alsubaie and colleagues (2017) in their systematic review, found positive outcomes derived from the standardized mindfulness-based programmes, MBSR and MBCT. The authors argued that the studies they reviewed lacked rigour in their analysis of potential mechanisms of action and called for more robust mechanisms research and replication of previous studies (Alsubaie et al., 2017).

Despite the acknowledged role of bodily (interoceptive) awareness as a mechanism of action in mindfulness within the neuroscience and psychological literatures, there is a paucity of intervention studies examining the influence and interrelatedness of interoceptive awareness, mindfulness and psychological wellbeing (Gibson, 2019; Weng et al., 2021). In addition, there is a growing recognition that specific facets of mindfulness, namely acceptance and present moment attention, are the essential emotion regulation ingredients mediating the mental health benefits of mindfulness practice (Lindsay & Creswell, 2017; Rogge & Daks, 2021). Yet not enough is known about their differentiated, sequential and/or synergistic relationship, with some early hypothesis that acceptance alone can explain salutary benefits (Simione & Saldini, 2023).

In their systematic review and meta-analysis, Johansenn et al. (2022) selected primary mediators of mindfulness-induced psychological wellbeing to include *mindful attention, decentering and acceptance* (Fresco & Mennin, 2019; Hayes et al., 2006; Mennin et al., 2013). These were differentiated from secondary mediators such as rumination, worry, emotion regulation, and general maladaptive thinking styles (Johansenn et al., 2022)., which were defined as secondary mediators in that they are also applicable to CBT and not exclusive to mindfulness (Berking et al., 2013; Lemmens et al., 2017; Goldberg, 2022). Improved interoceptive awareness is also theorized as a key mechanism via which mindfulness training exerts its salutary effects (Gibson, 2019; Farb et al., 2015; Holzel et al., 2011; Mehling et al., 2009; Weng et al., 2021), with additional proposed mechanisms involving attention (Sumantry et al., 2021) and emotion regulation capacities (Guendelman et al., 2017), forming an overarching ‘self-regulation’ system (Tang et al., 2015; Holzel et al., 2011; Vago et al., 2021; Schuman-Olivier et al., 2020). Evidence has been found to suggest that all forms of mindfulness practice result in modulation of the interoceptive network (ie, the insula) (Gibson, 2019). The interoceptive neural network is implicated in bodily, emotional, and self-referential processing and intersects with attention, intention, and other core cognitive activities (Craig, 2009; Tabibnia, 2020).

Attention and Acceptance

Within the psychological literature, mindfulness is consistently described as comprising two underlying components: self-regulation of *attention*, and orientation to one's current experience with an attitude of *acceptance,* ie, a stance of nonreactivity, nonjudgment and noninterference toward aversive stimuli (Simione & Saldini, 2023; Bishop et al., 2004; Lindsay & Creswell, 2019; Ainsworth et al., 2017). These two factors are considered interrelated and may reciprocally facilitate disengagement from affect-dependent stimuli, leading to decreased emotional and behavioural reactivity (experiential avoidance) (McCluskey et al., 2020) and in turn promote adaptive emotion regulation (Lindsay & Creswell, 2017). Different mindfulness components can be measured separately using the Five Factor Mindfulness Questionnaire (FFMQ) (Baer et al., 2008), with each FFMQ facet being found to empirically measure different processes of psychological health (Iani et al., 2017). Despite the recognized importance of attention and acceptance processes in the mindfulness literature, there are limited studies seeking to operationalize these constructs, to correlate their component processes and to distinguish their clinical effects (Ainsworth et al., 2017).

A recent meta-analysis of mindfulness training demonstrated an overall enhancement of attentional processes (Sumantry et al., 2021). Attentional skills, or 'mindful lenses' can be represented by present moment awareness and/or observing of inner experience facets of mindfulness (Lindsay & Creswell, 2017). Attentional processes are proposed as either: (1) the first step in a sequence which gradually facilitates the second step which are the acceptance/decentering, or 'flexible responding' processes (see Unified Flexibility and Mindfulness model (UFM); Rogge & Daks, 2021), or (2) mood contingent, with less stability and reliability than the attitudinal, flexible responding components of acceptance/decentering (Elices et al., 2019). Nevertheless, the honing of attentional skills has long been considered a key mechanism in the mindfulness literature, thought to undergird the empirical evidence of stress amelioration via training in mindfulness (Chiesa & Malinowski, 2011; Lutz et al., 2008). Research suggests that even brief exposure to the body scan meditation improves allocation of attentional resources in novice meditators (Norris et al., 2018).

The two contrasting attentional styles in meditation practices are focused attention (FA), which involves focusing and sustaining attention on a chosen object, such as the breath; and open monitoring (OM), which encompasses the conscious meta-awareness of moment-to-moment experiences as they arise. Both FA and OM practices are embedded within standardized mindfulness-based programmes, with the earlier phases of training commonly targeting FA to enable the capacity to access present moment awareness, reduce mind wandering and build equanimity, prior to expanding to OM which cultivates a more expansive, metacognitive decentering and self-reflective awareness capacity (Lutz et

al., 2008). According to Lindsay and Creswell, (2019), experimental evidence suggests that prolonged training in attentional processes may promote emotional awareness which can gradually lead to emotion regulation (O'Brien et al., 2017). However, the authors assert that the earlier stages of attentional training in mindfulness does not independently promote stress reduction, with their dismantling findings indicating that attentional training alone did not enhance emotional wellbeing (Lindsay & Creswell, 2019). Their view is that the training of acceptance in mindfulness therapies is required in tandem with attention to exert its beneficial effects (Lindsay & Creswell, 2017).

The focus on acceptance, and related metacognitive capacities, is central to contemporary mindfulness research and practice (Iani et al., 2019; Soler et al., 2021; Bishop et al. 2004; Hayes, 2004; Lindsay & Creswell, 2017), as well as to traditional accounts of mindfulness (Grabovac et al. 2011). Bishop et al. (2004) included acceptance as part of their definition of mindfulness, and can be considered an active mechanism, a predictor of positive outcomes, and a component that distinguishes mindfulness from other clinical modalities (Lindsay & Creswell, 2017). Acceptance is conceptualized as a stance of openness and willingness toward emotion and experience (Campbell-Sills et al., 2006) and coincides with notions of decentering and nonattachment (Soler et al., 2021). Acceptance was found to be a significant factor in a study using bivariate and canonical correlation analyses of emotion regulation functions, forming part of a 'mindful emotion regulation' cluster which also included nonreactivity, reappraisal and describing of experience which Iani et al. (2019) argue may be a core pathway to mindfulness benefits. Acceptance is considered the contrast to experiential avoidance, or the unwillingness to experience negatively evaluated emotions, physical sensations, and thoughts which is associated with poor mental health (Hayes & Strosahl, 2004).

Mindfulness has been shown to cultivate adaptive and flexible emotion regulation responses to difficult inner experience, commonly referred to in the literature as an attitude of acceptance but also as decentering, an overlapped construct (Soler et al., 2021). Some researchers have utilized the nonreactivity subfacet of the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2008) to represent acceptance and decentering (Duncan et al., 2021; Lindsay & Creswell, 2017; Garland et al., 2017). Mindfulness constructs are still emerging, disputed and complex. Several researchers have contended that examination of intricate constructs at the facet level is fundamental to understanding their relationships with other variables (Sauer et al., 2013; Lilja et al., 2013; Lau & Yu, 2009; Ireland, 2013). Zhuang et al., (2017) suggest that various facets of the FFMQ may be differentially associated with self-awareness, attention control and emotion regulation. Researchers found that the *nonreactivity* and *acting with awareness* facets (acceptance and attention components respectively) predicted longitudinal amelioration of depression and anxiety, while the other facets did not (Webb et al., 2019). Most significantly, these FFMQ facets mediated depression and anxiety and outperformed CBT. This is a

significant finding, which informs this doctoral study's exploration of nonreactivity and acting with awareness as potential representations of attention and acceptance. See Table 2 for attention and acceptance variables, using the FFMQ facets of acting with awareness (attention), nonjudging (acceptance) and nonreactivity (acceptance) (Baer et al., 2012; Gu et al., 2016).

Table 2

*Step 1 (Attention) and Step 2 (Acceptance) Mindfulness Facets**

UFM Step	FFMQ Facet	Example Questions
Step 1		
Attention	Acting with Awareness	I don't pay attention to what I'm doing because I'm daydreaming, worrying or otherwise distracted** I find myself doing things without paying attention.**
Attention	Observing	I pay attention to sensations, such as the wind in my hair or sun on my face. When I take a shower or a bath, I stay alert to the sensations of water on my body.
Step 2		
Acceptance	Nonreactivity	When I have distressing thoughts or images I just notice them and let them go. When I have distressing thoughts or images I am able to just notice them without reacting.
Acceptance	Nonjudging	I believe some of my thoughts are abnormal or bad and I shouldn't think that way.** I tell myself I shouldn't be feeling the way I'm feeling.**

*Note. *UFM = United Flexibility and Mindfulness Model for Step 1 and Step 2 processes in their sequential mediation model (Rogge & Daks, 2021), FFMQ = Five Factor Mindfulness Questionnaire (Baer et al., 2012), Gu and colleagues (2016) recommend removing observing facet from analysis. **indicates reverse coded questions*

Theoretical models have provided fundamental insights for the underlying mechanism of acceptance. Mindfulness to Meaning Theory (MMT) is a process model suggesting multiple drivers that mediate mindfulness-induced psychological wellbeing. The relationship between acceptance, nonreactivity, and reappraisal can also be interpreted from the perspective of MMT. Its core tenet is the mindful reappraisal hypothesis, which suggests that mindfulness-based interventions enhance mental wellbeing by enabling reappraisal of negative stimuli (Garland et al., 2015). MMT's core sequential processes involve attentional control, decentering, broadened awareness, positive reappraisal leading to positive emotion regulation. The mindfulness stress-buffering theory (Creswell & Lindsay, 2014) proposes that acceptance is the main mindfulness component promoting adaptive coping responses for stress. The ability to accept stressors dampens habitual reactivity and cognitive evaluations, facilitating new appraisals and coping options (Slutsky et al., 2018). This led to Lindsay and Creswell (2016) investigating the mindfulness processes of acceptance and attention, and their synergistic or differential effects on emotion regulation. The Monitoring and Acceptance Theory (MAT) of mindfulness proposes that when attention and acceptance work in tandem, they strengthen and produce adaptive emotion regulation. However, when acceptance is absent, a strengthening of negative emotional reactivity in the form of stress and anxiety occurs (Desrosiers et all., 2014; Barnes & Lynn, 2010; Lindsay & Creswell, 2019). There are limited studies testing out the MAT theory, with a recent review suggesting mixed results (Simione & Saldini, 2023).

Other researchers propose that acceptance and attention work sequentially in mindfulness-based therapies, with present moment attention preceding acceptance, to produce improved wellbeing outcomes (Rogge & Darks, 2021). Given the lack of definitional and operational cohesion, the Unified Flexibility Model of Mindfulness and Acceptance (UFM) offers an integrative, sequential model of the salutary mechanisms implicated in mindfulness interventions (Rogge & Darks, 2021). The UFM proposes that the essential processes of mindfulness interventions involve (1) meditation practice (2) training present moment, attentional focus (3) which cultivates an accepting and decentering flexible stance toward experiences and (4) enables greater emotional and behavioral self-regulation (Crane et al. 2017; Rogge & Daks, 2021). Validating the UFM construct, Desbordes et al., (2015) found that attention and acceptance may initially dissociate, resulting in the attentional effects emerging primarily, followed at a later stage by acceptance. Accordingly, analysis of weekly change in a MBSR programme, using the FFMQ (Baer et al., 2012), found that 'observing', 'acting with awareness' and 'nonreactivity' preceded changes in 'nonjudging' (Desbordes et al., 2015).
There is some evidence that divergent mindfulness mechanisms mediate anxiety versus depression (Tran et al., 2014). Body awareness was found to predict the effects of dispositional mindfulness on anxiety symptoms, whereas nonattachment mediated depression (Tran et al., 2014). Nonattachment is defined as a general absence of inner pressures to hold on to, change or avoid specific experiences and the absence of a fixation on ideas, images and sensory experiences (Sahdra et al., 2017). In a mediational study of psychiatric patients receiving either of MBSR or MBCT, compared with CBT,

researchers found that the *nonreactivity* and *acting with awareness* facets of the Five Factor Mindfulness Questionnaire (FFMQ) (Baer et al., 2008) predicted longitudinal amelioration of depression and anxiety, and not the other facets (Webb et al., 2019). Most significantly, these FFMQ facets mediated depression and anxiety and outperformed CBT. These findings were validated by cross-sectional studies finding significant correlation between acting with awareness scores and lower depressive and anxiety symptoms (Branstrom et al., 2011; Curtiss & Klemanski, 2014; de Bruin et al., 2012; Royuela-Colomer & Calvete, 2016). The study by Royuela-Colomer & Calavete (2016) found that elevated acting with awareness and nonreactivity scores in over 450 adolescents over time (4 months later) mediated reduced depressive symptoms four months after initial assessment, while the observing facet predicted increased depression via rumination. Lindsay and Creswell (2017) have organized the FFMQ into attention versus acceptance factors, with attention being captured by the 'observing' and 'acting with awareness' facets and acceptance being represented by 'nonjudging' and 'nonreactivity'. These findings from the abovementioned studies (Royuela-Colomer & Calvete, 2016; Webb et al., 2019; Branstrom et al., 2011; Curtiss & Klemanski, 2014; de Bruin et al., 2012) provide the rationale for this study to select acting with awareness and nonreactivity as key attention and acceptance mediators respectively in multiple mediation analyses

Interoceptive (Body) Awareness

It has been argued that the core underlying mechanism of mindfulness practice is an increase in interoceptive body awareness with its corresponding insular activation, which is trained by cultivating sustained attention to bodily sensations (Farb et al., 2013; Mehling et al., 2012; Weng et al., 2021). Recent studies investigating the relationship between mindfulness and interoceptive awareness have examined the mechanistic influence of IA on emotional health variables (Gibson, 2019; Sharp et al., 2018). IA is referred to as a key 'ingredient' in most mindfulness interventions, explaining the positive effects on psychological wellbeing (Schuman-Olivier et al., 2020; Tabibnia, 2020; Mehling et al., 2012; Farb et al., 2015; Yang et al., 2015; Holzel et al., 2011). Mindfulness-based approaches are found to be effective in improving both bodily and emotional awareness and by extension their regulatory capacities (Cameron et al., 2014; Haase et al., 2016; Norman et al., 2019), via the strengthened awareness of bodily cues and their associated emotional representations (Ernst et al., 2014; Fissler et al., 2016). Mindfulness training is said to strengthen interoceptive abilities by enabling a shift from emotional and cognitive interpretations of bodily sensations to a nonevaluative, direct experience of sensing bodily stimuli (Farb et al., 2013; 2015; Mehling et al., 2017). Different mindfulness mechanisms have been found to drive different psychological outcomes, particularly stress, anxiety, and depression (Tran et al., 2014). Of interest, body awareness has been found to predict anxiety symptoms via mindfulness traits, whereas psychological distancing has been found to mediate depression (Tran et al., 2014).

Interoceptive awareness, defined as an adaptive skill, is described as a nonreactive and nonevaluative awareness of bodily sensations (Mehling et al., 2018), has been shown to have an association with wellbeing in nonclinical populations (Ferentzi et al., 2018). According to Hanley and colleagues (2017), mindfulness and interoceptive awareness are intertwined yet separate constructs that are proposed to independently exert an influence on psychological health. Both mindfulness and interoceptive awareness are oriented toward internal, or endogenous, attention and experience. However, mindfulness constructs do not adequately capture the influence of bodily awareness, due to its more diverse objective focus, including interoception, exteroception, thoughts and urges (Lutz et al., 2008). Clinical research has indicated that interoceptive awareness confers beneficial effects on range of mental health and psychosomatic diagnoses (Mehling et al, 2012; Farb et al., 2015). Researchers promoting bodily awareness as mediating positive outcomes describe a style of attention and awareness characterized by nonjudgmental acceptance and a sense of self that is embodied and grounded in present moment experience of bodily sensations and stimuli (Farb et al., 2013; Fissler et al., 2014; Gibson, 2019; Kabat-Zinn, 1994; Mehling, 2016; Craig, 2002).

Mehling et al. (2009) indicated that there has been some divergence and disparity in the literature between different interoception conceptualizations. Terms such as body or somatic awareness, interoceptive accuracy and interoceptive attention have been conflated with the concept of interoceptive awareness which has been distinguished in the literature by Mehling and colleagues (2012; 2016). Body awareness concepts have historically focused on clinical populations with psychosomatic conditions (Cioffi et al., 2016). In addition, the literature related to objective measures of interoception tends to focus on physiological biomarkers such as cardioceptive accuracy (Garfinkel et al., 2015; Trevisan et al., 2019) which may not map onto the IA self-report construct (Mehling et al., 2018). Owing to contradictory findings in the literature, there remains some debate as to whether interoception captures maladaptive forms of IA characterized by hypervigilance and anxiety (Trevisan et al., 2019; Fischer et al., 2017; Mallorquí-Bagué et al., 2014; Herbert & Pollatos, 2014; Pollatos et al., 2007b; Pollatos et al., 2009) or adaptive forms of IA that require the interplay between perceptual body states and the cognitive/emotional appraisal of those body states (Farb et al., 2015) and may be characterized by attention regulation and acceptance (Hanley et al., 2017; Trevisan et al., 2019).

To integrate the mixed findings as to whether interoception corresponds to bodily attention, accuracy, self-regulation, Mehling and colleagues (2012, 2018) developed a multidimensional construct of interceptive awareness, the Multidimensional Assessment of Interoceptive Awareness self-report instrument (MAIA; Mehling et al., 2012). Whereas prior measures did not capture the beneficial and maladaptive aspects of interoceptive body awareness, the MAIA assesses essential psychological and regulatory components related to the perception and evaluation of bodily sensations. The MAIA has been widely used as a research tool to examine interoceptive sensibilities or capacities in various populations, including clinical groups (Atanasova et al., 2021; Blackwood et al., 2023; Brown et al., 2017; Fissler et al., 2016; and nonclinical populations (Mehling et al., 2018;

Bornemann et al., 2014; Cali et al., 2015; Ferentzi et al., 2021; Ozpinar et al., 2021). See Table 3 for a selection of Interoceptive Awareness subscales and sample questions from the Multidimensional Assessment of Interoceptive Awareness (MAIA) questionnaire (Mehling et al., 2012).

Table 3

*Interoceptive Awareness Subscales**

MAIA Subscale	Example Question
Attention Regulation	I can refocus my attention from thinking to sensing my body.
Body Trusting	I trust my body sensations.
Body Listening	I listen for information from my body about my emotional state.
Self-Regulation	When I bring awareness to my body, it brings a sense of calm.
Emotional Awareness	When something is wrong in my life I can feel it in my body.
Noticing	When I am tense, I notice where the tension is located in my body.

Note. *Multidimensional Assessment of Interoceptive Awareness (MAIA: Mehling et al., 2012). Six of the eight MAIA subscales are presented in this table with an example question for each scale.

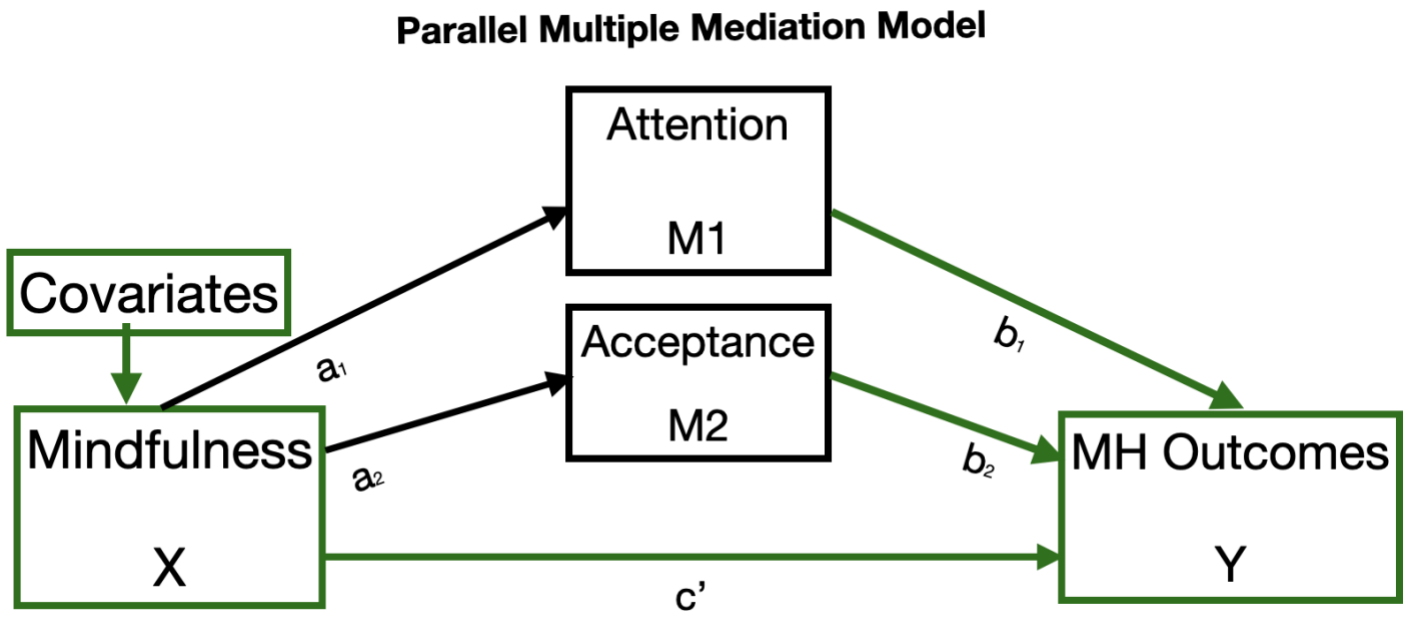
Mediation analyses

To strengthen the findings derived from this study, a robust parallel multiple mediation analysis will be employed. Hayes (2012) proposes using parallel multiple mediation model for a more robust mediation analysis whereby proposed mediators can covary in the model (Preacher & Hayes, 2008; MacKinnon, 2000; 2008). This offers an alternative to assuming a causal chain. In line with previous publications (Cuijpers et al., 2019), the hypothesized mediators in this study are conceptualized as intervening variables (interoceptive awareness, acceptance and attention) that may statistically account for the relationship between the independent variables and the outcomes. An alternative to assuming a causal chain linking multiple mediators is to be agnostic about the possibility of causal influence between mediators and simply allowing them to covary in the model (Hayes, 2012). PROCESS model 4 allows for multiple mediators between X and Y operating in parallel. Because a parallel mediation model is used to test the interventional indirect effects, confidence intervals, conveying the precision of the estimates with respect to sampling variability, may be construed using inferential procedures, such as a nonparametric bootstrap, or a Monte Carlo (or parametric bootstrap) method (MacKinnon et al., 2002; Preacher & Selig, 2012)

This study will conduct two separate parallel multiple mediation analyses using PROCESS model 4 is SPSS (Preacher & Hayes, 2008). A defining feature of parallel multiple mediation analyses is that none of the mediating variables are modelled as influencing another mediator in model 4. This facilitates the estimation of a simultaneous testing of more than one mediator variable, while controlling for the shared variance between the different mediators (Goodall et al., 2020). The first analysis tests whether overall mindfulness and/or overall interoceptive awareness mediated the relationship between the exposure group (mindfulness intervention versus waitlist control) and individual mental health outcomes of psychological distress, generalized anxiety, perceived stress. The second subfacet analysis tested whether mindful attention and/or mindful acceptance mediated the relationship between mindfulness training and the 4 mental health outcomes. See Figure 8 for a graphical representation of the parallel multiple mediation model for attention and acceptance

Figure 8

Parallel multiple mediation analysis model for attention and acceptance



Note. This mediation model is informed by UFM (Rogge & Daks, 2021) and utilises the SPSS PROCESS Macro Model 4 (Preacher & Hayes, 2008) to analyse the unique and temporal mediational influences of attention and acceptance on mental health outcomes produced by mindfulness training.

MBSR

Standardised, structured mindfulness protocols, the gold standard of mindfulness interventions, remains a popular in psychological research and practice, due to the empirical validation of its efficacy and clinical applicability (Bueno et al., 2015; Cole et al., 2016; de Lisle et al., 2012; Gu et al., 2016; Hesslinger et al., 2002). In a recent systematic and meta-analysis (Fisher et al., 2023), Mindfulness Based Stress Reduction (MBSR) has been found to be particularly effective in attenuating the distressing symptoms anxiety and depression. MBSR has also been found to be a protective factor in mental health (Kabat-Zinn, 2013; Li et al., 2020), to reduce stress (Tsai & Chou, 2016; Chiesa & Seretti, 2009) and improve multiple psychopathologies (Alsubaie et al., 2017; Grossman et al., 2004; Josefsson et al, 2012; Shamini et al., 2007; Shapiro et al., 2005; Wielgosz et al., 2019).

Mindfulness-based interventions (MBIs) or mindfulness-based programmes (MBPs) are treatments that employ systematic and sustained training in mindfulness meditation teaching/practice as a core methodology (Crane et al., 2017) and both mindfulness-based stress reduction and mindfulness based cognitive therapy are considered exemplar for psychological research (Dimidjian & Segal, 2015). Carmody and Baer (2009) assert that the intensity, duration and aims of the recognised mindfulness interventions vary, from short-term skills-based exercises (Josefsson et al., 2012) to formal mindfulness meditation practiced daily over many weeks (Segal et al., 2002; Kabat-Zinn, 2003) and to mindfulness integrated into a way of being in daily life (Baer et al., 2008).

Among the established mindfulness-based interventions, Mindfulness-Based Stress Reduction (MBSR) and Mindfulness-Based Cognitive Therapy (MBCT) follow an intensive 8-session model and use group sessions to introduce 40-45-minute formal mindfulness practices each week (Kabat-Zinn, 2003; Segal et al., 2002). In contrast, ACT and DBT use shorter, more focused mindfulness tasks and practices, in order to achieve other primary treatment objectives (Hayes, 2013; Linehan, 2015). Both ACT and MBSR can be applied to clinical and healthy stressed populations (Carmody et al., 2009; Hayes et al., 2004). To adhere to Stage 3 clinical research protocols (Onken et al., 2014), this study utilized an MBSR format, delivered by a highly experienced mindfulness teacher and mental health nurse, following the University of Bangor's Centre for Mindfulness Practice and Research protocols and supervision.

This present study

The aim of this paper is to contribute to these gaps in the mindfulness literature. This study explored change mechanisms mediating mindfulness-induced psychological wellbeing, including attention (present moment focus versus mind wandering), acceptance (a decentering and emotion regulation strategy), and interoceptive awareness (with its explicit attending to the body for emotional regulation). These specific psychological variables are

selected because prior reviews and studies have documented their mediating role in explaining the effects of mindfulness-based practices (Schuman-Olivier et al., 2020; Holzel et al., 2011; Gu et al., 2015; Luberto et al., 2015). The multiple mediation models selected in this study are informed by the sequential Unified Flexibility and Mindfulness model (Rogge & Daks, 2021), where Step 1 attentional processes are proposed to be strengthened a priori to cultivating Step 2 processes of acceptance/decentering. The UFM model has been adapted to include interoceptive (bodily) awareness processes.

This study also addresses another gap in the field by conducting an ecologically valid NIH-defined Stage III RCT efficacy study, delivering a programme of standard mindfulness-based therapy with a healthy stressed community population, rather than a student population. The present study is conducted through a randomised controlled trial (RCT) of treatment versus waitlist control. Onken et al., (2014) deem the utilisation of waitlist control subjects may be defensible, given the limited number of empirical Stage 3 studies of exemplar mindfuless-based interventions (eg., MBSR). A randomised controlled 2x3 mixed design was conducted, with forty-three working age adults from a healthy stressed community population will be allocated to either the treatment group (n =21) (ie., an 8-week MBSR programme) or a waitlist control group (n =22). At three intervals (pre, mid, post), participants will complete self-report measures on specific mental health outcomes (psychological distress, anxiety), and on mediator variables (interoceptive awareness, acceptance and attention).

The hypotheses of this first study are that: 1. mindfulness training will significantly improve primary mental health outcomes (distress, anxiety, stress) for the mindfulness group over the control group; 2. MT will also improve mediator outcomes (interoceptive awareness and overall mindfulness, including the acceptance and attention facets) over the control group; 3. a parallel mediation analysis of attention and acceptance will find acceptance exertan indirect mediation effect on mental health outcomes beyond the mediational influence of attention; and 4. a parallel multiple mediation analysis will find that both mindfulness and interoceptive awareness will exert specific indirect mediation effects on mental health outcomes.

Method

Participants

An overall sample of 43 participants (aged 22-63 years; 38 females, 5 males) was recruited to evaluate the efficacy of a Mindfulness-Based Intervention (MBI) designed and delivered by a branch of a national mental health charity located in London, United Kingdom. The MBI formed part of the charity's low-intensity mental health provision for the local community and was advertised via a recruitment poster circulated across local health and social care service locations. The poster targeted individuals experiencing reduced well-being, elevated stress, or a common mental health problem (e.g., anxiety, depression, or burnout). A pool of 48 individuals completed an application form and underwent email and/or telephone screening. Exclusion criteria included vulnerability to primary diagnoses of personality disorder, psychosis, alcohol or other substance dependency, organic syndrome, or learning disability; individuals meeting these criteria were referred to higher-intensity provision within the charity. Screening was conducted by one of the charity's mental health clinicians.

Participants were primarily recruited from Northeast London boroughs and were representative of a healthy distressed population seeking preventative support for stress. Given the doctoral study's scope and resource constraints, a modest sample was feasible for the randomized controlled trial (RCT). Prior work has detected medium-sized intervention effects with similar sample sizes (Flaxman & Bond, 2010). A randomization calculator allocated 21 working-age adults to the MBSR intervention and 22 to a waitlist control group. The study enabled Mind, the mental health charity, to offer an evidence-based intervention to working people outside of normal business hours (6.30-9 pm), which would otherwise be inaccessible or unaffordable.

In total, 43 volunteers were recruited via Mind CHWF. Participants were required to speak English sufficiently to permit administration of study measures without an interpreter. The mean ages reported by group were: treatment group, 33 years (SD = 11.65); waitlist control group, 35 years (SD = 11.22). Participants were randomly allocated to experiment or control groups after meeting entry criteria. Volunteers comprised individuals from both healthy stressed and moderately distressed populations, with over half in each condition meeting threshold criteria for a mild psychiatric disorder and clinical anxiety. Baseline and follow-up measures were completed at pre-intervention, mid-intervention, and post-intervention via an online platform (Qualtrics). Each participant was assigned a unique identification number used for questionnaire administration.

Retention was satisfactory: 91% overall, with 4 participants dropping out from the mindfulness group before completion (intervention group retention: 81%). An exclusion criterion removed vulnerable individuals with primary diagnoses as described above, determined by a qualified clinician at Mind. Most participants (86%) reported no prior meditation experience, with 14% reporting a little.

Clinical case indicators (treatment group): at pre-intervention, 59% met criteria for clinical anxiety (reduced to 12% at post-intervention); 71% met criteria for psychiatric distress (reduced to 6% at post); 24% met criteria for clinical alexithymia (reduced to 6% at post). In the control group, 55% met criteria for clinical anxiety at pre-intervention (increasing slightly to 59% at post); 55% met criteria for psychiatric distress at pre (reduced to 32% at post); 32% met criteria for clinical alexithymia at pre (increasing to 59% at post).

Measures were self-reported and collected at baseline (pre), mid-point (mid), and end of the mindfulness course via Qualtrics. Participants were assigned to unique reference numbers and completed online questionnaires accordingly. See Table 4 for percentage of participants meeting clinical cases for a mental health disorder by group and time.

Table 4

*Percentage of Participants at Caseness by Group and Time**

Variable	Time	Mindfulness	Control
Clinical Anxiety	Pre	59%	55%
	Post	12%	59%
Clinical Distress	Pre	71%	55%
	Post	6%	32%
Clinical Alexithymia	Pre	24%	32%
	Post	6%	59%

Procedure

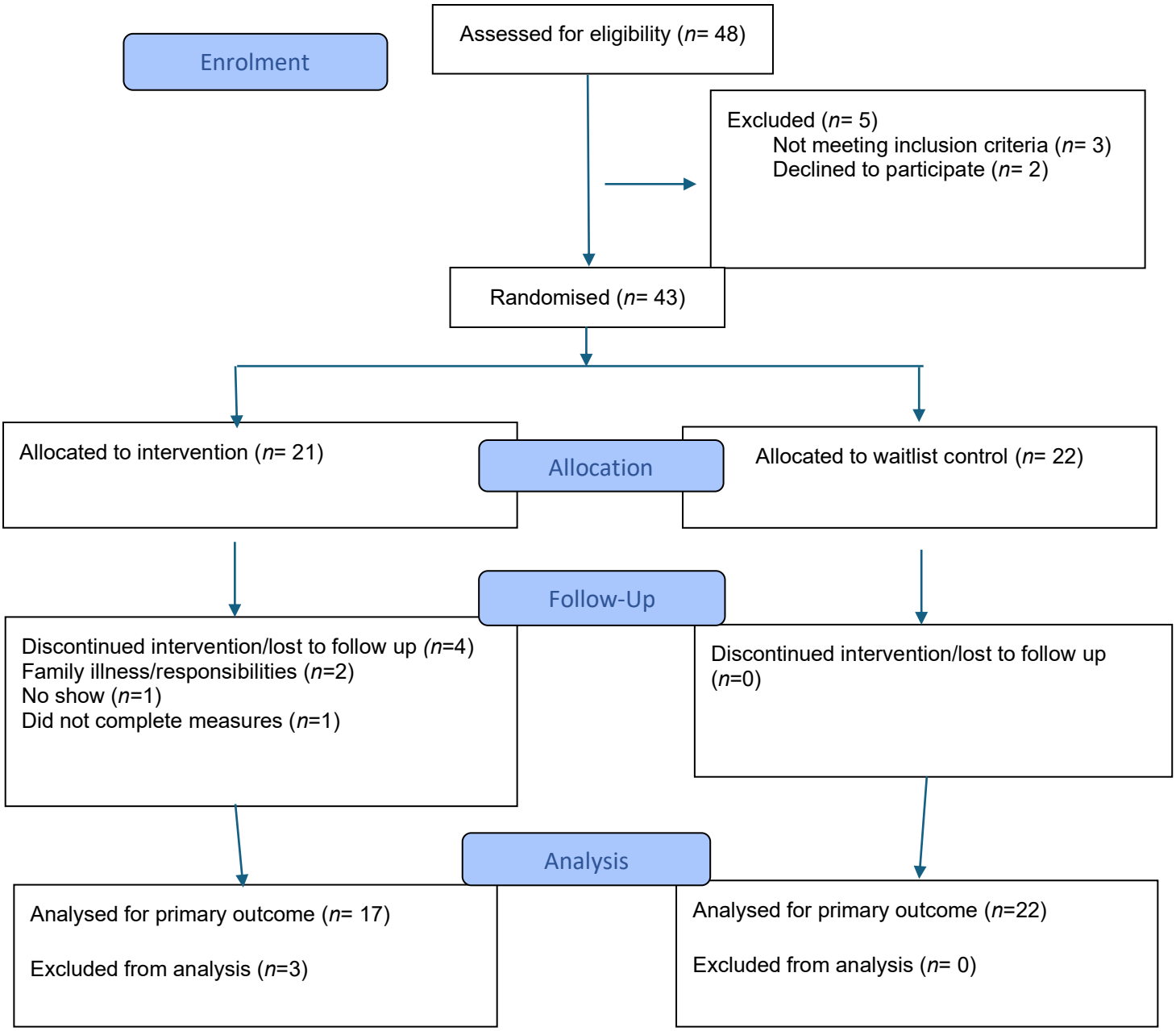
The Mindfulness-Based Intervention (MBI) was delivered to participants in person by one of the charity's qualified mindfulness teachers, who adhered to established quality standards for mindfulness-based approaches (as produced by Bangor University) and received mindfulness supervision throughout the intervention by a highly experienced mindfulness teacher and mental health professional. Group training sessions occurred in the evening (6.30-9.00 pm) to accommodate working adults, one of the charity's target populations for mindfulness-based mental health support. The MBI was provided free of charge. An RCT design was employed to establish efficacy, with a battery of self-report questionnaires administered pre, mid, and post-intervention.

Recruitment and enrolment proceeded as follows. A research poster circulated across Mind's associates prompted 76 individuals to respond, complete an application, and undergo brief screening. Of these, 43 met inclusion criteria and were enrolled for randomization. Informed consent, demographic data, and baseline psychometric scores were collected prior to randomization. Participants were randomly allocated using a random-number generator to either immediate treatment or waitlist control. The treatment group began the mindfulness course within two weeks of randomization; the control group waited until after the study period to commence the MBSR training program. Control participants were not informed they were controls, but were told their mindfulness course would begin in three months' time and would complete an eight-week assessment period before the first mindfulness session. Unique reference numbers were used in Qualtrics for all questionnaire data. The experiment group attended weekly group mindfulness sessions (6.30-9 pm) and were asked to maintain daily home practice (up to 45 minutes, six days per week) during the eight-session program. Participants received an instructional MP3 audio file, written practice instructions, and a practice record log.

Outcome measures included psychological distress, anxiety, stress, and alexithymia (primary and secondary outcomes) and mediator measures including mindfulness and interoceptive awareness. Assessments occurred at pre-intervention, mid-intervention, and post-intervention for all participants. After the study period, control participants were offered the mindfulness program. The study received ethical approval from City University's Ethics Committee and adhered to the Centre for Mindfulness Research and Practice (Bangor University, Wales) quality standards for delivering comprehensive MBSR. Informed consent was obtained from all participants. A CONSORT flow diagram (Figure 9) illustrates participant flow (Eldridge et al., 2016).

Figure 9

CONSORT Flow Diagramme



Mindfulness-Based Intervention (MBI) Programme

The Mindfulness-Based Stress Reduction (MBSR) program served as the intervention. It was an intensive eight-session weekly group course totalling 26 hours (2.5 hours per week plus a 6-hour retreat). Each session combined didactic content, experiential practice, and group enquiry, with an emphasis on fostering daily home practice and integration of mindfulness into ordinary life. The program aimed to enhance wellbeing and connectedness through sustained mindfulness practice, develop insight into stress response patterns, teach self-care and self-efficacy for symptom management, and promote active problem-solving to overcome barriers to regular practice.

Formal mindfulness practices included body scan, sitting meditation, movement meditation, and walking meditation, each lasting approximately 40-45 minutes. Informal practices were embedded within daily life, including the 3-minute breathing space, mindful eating, and 10-minute meditation. Breath awareness was emphasized as an anchor for present-moment awareness during prolonged practice.

At each session, participants received handouts detailing homework practices and theoretical content. MP3 files of the four formal practices (sitting meditation, gentle yoga meditation, walking meditation, body scan) were provided for home practice, along with practice logs. In-session provisions included yoga mats and cushions. The delivery adhered to quality standards set by Bangor University's Centre for Mindfulness Research and Practice (CMRP) with supervision from an approved supervisor. Audio recordings of two sessions were made for external review and quality control, indicating ongoing fidelity monitoring (the provided text ends with a truncation at this point).

Intervention fidelity was maintained through adherence to established MBSR structure, standardised materials, professional supervision, and alignment with CMRP guidelines. The content suggests a commitment to consistent delivery across participants and to maintaining program quality and safety.

Research Design

The study employed a randomized controlled trial (RCT) to evaluate the efficacy of the Mindfulness-Based Intervention for mental health outcomes. The design compared an immediate mindfulness treatment group with a waitlist control group to assess short-term effects and potential delayed benefits for controls.

Randomisation and allocation followed computer-generated methods. Group assignment comprised an immediate treatment arm and a waitlist control arm. Allocation concealment details were not explicitly described; however, participants were unaware of their control status, and control participants were informed of a future mindfulness course after the study period. Measures and data collection points included baseline (pre), mid-intervention, and post-intervention assessments.

Outcomes included self-reported psychological distress, anxiety, stress, and alexithymia (primary and secondary outcomes) and mediator variables such as mindfulness and interoceptive awareness. Assessments were conducted online via Qualtrics with unique participant IDs; paper forms were used when appropriate. The study encountered resource-related constraints, resulting in a modest sample size, but retention was strong

(91% overall; 81% retention within the intervention group due to some dropout). Ethical approval was granted by City University's Ethics Committee, and adherence to CMPRP standards at Bangor University was maintained.

Main Outcome Analysis

Mixed repeated measures 2x3 ANOVAs (within and between groups) were used to test the main interaction effects of group (mindfulness v control) by time (pre, mid and post intervention) on primary outcomes and mediator variables. Mauchly's test of sphericity was used to assess whether the sphericity assumption has been violated. When mauchly's test of sphericity is significant ($P < 0.05$), the degrees of freedom are corrected using greenhouse-geisser estimates of sphericity. The effect size calculation used is partial eta squared (Lakens, 2013). A *p*-value of 0.05 is set as the significance level for the main analysis tests. Posthoc testing, using bonerroni correct pairwise comparisons, was conducted for group differences at pre, mid and post.

Multiple Mediation Analysis

As recommended by Preacher and Hayes (2008), a non-parametric bootstrapping method was used in a parallel, or multiple, mediator model to test for the specific indirect mediational effects of the mindfulness intervention on mental health (distress, anxiety, stress) and mediator outcomes (interoception, acceptance, attention). Hayes' (2012) SPSS Version 4.2 macro and syntax was employed to request 5000 bootstrap resamples from the study data and 95% bias corrected and accelerated confidence intervals (using Process Model 4). When the upper and lower bound of the 95% bias corrected and accelerated confidence intervals do not contain zero, a statistically significant indirect mediation effect is assumed. Pre scores on all mediator and outcome variables were included as covariates. Given the modest sample size mediation analysis was conducted on pre to post scores only.

Power Analysis

Based on previous MBSR meta-analytic studies (Goldberg et al., 2022; Khoury et al., 2015; de Vibe et al., 2012) and medium treatment effect for stress, anxiety and depression, an a priori power analysis using G*Power 3.1 (Faul et al., 2007) determined the minimum sample size required to detect a medium effect size ($d = 0.5$) with alpha α set at .05, and power (1 - β betaβ) at .80. The analysis indicated that a minimum of 34 participants were needed. The sample size of this study was 43 participants.
A meta-analysis of MBSR on healthy/nonclinical populations (Khoury et al., 2015) found a large effect size for depression outcome, showing an overall Hedge's g of .80 ($p<0.0001$), a large Hedge's g effect of .74 on stress ($p<0.00001$), and moderate effect size showing an overall Hedge's g of .64 for anxiety ($p<0.00001$).

A systematic review of 44 meta-analyses (Goldberg et al., 2022) demonstrated that at post-treatment for passive controls, MBIs showed superiority to passive controls for most outcome types, except for objective measures and physiological measures (*d* = 0.48, (−0.39, 1.35)). Statistically significant meta-analytic effect sizes ranged from small (*d* = 0.21, for well-being) to moderate (*d* = 0.55, for psychiatric symptoms).
In a systematic review of 31 RCTs of MBSR with 1,932 participants (de Vibe et al., 2012), effect sizes for the combined mental health outcomes were relatively similar across the range of target groups: 0.50 for clinical and 0.62 for non-clinical populations and this difference is not significant. Effect sizes for mental health were not influenced by the length of intervention, self-reported practice, risk of bias, or whether analyses were done as intention to treat or per protocol, though positively correlated with course attendance (de Vibe et al., 2012). It should be acknowledged that the chosen medium effect size is an assumption, based on prior literature, however may not hold in this sample.

A small, demographically or clinically homogeneous sample limits generalisability to broader populations. In line with the National Institute of Health (NIH) classification of "Stage 3" (i.e., community-based) efficacy trials (Dimidjian & Segal, 2015; Onken et al., 2014), this study recruited a heterogenous sample of different ages, baseline distress levels and comorbidities, however the majority of participants were females. Recruitment was not from a small locality or a specific community, in order to preserve external validity as much as possible.

Primary Outcome Measure - Psychological Distress

General Health Questionnaire (GHQ-12: Goldberg et al., 1997).

The General Health Questionnaire (GHQ-12) is a widely used self-report instrument comprising 12 questions and measuring mild psychiatric features in the general population (Goldberg et al., 1997). The GHQ-12 assesses symptoms of anxiety, depression, social impairment, and low confidence (Makikangas et al., 2006). It was originally developed to screen for non-psychotic minor psychiatric symptoms in general practice and has been extended to a large body of survey studies. Responses are coded as 0 (e.g. better or same as usual) or 1 (e.g. less than usual, much less than usual) and summed to provide a global score ranging from 0 to 12, as per Goldberg et al. (1997). Elevated GHQ scores indicate higher levels of distress and the presence of psychiatric morbidity. This study also employed the GHQ caseness scoring system. A 3/4 caseness threshold is considered the most accurate for detecting psychiatric cases in the general UK population (Goldberg et al., 1997; Hardy et al., 1999). This construct has been validated by standardized psychiatric interviews and can detect likely depression and anxiety (Aalto et al., 2012). Individuals scoring four or more are considered 'cases' for mild psychiatric disorder while noncases have a score of less than four.

This instrument has become a highly recognized mental health measure for UK-based population studies (Propper et al., 2005; Thomson & Katikireddi, 2018), in large part owing to its use as a core mental health outcome measure for large scale surveys such as the UK Household Longitudinal Survey (McFall, 2001) and the Health Survey for England

(Mindell et al., 2012). Salama-Younes et al. (2009) measured the internal consistency of the GHQ-12 using Cronbach's alpha coefficient. This coefficient was found to be α = 0.78 for the unidimensional construct, and for the other two-factor and three-factor models the alpha values were found to be Anxiety/depression, α = 0.84; Social dysfunction, α = 0.76; and Loss of confidence, α = 0.81.

Primary Outcome - Generalized Anxiety

Generalized Anxiety Scale (GAD7; Spitzer et al., 2006)

The GAD-7 is a brief self-report questionnaire designed as a screening tool for Generalized Anxiety Disorder (GAD) and valid for use with clinical and nonclinical populations. The 7 items are questions related to worry and anxiety sypmtoms and are scored on a Likert scale of 0-3 (with a global score ranging from 0-21) and capture the frequency one experiences symptoms associated with generalized anxiety within the previous 2 weeks. Total scores of 5, 10 and 15 represent cutoff thresholds for mild, moderate and severe anxiety. The GAD-7 has shown good reliability and construct validity (Kroenke et al., 2007; Lowe et al., 2008). A person is said to be at caseness when their symptom score exceeds the accepted clinical threshold for the relevant measure of symptoms. For the GAD-7, this is a score of 10 or above (Spitzer et al., 2006). The reliability coefficient Cronbach's α for the overall GAD-7 scale is α =.90, item 1 α =.88; item 2 α =.87, item 3 α =.87, item 4 α =.88, item 5 α =.89, item 6 α =.88 and item 7 α =.88 (Dhira et al., 2021).

Primary Outcome - Perceived Stress

Perceived Stress Scale (PSS10; Carmody et al. 2009; Cohen and Williamson, 1988).

Perceived stress can be measured using the perceived stress scale (PSS) (Cohen et al., 1983), which consists of 10 questions on a Likert scale from 1 to 5, where 0 = never and 4 = very often. The PSS was developed to measure chronic stress in the general population along dimensions of unpredictability, uncontrollability, and overload which indicate risk for adverse health outcomes. The PSS has strong construct validity and reliability across gender, socioeconomic status, age groups, ethnicity, and other demographic characteristics (Cohen et al., 1983) and is widely used in studies investigating chronic stress (Pompon et al., 2019). The PSS was used in one of the small number of studies examining the relationship between attention and chronic stress (Liu et al., 2020). Lee (2012) conducted a reviewed of all three versions and found that the psychometric properties of the PSS-10 are superior to those of the PSS-14 and PSS-4. The Cronbach's alpha of the PSS-10 was found at α >.70 in all 12 studies in which it was used. The test-retest reliability was also assessed in four studies and met the criterion of α >.70 in all cases.

Mediator measure - Interoceptive (Body) Awareness

Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012)
The MAIA is a 32-item instrument used to measure and assess individual differences in the trait and modifiable dimensions of self-reported interoceptive awareness. The MAIA consists of eight subscales and five dimensions: (1) *awareness of mind/body integration* which comprises (a) self-regulation (4 items), showing the ability to regulate distress by paying attention to bodily sensations; (b) body listening (3 items), reflecting the body's active listening for self-insight and (c) emotional awareness (5 items), indicating awareness of the relationship between bodily sensations and emotional states; (2) *attention regulation* which comprises one larger subscale (7 items), pointing to the ability to maintain attention and control over bodily sensations; (3) *noticing* (4 items), indicating an awareness of uncomfortable, comfortable, or neutral bodily sensations; (4) *trusting* (3 items), pointing to the experience that one's body is safe and trustworthy and finally (5) *emotional reaction and attentional response to sensations* comprising (a) not distracting (3 items), showing a tendency not to ignore or distract oneself from painful or uncomfortable bodily sensations; (b not worrying (3 items), reflecting a tendency not to worry or experience emotional distress associated with painful or uncomfortable sensations. For each facet, higher scores indicate greater adaptive tendencies in interoceptive attention. A global score is also commonly used in research though not recommended by the developers (Mehling et al., 2012; Vig et al., 2022).

The 32-item MAIA has shown low internal consistency for two of its scales (not worrying and not distracting) which has been revealed by its numerous applications in English and other language (Ferentzi et al., 2021; Van Bael et al., 2024; DaCosta Silva et al., 2022; Mehling et al., 2012). Todd and colleagues (2020) provide an overview of the key psychometric strengths and weaknesses of the subscales of the instrument across studies and language adaptations. With respect to internal consistency most studies find good to excellent values (Cronbach α range 0.7-0.9) across subscales, except for the *Not-Distracting* and *Not-Worrying* subscales which consistently displays suboptimal values (< 0.7). The number of items and reliability established by Cronbach's alpha (α), vary among the subscales: noticing (four items, α = 0.69), Not-Distracting (three items, α = 0.66), Not-Worrying (three items, α = 0.67), Attention Regulation (seven items, α =0.87), Emotional Awareness (five items, α = 0.82), Self-Regulation (four items, α = 0.83), Body Listening (three items, α = 0.82) and Trusting (three items, α = 0.79). As per Ferentzi et al. (2021), this study excluded Not Distracting and Not Worrying from the general factor because of the previous weak correlations with the other MAIA scales.

Mediator Measure -Mindfulness Disposition

Five Facet Mindfulness Questionnaire (FFMQ-15: Baer et al., 2012; Gu et al., 2016)

The 15-item FFMQ (FFMQ-15) self-report instrument was developed by Baer et al. (2012) as a shorter version of the original 39-item FFMQ (Baer et al., 2006). The FFMQ-15

includes same five facets as the longer version including observing, describing, acting with awareness, nonjudging of inner experience, and nonreactivity to inner experience. It selected three top loading items for each facet in order to maintain the breadth of content for each facet. The factor structure and psychometric properties of the FFMQ-15 were tested by Gu et al. (2016). They found that the factor structure of the FFMQ-15 was consistent with that of the FFMQ-39 and there were large correlations between total facet scores of the short and long forms, indicating that both versions measured comparable constructs. Gu and colleagues (2-15) also found that the two FFMQ versions did not differ significantly from each other in terms of convergent validity. Internal consistency was adequate for the FFMQ-15 and the measure was found to be sensitive to change over the course of Mindfulness-Based Cognitive Therapy (small/moderate to moderate/large and significant increases in total facet scores). The observing facet consists of 3 items (pre α = .64, post α = .69), the describing facet consists of 3 items (pre α = 80, post α = .83), the acting with awareness facet consists of 3 items (pre α = .68, post α = .70), the nonjudging facet consists of 3 items (pre α = .76, post α = .78), the nonreactivity facet consists of 3 items (pre α = .66, post α = .77).

Taken together, Gu et al.'s (2016) findings promote the use of the FFMQ-15 in research where briefer forms are needed. Some researchers propose that enhanced ***nonreactivity, an acceptance facet,*** plays a pivotal role in producing the observed clinical benefits following mindfulness training (Curtiss et al., 2017; Hanley et al., 2017; Mayer et al., 2019). Studies on a large-scale population including students, professionals, and clinically depressed individuals showed that FFMQ-15 is a predictor for positive thinking, an overall uplifted mood, and subjective feelings of wellbeing (Baer et al., 2012; Gu et al., 2016; Bohlmeijer et al., 2011).

Results

Main outcomes effects (group by time interactions)

All within-subjects and between-groups effects were analyzed using a 2x3 mixed design repeated measures ANOVA, with a within factor of time (pre, mid and post) and a between factor of group (mindfulness and control) for the mental health outcomes (distress, anxiety, stress, alexithymia) and the mediator variables (IA, acceptance, attention). A conservative estimate of degrees of freedom were corrected using greenhouse-geisser for violations to assumptions of sphericity. Follow on posthoc testing used bonferroni adjusted pairwise comparisons for group differences at pre, mid and post. As suggested by Field (2009), the correct degrees of freedom will be reported in the findings, rather than the rounded figure. See Table 5 for a summary of means, standard deviations, main group by time outcome effects and posthoc group differences for all of the study variables.

H1: Primary Mental Health Outcomes

H1: Psychological Distress

The assumption of sphericity was violated, as indicated by mauchly's test *($\chi 2(2) = 10.40$, $p = .006$),* therefore a conservative estimate of degrees of freedom was applied using greenhouse-geisser estimates of sphericity ($\varepsilon = 0.80$). A significant effect of time, *($F(1.60, 59.16) = 22.60$, $p < .001$, $\eta p^2 = .28$)* but not group was found *($F(1,37) = 2.54$, $p = .119$, $\eta p^2 = .06$). There* was a significant group by time interaction, *($F(1.60,59.16) = 9.75$, $p = < .001$, $\eta p^2 = .21$)*. Posthoc tests showed no significant group difference at pre (p=.154), with significant group differences at mid *($p = .01$)* and again at post *($p = .001$)*. **MT resulted in significant improvements in psychological distress.**

H1: Anxiety

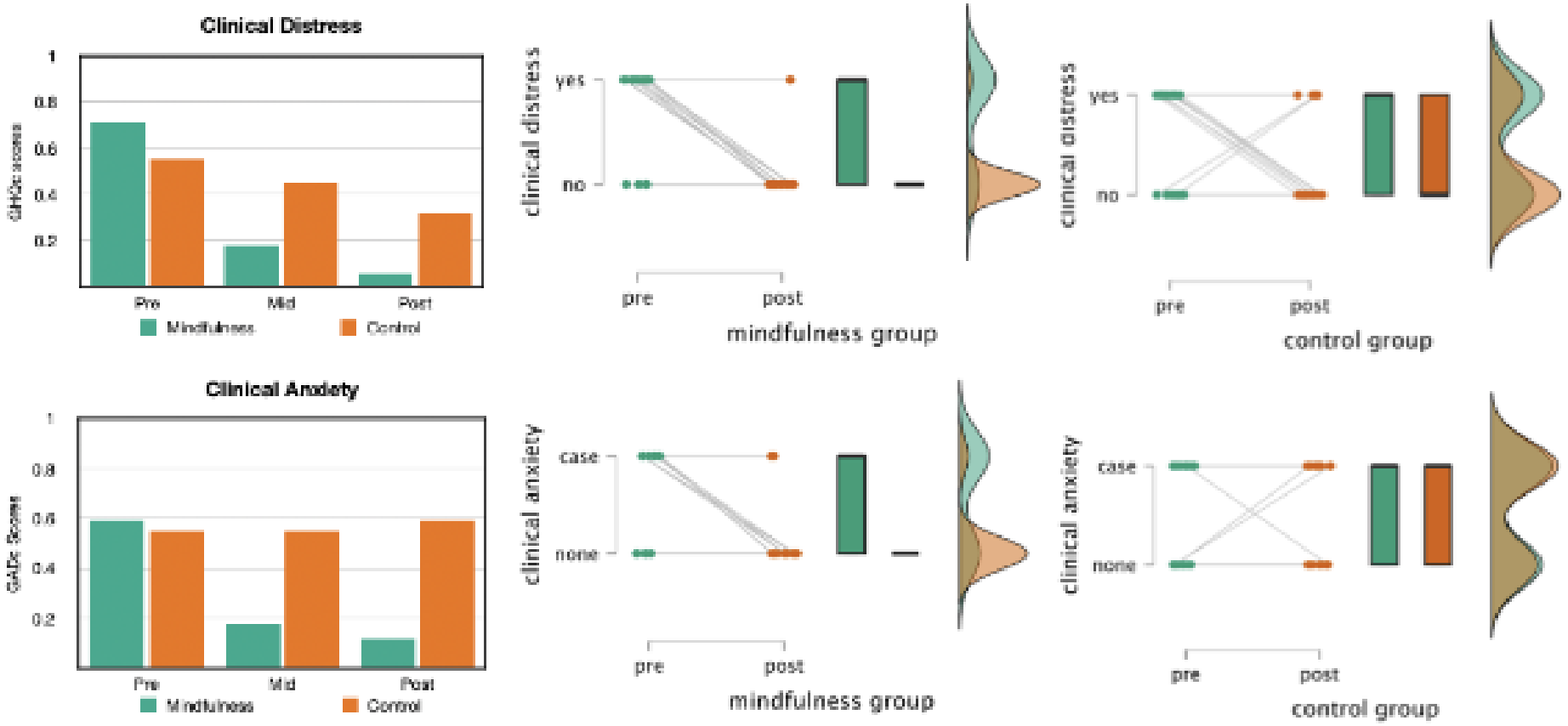
The assumption of sphericity was violated, as indicated by mauchly's test *($\chi 2(2) = 9.16$, $p = .010$),* therefore a conservative estimate of degrees of freedom was applied using greenhouse-geisser estimates of sphericity ($\varepsilon = 0.82$). Main effects of time, *($F(1.63, 60.43) = 8.09$, $p = .002$, $\eta p^2 = .18$) but not group were found ($F(1.37) = 3.65$, $p = .064$, $\eta p^2 = .09$).* There was a significant interaction between time and group, *($F(1.63,60.43) = 4.23$, $p = .026$, $\eta p^2 = .10$)*. Posthoc tests show no significant group difference at pre *($p = .794$), with* significant group differences at mid *($p = .035$)* and again at post *($p = .007$).* **MT produced a significant reduction in generalized anxiety.**

H1: Clinical distress and clinical anxiety

In the mindfulness treatment group, 59% met criteria for clinical anxiety at pre and by post a reduction to 12% was found while 71% met criteria as psychiatric cases at pre which reduced to 6% by post. As expected in the control group 55% met criteria for clinical anxiety and 59% were found to have clinical anxiety at post, and 55% were considered psychiatric cases at pre which reduced to 32% at post. See Figure 10 for graphs representing clinically significant change in distress and anxiety.

Figure 10

Clinical Outcomes for Psychological Distress and Generalised Anxiety



Note. Mean and individual change of clinical distress and anxiety by group (mindfulness versus control) across two time periods (pre & post). Raincloud plots show individual change, by group (mindfulness or control), showing trends in change and direction of change.

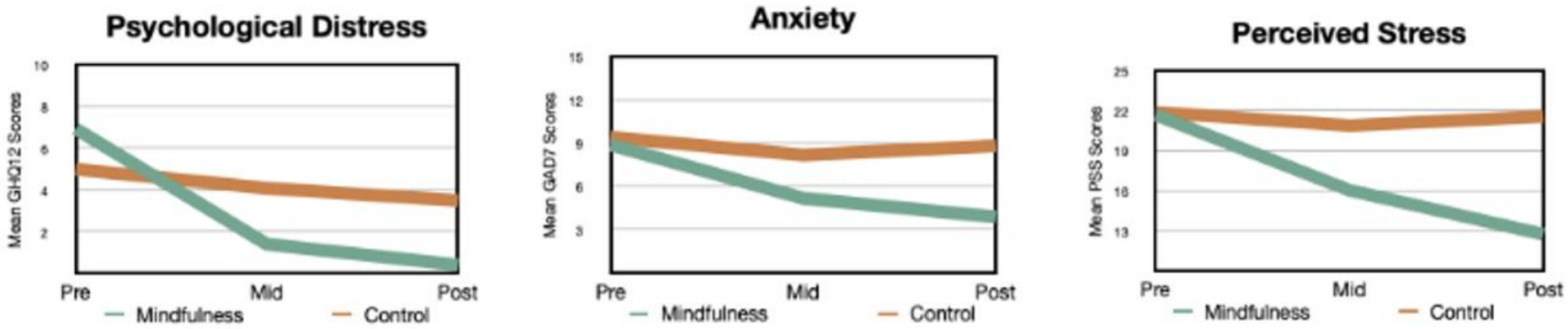
3.2.4 H1: Perceived Stress

The assumption of sphericity was not violated, as indicated by mauchly's test *(χ2(2) = 1.98, p= .373)*. However a conservative estimate of degrees of freedom was applied using greenhouse-geisser estimates of sphericity (ε = 0.95). Main effects of time, *(F(1.90, 70.25) = 15.72, p <.001 ηp² =.30)*, and group, *(F(1.37) = 5.12, p = .030,ηp² =.12)*, were qualified by a significant interaction between time and group, *(F(1.90,70.25) = 12.85, p<.001 ηp² =.26)*. There was no significant group difference at pre (p=.936), however there were significant group differences at mid *(p=.029)* and post *(p<.001)*. **Perceived stress was significantly reduced by the mindfulness training.**

See Figure 11 for graphs showing main mental health interaction effects.

Figure 11

*Main Mental Health Outcomes**



Note. *changes on study mental health outcomes across three intervals (pre, mid, post) as a function of group (mindfulness versus control).

As hypothesized, the mindfulness group (above the control group) showed significant improvements in all mental health outcomes (eg, psychological distress, anxiety, stress and). See Figure 1 for changes on study mental health outcomes. See Table 5 for means, standard deviations and main outcome effects (group by time interactions and group differences at pre, mid and post).

Table 5

*Main Outcome Effects for All Study Variables****

Variable	Time	Group		Results
		Mindfulness	Control	
Psychological Distress	Pre	6.94 (4.58)	5.00 (3.75)	
	Mid	1.41 (2.69)	4.09 (3.35)	
	Post	.41 (1.70)	3.50 (3.23)	group by time interaction effects: *F(1.60,59.16) = 9.75, p=<.001 ηp²=.21** between groups effects at mid *p=.011* and at post *p=.001***
Anxiety	Pre	8.88 (5.58)	9.41 (6.64)	
	Mid	5.18 (3.59)	8.18 (4.70)	
	Post	3.88 (3.04)	8.82 (6.55)	group by time interaction effects: *F(1.63,60.43) = 4.23, p=.026 np²=.10** between groups effects at mid, *p=.035* and post *p=.007***
Perceived Stress	Pre	21.71 (8.26)	21.91 (7.33)	
	Mid	16.06 (6.81)	20.91 (6.44)	
	Post	12.76 (5.67)	21.59 (7.35)	group by time interaction effects: *F(1.90,70.25) = 12.85, p=<.001 ηp²=.26** between groups effects at mid, *p=.029* and post *p<.001***
Overall Mindfulness	Pre	119.12 (18.41)	114.36 (23.58)	
	Mid	134.35 (20.08)	112.41 (25.08)	
	Post	145.06 (21.11)	113.27 (26.05)	group by time interaction effects: *F(1.61,59.89) = 18.24, p=<.001 ηp²=.33** between groups effects at mid, *p=.006* and post *p<.001***
Attention (ActAware)	Pre	21.29 (5.13)	22.73 (5.57)	
	Mid	23.71 (5.57)	20.77 (5.96)	
	Post	27.35 (6.20)	20.32 (6.28)	group by time interaction effects: *F(1.43,52.97) = 18.31, p=<.001 ηp²=.33** between groups effects at mid, *p=.125* and post *p=.001***
Acceptance (NonReact)	Pre	17.71 (4.69)	17.82 (4.69)	
	Mid	22.06 (3.70)	18.14 (4.63)	
	Post	24.41 (3.68)	19.27 (5.06)	group by time interaction effects: *F(1.78,65.70) = 11.59, p=<.001 ηp²=.24** between groups effects at mid, *p=.007* and post *p=.001***
Acceptance (NonJudge)	Pre	23.82 (8.21)	24.14 (8.20)	
	Mid	26.76 (7.17)	24.23 (8.64)	
	Post	29.24 (7.36)	25.00 (9.37)	group by time interaction effects: *F(1.62,59.82) = 3.88, p=.034 ηp²=.10** between groups effects at mid, *p=.334* and post *p=.134***
Attention (Observe)	Pre	26.59 (4.82)	25.86 (5.91)	
	Mid	30.47 (3.91)	25.73 (5.95)	
	Post	31.29 (3.51)	25.77 (5.49)	group by time interaction effects: *F(1.97,72.78) = 9.42, p=<.001 ηp²=.20** between groups effects at mid, *p=.007* and post *p<.001***
Atten and Accept (Describe)	Pre	29.71 (5.30)	23.82 (5.15)	
	Mid	31.35 (5.72)	23.55 (6.52)	
	Post	32.76 (5.78)	22.91 (6.78)	group by time interaction effects: *F(1.78,65.66) = 4.38, p=.020 ηp²=.11** between groups effects at mid, *p<.001* and post *p<.001***
Interoceptive (Body) Awareness	Pre	65.59 (22.59)	59.95 (16.44)	
	Mid	83.59 (18.54)	62.82 (18.75)	
	Post	94.24 (16.43)	64.27 (19.01)	group by time interaction effects: *F(1.82,67.34) = 25.06, p=.<001 ηp²=.40** between groups effects at mid, *p=.001* and post *p<.001***

Note. *partial eta squared for effect size (ηp²) and greenhouse geisser applied; **bonferroni adjusted, *****Means, SDs, Main Group by Time Interaction Effects and Simple Effects of Group Difference Across Time (Pre and Post Intervention)*

3.3 H2: Secondary Mediator Outcomes

3.3.1 H2: Interoceptive Awareness

The assumption of sphericity was not violated, as indicated by mauchly's test *(χ2(2) = 3.75, p= .153)*. However, a conservative estimate of degrees of freedom was applied using greenhouse-geisser estimates of sphericity (ε = 0.81). Main effects of time, *(F(1.82, 67.34) = 43.40, p <.001 ηp² =.54)*, and group, *(F(1.37) = 10.16, p = .003, ηp² =.22)*, were qualified by a significant interaction between time and group, *(F(1.82,67.34) = 25.06, p<.001, ηp² =.40).* There was no significant group difference at pre *(p=.68)*, with significant group differences at mid *(p=.001)* and again at post (p<.001).

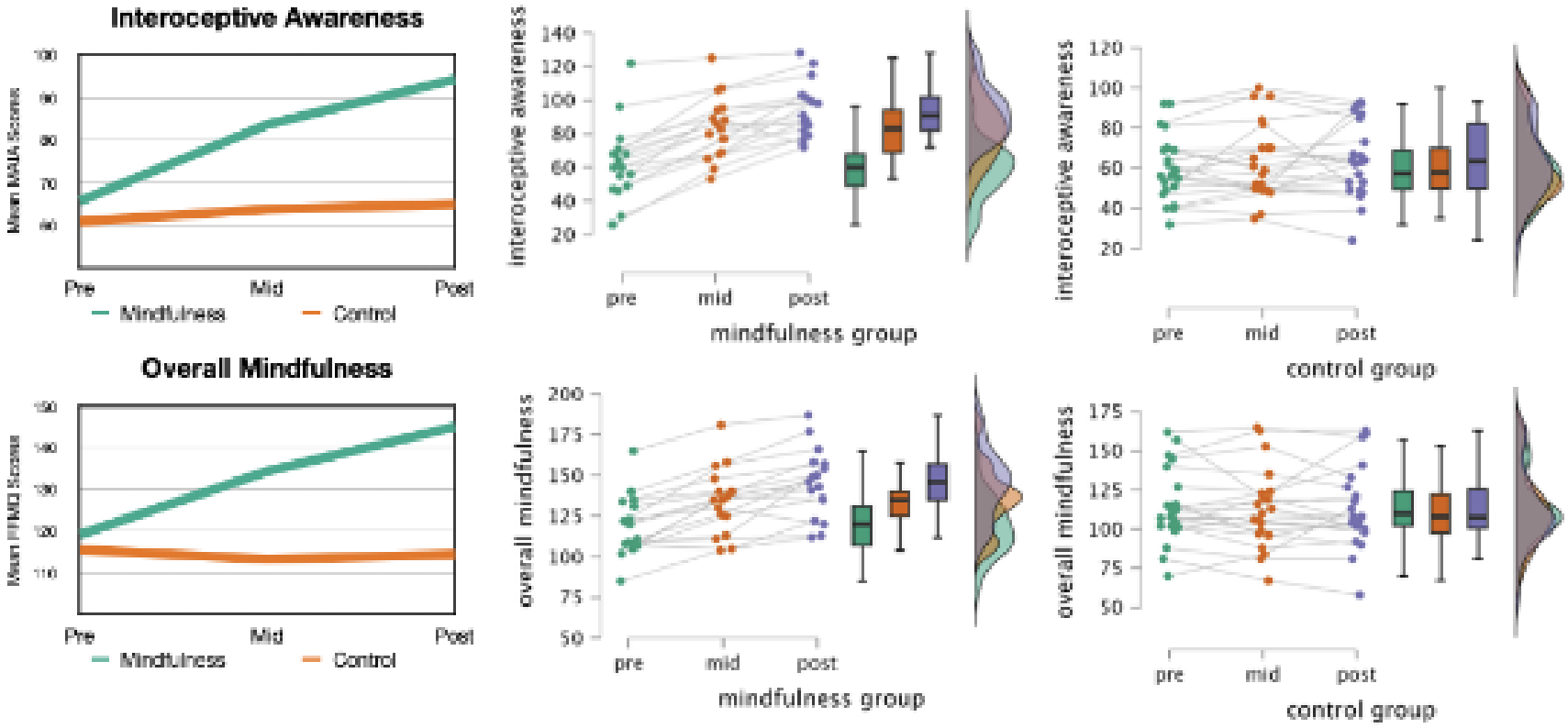
3.3.2 H2: Overall Mindfulness

The assumption of sphericity was violated, as indicated by mauchly's test *(χ2(2) = 9.68, p= .008),* therefore a conservative estimate of degrees of freedom was applied using greenhouse-geisser estimates of sphericity (ε = 0.81). Main effects of time, *(F(1.62, 59.89) = 15.07, p <.001 ηp² =.29)*, and group, *(F(1.37) = 7.95, p = .008, ηp² =.18),* were qualified by a significant interaction between time and group, *(F(1.62,59.89) = 18.24, p<.001 ηp² =.33)*. There was no significant group difference at pre *(p=.50)*. The MF group showed significant simple main effects at mid *(p=.006)* and again at post *(p<.001)*.

The mindfulness training group demonstrated significant improvements in overall interoceptive awareness and mindfulness. See Figure 12 for mean and individual changes on overall interoceptive awareness and mindfulness.

Figure 12

*Main Interaction Effects and Individual Change on Global Mindfulness and Interoceptive Awareness**



Note. *main interaction effects and individual changes using Raincloud Plots on dispositional mindfulness versus interoceptive awareness as a function of group (mindfulness versus control) across three time points (pre, mid, post).

3.3.3 H2: Acting with Awareness Facet (Attention)

The assumption of sphericity was violated, as indicated by mauchly's test *(χ2(2) = 18.22, p< .001),* therefore a conservative estimate of degrees of freedom was applied using greenhouse-geisser estimates of sphericity (ε = 0.72). A main effect of time was found *(F(1.43, 52.97) = 4.04, p =.036 ηp² =.10).* No group effect was found *(F(1,37) = 2.81, p = .102, ηp² =.07)*. There was a group by time interaction effect *(F(1.43,52.97) = 18.31, p<.001, ηp² =.33)*. There was no significant group difference at pre *(p=.42)* or mid *(p=.125)*. The mindfulness group showed a significant simple main effect at post *(p=.001)*.

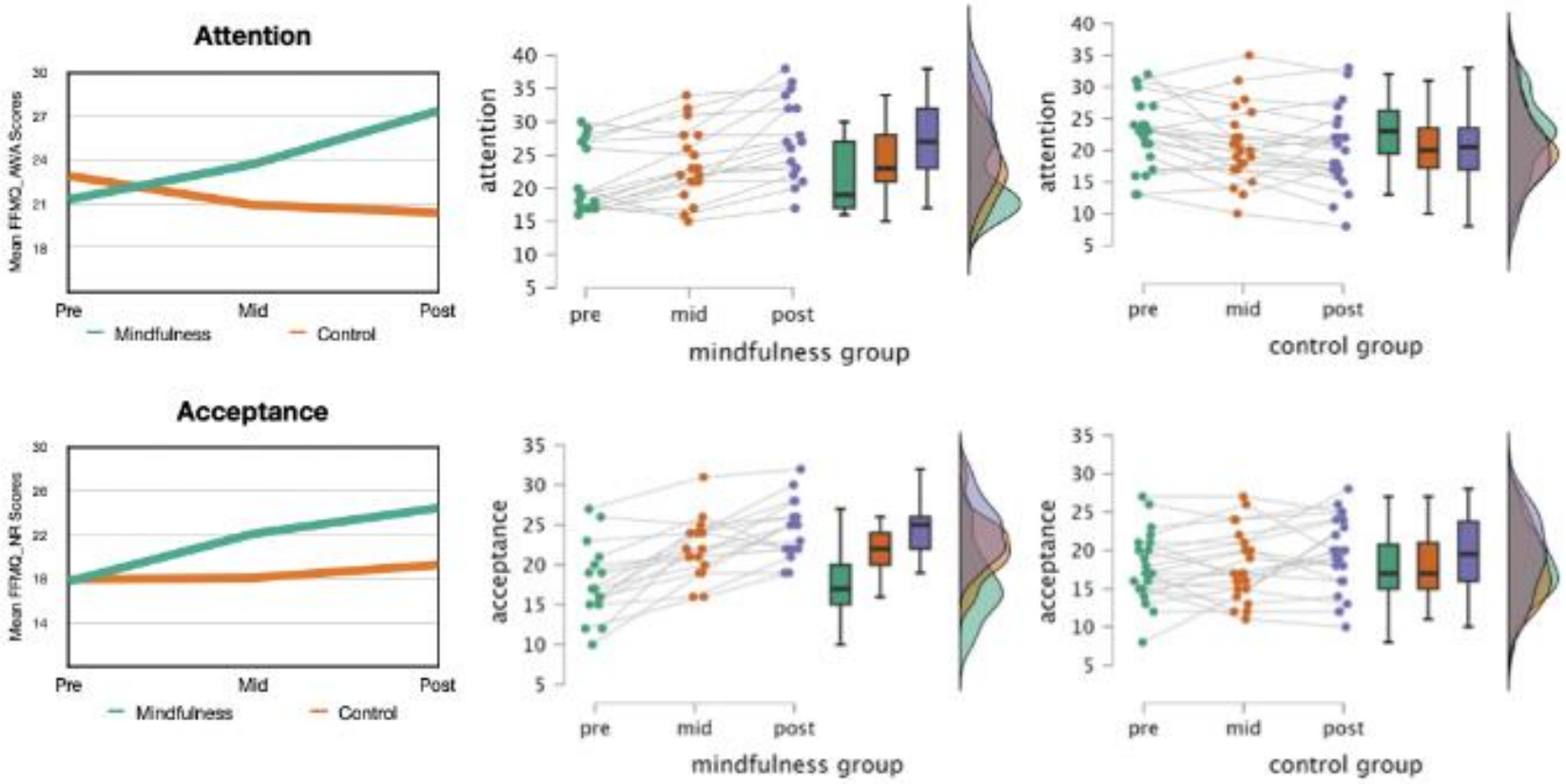
3.3.4 H2: Nonreactivity Facet (Acceptance)

Main effects of time, *(F(1.78, 65.70) = 25.71, p <.001 ηp² =.41)*, and group, *(F(1,37) = 5.44, p = .025, ηp² =.13)*, were qualified by a significant interaction between time and group, *(F(1.78,65.70) = 11.59, p<.001, ηp² =.24)*. There was no significant group difference at pre (*p=.940)*. The mindfulness group showed significant simple main effects at mid *(p=.007)* and at post *(p=.001)*.

The mindfulness training group demonstrated significant improvements in acceptance (FFMQ NR)) and attention (FFMQ AWA). See Figure 13 for mean and individual changes on subfacet mediators (attention and acceptance).

Figure 13

*Main Interaction Effects and Individual Change on Mindfulness Attention and Acceptance Facets**



Note. *main interaction effects and individual changes using Raincloud Plots on core mediation variables (attention and acceptance) as a function of group (mindfulness versus control) across three time points (pre, mid, post).

3.3.5 H2: Observing Facet (Attention)

The assumption of sphericity was not violated, as indicated by mauchly's test *(χ2(2) = .61, p= .74)*. However, a conversative estimate of degrees of freedom was applied using greenhouse-geisser estimates of sphericity (ε = 0.98). Main effects of time, *(F(1.97, 72.78) = 8.55, p <.001 ηp² =.19)*, and group, *(F(1,37) = 5.89, p = .020, ηp² =.14),* were qualified by a significant interaction between time and group, *(F(1.97,72.78) = 9.42, p<.001, ηp² =.20)*. There was no significant group difference at pre *(p=.684)*. The mindfulness group showed significant simple main effects at mid *(p=.007)* and post *(p<.001)*.

3.3.6 H2: Nonjudging Facet (Acceptance)

The assumption of sphericity was violated, as indicated by mauchly's test *(χ2(2) = 9.74, p= .008),* therefore a conservative estimate of degrees of freedom was applied using greenhouse-geisser estimates of sphericity (ε = 0.81). Main effects of time were found *(F(1.62, 59.82) = 7.23, p =.003 ηp² =.16)*, with no group effect *(F(1,37) = .75, p = .394, ηp² =.02).* A weak significant group by time interaction effect was found *(F(1.62, 59.82) = 3.89, p=.034, ηp² =.10)*. There were no significant group differences at pre *(p=.97)* or mid *(p= .334)* or post *(p=.134).*

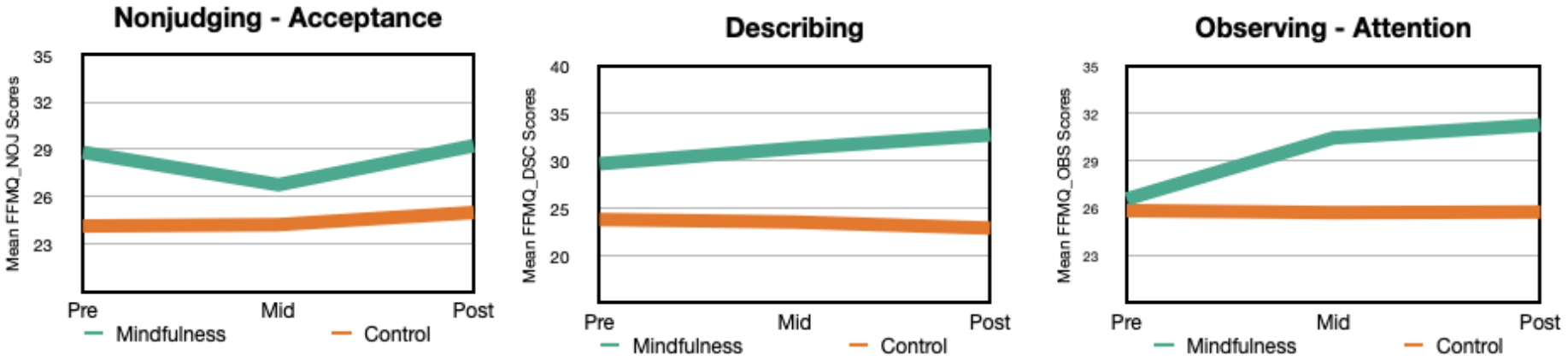
3.3.7 H2: Describing Facet

The assumption of sphericity was not violated, as indicated by mauchly's test *(χ2(2) = 4.89, p= .087)*. However, a conversative estimate of degrees of freedom was applied using Greenhouse-Geisser estimates of sphericity (ε = 0.89). There was no significant effect of time *(F(1.78, 65.66) = 1.32, p =.273 ηp² =.03).* There was a significant group effect *(F(1,37) = 19.96, p < .001, ηp² =.35), which* was qualified by a weak significant interaction between time and group, *(F(1.78, 65.66) = 4.38, p=.020, ηp² =.11)*. There were significant group differences at pre *(p=.001)*, mid *(p<.001)* and post *(p<.001).*

There were significant but weaker improvements in the facets of nonjudging and describing produced by the mindfulness training. See Figure 14 for changes on FFMQ subfacets of nonjudging, observing and describing.

Figure 14

Main Interaction Effects for Secondary Mindfulness Facet Outcomes



Note. main group by time interaction effects of mindfulness training by group (mindfulness or control) and time (pre, mid and post) on mindfulness facets

Finally, as hypothesized (H2), significant group by time interaction effects were found on all mediator variables, indicating that scores improved from pre to post. Findings suggest that the improvements over time on outcomes (psychological distress, anxiety, stress, alexithymia) were significantly higher in the mindfulness treatment group than in the control group. As the strongest outcomes on the mindfulness facets were nonreactivity and acting with awareness (see Table 2.5), these were selected as the corresponding mediator variables for 'acceptance' and 'attention' respectively.

Multiple Mediation Effects

Multiple mediation analyses were conducted to examine for total and specific (i.e., unique) indirect effects of mindfulness training on the study's mental health outcomes, via the proposed mediating variables (i.e., attention and/or acceptance). See Figure 2.7 for graphical representation of multiple mediation models.

H3: Multiple Mediation: Acceptance vs Attention

To analyze attention and acceptance components together, 2 FFMQ facets corresponding to attention (AWA) and acceptance (NR) that were found to have the strongest within-subjects group by time interaction effects and between groups simple main effects were selected for mediation analysis. These 2 facets were tested simultaneously in a bootstrapped subfacet multiple mediation model (Process Model 4) for total and specific indirect effects on the main outcomes of psychological distress, anxiety and perceived stress.

For the distress outcome, the results partially support hypothesis 4 by demonstrating a specific (ie., unique) indirect effect of the impact of MT on distress via *acceptance* (b= 2.2181, BootSE= .9195, CI .5784, 4.2011). The study did not find a specific indirect effect of mindfulness training on distress via attention (b= -1.1131, BootSE= .8058, CI -2.6753, .42011) or a total indirect effect (b= 1.1050, BootSE= .7023, CI -.3442, .2.6592). **Mindful acceptance functions as a unique mediator of change (for distress), over and above the mediational influence of attentional change.**

For the anxiety outcome, the results partially supported Hypothesis 3. There was a total indirect effect of acceptance & attention on the mindfulness-induced anxiety outcome (b= 2.9395, BootSE= 1.0250, CI .9038, 5.0174), however there were no specific indirect effects of attention (b= 1.1548, BootSE= 1.7013, CI -.1.6807, 5.0686) or acceptance (b= 1.7846, BootSE= 1.1436, CI -1.4350, 4.2003). **Neither mindful acceptance nor attention functions as a unique mediator of change (for the anxiety outcome), over and above the total mediational influence of both acceptance and attention.**

For the stress outcome, the results did reveal specific indirect effects of MT on stress via both acceptance (b= 2.0638, BootSE= 1.1612, CI .0367, 4.6393) and attention (b= 4.0888, BootSE= 1.376, CI 1.7040, 7.2722) as well as total indirect effect (b= 6.1526, BootSE= 1.6840 CI 3.2460, 9.8244). **Both acceptance and attention function as unique mediators of change (for the stress outcome).**

Mindful acceptance emerged as a unique mediator of change (for the outcome of psychological distress), over and above the mediational influence of attention. There was a total indirect mediational effect of both mediators on anxiety, however there was no unique mediational influence. Finally for the stress outcome, both acceptance and change, as well as the two together, emerged as unique mediational influences. See Table 6 for indirect mediation effects (attention vs acceptance) on mental health outcomes.

Table 6

*Mediation Results for Step 1 and Step 2 Mindfulness Processes***

Total Effect (MT—>Outcome)	Direct Effect (MT—>Outcome)	Hypothesis: Mediation Relationship	Indirect Effect	SE*	Confidence Interval* Lower Bound	Upper Bound	Inference
Psychological Distress							
3.0237 (.0003)	1.9187 (.0616)	MT—>Total Attention and Acceptance—>Distress	1.1050	0.7023	-0.1342	2.6592	No Mediation
		MT—>Attention—>Distress	-1.1131	0.8058	-2.6753	0.5493	No Mediation
		MT—>Acceptance—>Distress	2.2181	0.9195	0.5784	4.2011	**Mediation**
Stress							
8.6412 (.0000)	2.4886 (.0834)	MT—>Total Attention and Acceptance—>Stress	6.1526	1.6840	3.2460	9.8244	No Mediation
		MT—>Attention—>Stress	4.0888	1.3976	1.7040	7.2722	**Mediation**
		MT—>Acceptance—>Stress	2.0638	1.1612	0.0367	4.6393	**Mediation**
Anxiety							
4.5008 (.0000)	1.5613 (.3664)	MT—>Total Attention and Acceptance—>Anxiety	2.9395	1.0250	0.9038	5.0174	No Mediation
		MT—>Attention—>Anxiety	1.1548	1.7013	-1.6807	5.0686	No Mediation
		MT—>Acceptance—>Anxiety	1.7846	1.1436	-1.4350	4.2003	No Mediation

*Note. **Step1 and Step2 processes are from the adapted UFM mediational model (Rogge & Daks, 2021)* * Estimated on 5,000 bootstrap samples using the SPSS PROCESS Model 4 Macro (Preacher & Hayes, 2004). Bold characters indicate unique indirect mediation effects.
MT = Mindfulness Training IA= Interoceptive Awareness, MF = Mindfulness Disposition, SE = standard error;
CI = confidence interval; SD = Standard deviation; ES = Effect size (ratio of the indirect effect to the total effect

H4: Multiple Mediation: Global IA vs MF

To analyze interoceptive awareness and overall mindfulness together, total MAIA scores using 6 of the 8 subscales (AttnReg+SelfReg+BodyListen+Trust+EmoAware+Notice) and total FFMQ scores (AWA+OBS+NR+NJ+DSC) were tested simultaneously in a bootstrapped parallel multiple mediation model (Process Model 4) for total and specific indirect effects on main outcomes of psychological distress, anxiety and perceived stress.

For the distress outcome, the results did not reveal a specific indirect effect of MT on distress via interoceptive awareness (b= -.0413, BootSE= 1.7708, CI -4.6099, 2.6149), not supporting Hypothesis 3. Furthermore, the study did not find a specific indirect effect of MT on distress via overall mindfulness (b= 1.5269, BootSE= 1.4246, CI -.2514, 5.4523) or a total indirect effect (b= 1.4856, BootSE= 1.0197, CI -.5979, 3.4442). **Neither overall mindfulness nor interoceptive awareness functions as a unique mediator of change (for psychological distress), over and above the total mediational influence of both overall mindfulness and interoception.**

For the anxiety outcome, the results did not reveal a significant indirect effect of impact of MT on anxiety via interoceptive awareness (b= -1.2449, BootSE= 2.2834, CI -5.6195, 3.3666), not supporting Hypothesis 3. The study did find a significant indirect effect of MT on anxiety via overall mindfulness (b= 3.4161, BootSE= 1.6624, CI .0161, 6.7561). **Overall mindfulness functions as a unique mediator of change (for the anxiety outcome), over and above the mediational influence of interoceptive awareness.**

For the stress outcome, the results did not reveal a specific indirect effect of the impact of MT on stress via interoceptive awareness (b= .9208, BootSE= 1.8198, CI -2.8945, 4.3353), not supporting Hypothesis 3. The study found a specific indirect effect of MT on stress via overall mindfulness (b= 5.8011, BootSE= 1.5673, CI 3.2384, 9.4184). **The increase in overall mindfulness was a unique mediator of MT's pre to post effect on stress, even while controlling for change in interoceptive awareness.**

Contrary to hypothesis 4, overall mindfulness was found to be a unique mediator of change (for the outcomes of anxiety and stress), above and beyond the mediational influence of interoceptive awareness. For distress, neither interoception nor mindfulness emerged as mediators. Mediation summary presented in Table 7.

Table 7

*Mediation Results for Interoception vs. Mindfulness in Predicting Mental Health Outcomes**

Total Effect (MT—>Outcome)	Direct Effect (MT—>Outcome)	Hypothesis: Mediation Relationship	Indirect Effect	SE*	Confidence Interval* Lower Bound	Upper Bound	Inference
Psychological Distress							
3.925(.0003)	2.2069 (.1328)	MT—>Total global IA and MF—>Distress	1.4856	1.0197	-0.5979	3.4442	No Mediation
		MT—>global Interoceptive Awareness—>Distress	-0.0413	1.7708	-4.6099	2.6149	No Mediation
		MT—>global Mindfulness—>Distress	1.5269	1.4246	-0.2514	5.4523	No Mediation
Anxiety							
4.7005 (.0023)	2.5293 (.2621)	MT—>Total global IA and MF—>Anxiety	2.1712	1.6549	-1.4065	5.2264	No Mediation
		MT—>global Interoceptive Awareness—>Anxiety	-1.2249	2.2834	-5.6195	3.3666	No Mediation
		MT—>global Mindfulness>Anxiety	3.4161	1.6624	0.0161	6.7561	**Mediation**
Stress							
8.6692 (.0000)	1.9473 (.2758)	MT—>Total global IA and MF—>Stress	6.7219	1.9504	3.0085	10.5966	No Mediation
		MT—>global Interoceptive Awareness—>Stress	0.9208	1.8198	-2.8945	4.3353	No Mediation
		MT—>global Mindfulness—>Stress	5.8011	1.5673	3.2384	9.4184	**Mediation**

Note. * Estimated on 5,000 bootstrap samples using the SPSS PROCESS Model 4 Macro (Preacher & Hayes, 2004). Bold characters indicate unique indirect mediation effects. MT = Mindfulness Training IA= Interoceptive Awareness, MF = Mindfulness Disposition, SE = standard error; *CI = confidence interval; SD = Standard deviation; ES = Effect size (ratio of the indirect effect to the total effect).*

Discussion

This study examined the efficacy of MBSR on mental health outcomes in a non-clinical, stressed community population and the competing mediating effects, using the UFM model to analyse: 1. a Step 2 process (acceptance) against a Step 1 process (attention) (Rogge & Daks, 2021) and 2. interoceptive awareness versus overall mindfulness skills and in explaining this effect. Four hypotheses were proposed. This first hypothesis was well supported in the findings. It was expected that mindfulness training would significantly improve mental health, represented by psychological distress, generalized anxiety, perceived stress. In support of the first hypothesis, the mindfulness training group, beyond the control condition, demonstrated significant improvements across all mental health outcome measures including psychological distress, generalized anxiety, perceived stress. Further, there was clinical caseness in both anxiety and distress were reduced as a result of the mindfulness training. The findings replicated MBSR's well-documented effect on anxiety, perceived stress and psychological distress reduction (Galante et al., 2021; Gu et al., 2015; ; Shapero et al., 2018; Zollars et al., 2019; Khoury et al., 2015; Ma et al., 2018) with high effect sizes.

A second hypothesis was strongly validated in that mindfulness training was shown to significantly improve outcomes on all mediator variables. The mediator variables selected for this study were overall interoceptive awareness (MAIA: Mehling et al., 2012) and multifaceted mindfulness skills using the FFMQ (Baer et al., 2008). The FFMQ was used to measure the impact of mindfulness training on overall trait mindfulness, but also on specific facets of mindfulness, specifically acceptance and attention which were mechanisms of interest in this study. There were strong group by time interaction effects for the FFMQ facets of nonreactivity, acting with awareness, and observing, with moderate effects for nonjudging and describing MF facets. The significant improvement in observing was interesting in that there is mixed evidence in the literature as to whether observing is an internally valid facet of mindfulness (Gu et al., 2015), and it has not been found to correlate with emotional conditions, while the other facets do (Carpenter et al., 2019). Finally, it was surprising to find that nonjudging was only moderately improved by MBSR, and it is described in the literature as a strong acceptance process. An explanation may be that nonjudging takes longer to fully cultivate, and that the positive mediational effects of nonjudging as an acceptance factor would emerge with longer training than the standard MBSR, which is in line with UFM sequential mediation model (Rogge & Daks, 2021).

Hypothesis 3 was partially substantiated. Analyzing attention versus acceptance, acceptance emerged as a specific mediator of distress. This can be explained in the context of the mindfulness Unified Model of Flexibility, where a Step 2 process of flexible responsiveness (acceptance) overrides a Step 1 mindful lens process (attention) (Rogge & Daks, 2021). The acceptance mediational finding for distress can also be understood in the context of a recent paper criticizing the MAT theory of acceptance and attention mediating mindfulness-based wellbeing (Simione & Saldini, 2023). The proposition is that acceptance can independently mediate positive emotional outcomes without the influence

of attention, which was found with distress, but not for stress or anxiety. Ultimately, this study has produced some preliminary data about specific mechanisms (mainly the acceptance or decentering facet of *nonreactivity* and the attention facet of *acting with awareness*) that may indirectly and differentially facilitate change in clinical outcomes achieved by standard mindfulness training. It could be argued that the nonreactivity facet may sequentially be the initial acceptance-based skill enhanced by a standard MBP (Simione & Saldini, 2023), before strengthening of the 'nonjudging' aspect of acceptance.

For the stress outcome, both attention (Step 1) and acceptance (Step 2) were found to have unique indirect mediation pathways influencing the stress reduction via MBSR. This is supported by the large body of evidence that present moment awareness and other attentional processes improve stress. A meta-analysis and systematic review (Pascoe et al., 2017) found strong evidence for the attentional facets of mindfulness improve physiological stress markers such as cortisol, heart rate, and blood pressure. Finally for anxiety, there was a total mediation effect for Step 1 (attention) and Step 2 (acceptance), with neither specifically overriding the other. This finding was unexpected, given the body of evidence from systematic and meta-analytic reviews that non-biased attention and attentional regulation may be important therapeutic targets for anxiety (Johansenn et al., 2022).

Contrary to hypothesis 4, overall mindfulness was found to be a unique mediator of change (for the outcomes of anxiety and stress), above and beyond the mediational influence of interoceptive awareness. For distress, neither interoception nor mindfulness emerged as specific indirect mediators while for alexithymia both mediators were found to have a total indirect mediation effect on the construct of cognitive alexithymia, which is linked to emotional awareness deficits (Bermond et al., 2018). Conversely, interoceptive awareness did not emerge as a unique mediator distinguished from overall mindfulness and this study was not able to replicate the findings of Lima-Araujo et al. (2022) that overall interoceptive awareness mediated improved anxiety following brief mindfulness. The limitation of this study is that a global score of the MAIA was used, which is widely used but not recommended by the developers (Mehling et al., 2012; Vig et al., 2022). In the next chapter, an in-depth exploration of various interoception dimensions, including the mediation effects of the six MAIA subscales of interest, will be undertaken to better understand the role of interoception in the salutary effects of mindfulness therapies.

Limitations

Despite the strengths of the mediation-focused design, several limitations temper the interpretation and generalisability of the findings. First, the sample was modest and drawn from a single site, which limits statistical power and restricts generalizability to broader, more diverse populations. Second, no objective physiological measures were included in this trial, so conclusions about physiological mechanisms remain indirect and rely on self-report mediators and outcomes.

Although the mediation analyses provide insight into incremental pathways (acceptance and attention), causal inferences about the temporal sequencing of mediators are constrained by the measurement schedule and potential unmeasured confounding. Attrition and any resulting drop out may have biased estimates and reduced precision and attenuate or distort mediation effects. Multiple mediators were analyses, raising concerns about Type I error. While bootstrap confidence intervals help to mitigate this, pre-registered hypotheses and adjustments for multiple comparisons would strengthen future studies. Adherence and engagement with the mindfulness programme, as well as potential co-interventions or concurrent stressors, were not exhaustively controlled, which may influence the observed effects. Future multi-site trials with larger samples, objective biomarkers, and preregistered mediation models will be critical to corroborate and extend these results.

Due to the community research partnership and delivery with a local mental health agency, this study had resource limitations, with a maximum participant recruitment capped at 48 participants in total. Mind could only fund one highly experienced MBSR teacher to deliver two MBSR groups simultaneously (four groups total to include control group later receiving the MBSR intervention), with maximum of 12 people in each MBSR cohort. There were additional restrictions based on classroom size and the need for adequate space for chairs, yoga mats for movement and yoga exercises and other MBSR accessories.

A further limitation which needs to be acknowledged is the drawback of self-report instruments. This study mitigated the potential weakness of using a waitlist control by conducting robust multiple mediation analyses. In fact, a strong recommendation has been made by both the UK Medical Research Council (Moore et al., 2015) and the US National Institute of Health to conduct hypothesis-led mechanisms research into the intervention-specific processes that exert their therapeutic influence on public health priorities such as the prevention and risk reduction of anxiety and depression (Nielsen et al., 2018). By identifying and teasing out the differential roles of hypothesized mechanisms of mindfulness interventions, researchers and clinicians can contribute to the optimization of treatment.

Additionally, this study compared MBSR to a passive control group rather than an active or placebo condition. The selection of a waitlist group was made on the basis of resource limitation, but also to weigh the ethics of withholding a desired treatment from the general population seeking support from a community mental health service. Randomisation numerator was used to make the group allocation as unbiased as possible. The present study was limited by a small sample size which can reduce statistical power. The sample comprised of mostly women and highly educated participants, as such caution should be exercised when generalizing to a wider general population. More than half of the participants from this study presented with clinical levels of distress, anxiety and alexithymia, greater than the general population. There was a low drop-out rate in both mindfulness and waitlist control conditions, with all participants in the control group

completing the study. This points to the benefits of a waitlist control condition in community mental health settings with challenged resources and client need. The criticism of passive controls is that psychological improvements may be less attributable to the intervention and more linked to non-specific factors such as the placebo or positive bias effect related to receiving any treatment. To eliminate the potential noise affecting the current findings, future research should compare MBSR with active treatments, such as progressive relaxation or standard cognitive behaviour therapy. A relevant limitation is the lack of follow-up data for these participants. Thus, an important future direction for research is whether or how long the effects persist post MBSR.

A final limitation, again due to the complexity and constraints of a community implemented research programme is the absence of a 3-month follow-up due to the ethical requirement that the waitlist control participants receive the MBSR intervention promptly after the initial 8-week study period. Consequently, long-term durability or evolution of these mediation effects beyond the immediate post-intervention window cannot be adjudicated. A lack of 3-month follow-up data limits conclusions about the durability of these mediation effects and the long-term mechanism, but the present findings still highlight acceptance as a key proximal mechanism in real-world MBSR delivery for stressed workers. Resource constraints prevented longer-term follow-up, a common challenge in real world settings; future work should aim to extend follow-up to 6-12 months to examine the persistence or evolution of these mediation effects.

This was a real-world efficacy/evaluation study in line with the updated MRC guidance and NIH Stage III framework for ecologically valid efficacy research conducted in community-real life environment. Mind, as research partner, provided participants, clinical oversight and MBSR practitioner/teacher and supervision. In accordance with Mind's ethical requirements and their commitment to prompt access to the intervention for participants seeking stress management, longer-term follow-up (e.g., 3-month) data could not be collected for the control condition. After the initial 8-week MBSR period, control participants were offered access to the same MBSR program, and this provision precluded the feasibility of a subsequent longitudinal follow-up window within the study's time frame.

The decision was driven by ethical considerations and the partner organisation's policy to minimise delay in delivering effective support to participants, rather than by methodological limitations alone. No adverse effects were reported during the study, and Mind staff provided mental health screening and support as needed.

In the current RCT, no objective physiological measures were analysed; instead, the investigation focused on mediation processes. Using a parallel mediation framework, acceptance and attentional processes were examined as to whether they mediated the effect of the mindfulness intervention on stress reduction. The analyses revealed a unique mediation effect for acceptance on distress reduction, indicating that shifts toward nonjudgmental acceptance accounted for a portion of stress reduction beyond the direct effect of the intervention. Importantly, both acceptance and attention contributed to stress reduction in a combined, joint manner, with evidence supporting significant indirect effects for the two mediators together beyond their individual contributions. These findings suggest that the therapeutic benefits of mindfulness-based interventions for stress are carried by multiple, interlinked mechanisms, particularly acceptance-oriented processes and attentional regulation, operating in in tandem. The results underscore the value of examining multi-mediator pathways to illuminate the mechanisms of action in MBIs within an RCT framework.

The subsequent chapters will explore objective, psychophysiological measurements of interoceptive awareness and emotion regulation and whether mindfulness training will demonstrate a significant change (improvement) in these biomarkers and their correspondence to self-reported outcomes.

Conclusion

The findings may inform short-term mechanism and MBSR impact in a real-world, public health, wellbeing and prevention setting, guiding immediate implementation and refinement, but do not address longer-term maintenance of benefits.

This exploratory RCT study may offer some preliminary findings to the existing body of literature that MBSR in a community mental health programme with mixed clinical and nonclinical populations improves emotional health outcomes (distress, anxiety, stress) with a high effect size. Participants were randomized to the intervention or waitlist control groups, to decrease bias (Hariton & Lorascio, 2018). To further strengthen these findings, this study examined predicted mechanisms of change that mediate the mindfulness benefits, including acceptance, attention and a novel exploration of interoceptive awareness. Mediation analysis, particularly multiple parallel mediation, is a valuable tool for studying psychological mechanisms induced by mindfulness practices.

The MBSR programme significantly improved psychological distress, anxiety and stress as hypothesized. A more unexpected finding was the improvement of emotional awareness in alexithymia (cognitive type) in subjects with clinical alexithymia at baseline. This is an interesting result as the traditional view of alexithymia is as a fixed personality trait (Preece et al., 2024). Cognitive aspects of alexithymia involve difficulties in verbalizing and identifying feelings (Taylor & Bagby, 2013; Fonagy et al., 2002) which is linked to deficits in emotion awareness of others and empathy, connoting an externalized thinking style (Grynberg et al., 2010; Moriguchi et al., 2007). This study analyzed participants with high baseline alexithymia as evidence suggests changes via mindfulness training are evident in those with high trait alexithymia (McGillivray et al., 2017; Norman et al., 2019)

Further, there was a strong effect of ‘clinically significant improvement’ in both anxiety and distress as a result of the mindfulness training. The findings replicated MBSR’s well-documented effect on anxiety, perceived stress and psychological distress reduction (Galante et al., 2021; Gu et al., 2015; Hoffman & Gomez, 2017; Shapero et al., 2018; Zollars et al., 2019; Khoury et al., 2015; Ma et al., 2018) with high effect sizes. In addition, the mindfulness training improved mediator variables of global interoceptive awareness, overall mindfulness and its acceptance and attention subfacets. There were significant but weaker improvements on the nonjudging and describing facets of mindfulness. In selecting the acceptance and attention mediator variables, this study was guided by the strong outcomes of the nonreactivity and acting with awareness facets respectively. There is some evidence that nonreactivity may be considered a decentering, or ‘psychological distancing’ skill (Tran et al. 2014) which has been shown to be strengthened by mindfulness and serve as a core mechanism of change mediating the salutary benefits of mindfulness.

This study was informed by the United Flexibility and Mindfulness process model of wellbeing, which proposes that attention and acceptance processes sequentially mediate positive outcomes of mindfulness (Rogge & Daks, 2021). As hypothesized, acceptance was found to exert a unique mediational influence on the amelioration of psychological distress, when analyzed together with attention in a parallel mediation analysis. This was not the case for stress reduction, whereby both attention and acceptance each exerted specific mediational influences on the outcome. Finally, there was a total, rather than specific, mediational influence of attention and acceptance on anxiety reduction. Findings suggest that for the outcome of psychological distress, the attitudinal skill of **acceptance**, considered a Step 2 process of 'flexible responding to difficult experience' overrides the mediational impact of the Step 1 process of present moment **attention**, also referred to as the 'mindful lens' (Rogge & Daks, 2021). These preliminary findings indicate that acceptance is sequentially cultivated at a later stage to attentional processes and overrides attention in mediating the psychological wellbeing effects achieved by mindfulness. However, this was not the case for anxiety and stress, where neither acceptance nor attention uniquely mediated the symptom reduction. This lack of mediational specificity for anxiety is unexpected, given the body of mindfulness literature that attention and acceptance are mechanisms of change improving both the psychological (worrying) and somatic (hypervigilance) symptoms of anxiety (Ainsworth et al., 2017; Simione & Saldarini, 2023).

Strengths

Several important strengths of the present study are 1. its ecological validity with a healthy, distressed sample with mixed clinical and nonclinical features which contributes to the scarce literature on MRC/NIH effectiveness studies of standardized MBIs (Skivington et al., 2021); 2. its external validity in comparison with other RCTs investigating MBIs as the sample reflects a population that would likely participate in mindfulness training in the community; 3. its inclusion of multidimensional instruments and the assessment of interoceptive awareness as a change mechanism which is limited in the mindfulness literature; 4. its assessment of relevant mindfulness process variables to advance the literature on the transdiagnostic nature of MBSR and the differential and interrelatedness of core mechanisms involved in explaining its positive mental health effects.

Another novel area of exploration was whether interoceptive awareness, given the relevance of the body in mindfulness therapies, would exert greater mediational influence on mental health outcomes than overall mindfulness. Interoception is proposed as a core underlying mechanism of mindfulness, particularly in the neurophysiological literature, however it is poorly understood and understudied in clinical and intervention studies. Overall mindfulness was found to exert a unique mediational influence on improvements in distress and stress, but not anxiety, above and beyond the mediational influence of

interoceptive awareness. This finding points to the need for further mediation analysis of multiple specific interoceptive awareness subscales, to examine whether certain interoceptive dimensions exert their salutary mediational influences over others. The lack of mediational finding for global interoceptive awareness conflicts with the evidence from neuroscience which has found direct neuroplastic changes that mindfulness practice provokes the activation of the interoceptive brain network, namely the insular cortex (Gibson, 2019). Finally, non-specific mediational finding for anxiety was surprising, given the large body of evidence, including from this study, that mindfulness training significantly remediates anxiety conditions. As anxiety tends to show up somatically, the second study focusing in multiple interoceptive dimensions could offer insights into whether specific IA facets are more likely to mediate anxiety outcomes than mindfulness skills.

Taken together, this study yields interesting preliminary findings in the isolation of specific mechanisms of change implicated in mindfulness-induced mental health and points to the need for further investigation into differing dimensions of interoception and emotional regulation exerting their mindfulness influence on psychological wellbeing. To overcome the limitations of self-report measures, future randomized controlled trials would seek to triangulate data with behavioural and psychophysiological measures of interoception and emotion regulation. The next study/chapter will focus on different dimensions of interoception influencing mindfulness training outcomes and will examine a psychophysiological measure of interoception.

Chapter 3, Study 2

The impact of mindfulness training on psychological and psychophysiological processes of interoceptive awareness domains mediating salutary mental health outcomes

Abstract

Interoceptive awareness, with its explicit bodily attending, has been proposed as a core adaptive outcome and mechanism of mindfulness therapies and emotional wellbeing, though not well understood. This chapter explored the relationship between interoception and mindfulness training, examining psychophysiological and self-report dimensions. From the previous chapter, this study examined multiple IA subscales, particularly mind/body awareness and attention regulation, mediating psychological wellbeing produced by mindfulness.

Method: This study utilized a randomized controlled mixed 2x2 design, with subsequent multiple mediation analyses (see previous chapter). At two intervals (pre and post), participants completed a psychophysiological task (cardioception) and self-rated confidence of accuracy for a metric of metacognitive insight. Participants completed self-report measures of multidimensional interoceptive awareness and wellbeing.

Results: Mindfulness training improved metacognition, confidence and IA, including attention regulation and mind/body integration subscales. There was some improvement in interoceptive accuracy though not significant. Multiple subscale mediation analyses found IA attention regulation to exert specific indirect mediation effects on the attenuation of distress, anxiety and stress, while mind/body awareness dimension was found to be a specific indirect mediator of alexithymia.

Conclusion: Mindfulness training enhances IA represented by confidence, metacognition, and self-report yet not by accuracy, offering further validation that cardioceptive accuracy may not be a relevant psychophysiological marker implicated in mind/body therapies. In the mindfulness group, attention regulation subscale emerged as a unique mediator of mental health, while mind/body awareness mediated alexithymia. This finding offers a rationale for including specific IA dimensions within the Unified Flexibility and Mindfulness model (UFM) of sequential processes predicting the salutary benefits of mindfulness, to further investigate whether mindful and/or IA attentional processes precede mindful and/or IA attitudinal processes as overarching, interdependent emotion regulation strategies.

Introduction

Over the past decades, the modulation of interoceptive sensations has been identified as playing a significant mechanistic role in the health benefits of mind-body interventions and said to affect all aspects of human emotional, self-referential and cognitive experiences (Ceunen et al., 2016; Farb et al., 2015; Khalsa et al., 2018; Price & Hooven, 2018). Some have argued that interoception may even serve as a primary mechanism by which mindfulness practitioners experience their positive effects (Gibson, 2019; Bornemann & Singer, 2017; Mehling et al., 2012; Farb et al., 2013; 2015). This has been underpinned by seminal neuroscience frameworks proposing that interoceptive awareness (attending to the body) may be a primary mediator of mindfulness-induced emotional health, with its corresponding neuroplasticity changes and core methodology to cultivate focused and sustained attention to bodily sensations (Farb et al., 2013, 2022; Mehling et al., 2012; Weng et al., 2021). Differences in interoceptive awareness and abilities have been associated with various mental health conditions (Khalsa et al., 2018; Pollatos et al., 2009; Pollatos et al., 2007b; Quadt et al., 2018) including depression (Harshaw, 2015; Terhaar et al., 2012), anxiety (Paulus & Stein, 2006), alexithymia (Herbert & Pollatos, 2012) and anorexia (Pollatos et al., 2016). Dysfunction related to poor interoceptive capacities has also been linked to somatic issues such as hypersensitivity to pain (Simons et al., 2014), obesity and diabetes mellitus (Herbert & Pollatos, 2012). Interoception is considered a key dynamic mechanism for the development of the embodied self (Khalsa et al., 2018; Quadt et al., 2018) and self-awareness (Seth, 2013). Despite advances in interoceptive investigations, the developmental span of interoceptive modulation is understudied (Murphy et al., 2017). See Figure 3 for a representation of interoceptive information and its integration with emotions, cognitive and motivational signals from a range of cortical and subcortical regions.

Interoception broadly refers to the processing of endogenous physiological signals (Craig, 2009; Khalsa et al., 2018; Mehling et al., 2009) and can be both conscious and unconscious. Interoceptive awareness (IA) can be distinguished from other forms of interoception in that it concerns the *conscious* processing of endogenous bodily signals (Cameron, 2001; Khalsa et al., 2018; Price & Hooven, 2018). IA is thus the subjective perception of and attendance to internal bodily stimuli such as heartbeat, pain, breathing, hunger and thirst and is extended to further include the emotions, evaluations and attitudes that are associated with the internal bodily state (Khalsa et al., 2018; Mehling, 2009; 2016; Price & Hooven, 2018). To that effect, interoceptive awareness has been recognized and operationalized as a multifaceted construct (see Introduction Chapter and Garfinkel et al., 2015; Khalsa et al., 2018; Mehling et al., 2018, Mehling, 2016, for analysis of IA concepts and definitions). Interventions for interoception, such as those comprising mindfulness and contemplative approaches, have been deployed and adapted as a treatment to improve emotional processing and regulation (Aaron et al., 2020; Remmers et al., 2016). Both interoceptive ability and awareness have been proposed to be modifiable by mindfulness-based practices (Bornemann et al., 2014; de Jong et al., 2016; Ferentzi et al., 2019; Fissler et al., 2016), though there is also some evidence to the contrary when

using a cardiac accuracy measurement of interoception (Parkin et al., 2014; Khalsa et al., 2008; Treves et al., 2019).

Longitudinal intervention research into mindfulness and interoceptive awareness is limited but growing, with mindfulness-based approaches recently found to be effective in improving both bodily and emotional awareness and regulation (Norman, 2019). A major gap in the literature involves the specific mechanistic roles of interoceptive dimensions implicated in mindfulness outcomes, such as anxiety and avoidance (Lima-Araujo et al., 2022). There is recent theorizing that the positive effects of mindfulness training on wellbeing can be attributed to improving the relationship with interoceptive signals by strengthening receptivity and acceptance towards physiological sensations and eliminating experiential avoidance (Weng et al., 2021; Farb et al., 2022; Price & Hooven, 2018; Khalsa et al., 2018). Accordingly, interoception seems to be modulated by enhanced attentional focus via mindfulness exposure (Lima-Araujo et al., 2022). However divergent evidence reveals that mindfulness practice does not affect interoceptive accuracy (Khalsa et al., 2022; Parkin et al., 2014). This discrepancy may be due to differences in the operationalization and measurements of interoception which has been identified by a recent meta-analytic review by Treves et al. (2019) into the relationship between mindfulness and 'objective' interoceptive measurements. The authors thus call for future research to examine mindfulness-induced health benefits via two axes of interoceptive dimensions (Treves et al., 2019): 1. 'interoceptive accuracy' and corresponding 'interoceptive metacognition' using a psychophysiological marker such as cardiac awareness and; 2. 'interoceptive sensibility' which can be measured by self-report questionnaires such as the Multidimensional Assessment of Interoceptive Awareness scale (MAIA; Mehling, 2012).

In this chapter, the focus is specifically on interoception due to its demonstrated link to mindfulness and psychological wellbeing (Khalsa et al., 2018). To better understand the mediational role of IA and differing interoceptive outcomes enhanced by mindfulness training, this study examined multiple dimensions of interoception affected by mindfulness training. It follows on from the main RCT study, whereby global interoceptive awareness was improved by mindfulness training but not found to be a unique mediator of change above and beyond the mediational influence of overall mindfulness skills. This chapter will be categorized into two axes, exploring (1) *interoceptive awareness* measured by self-report with multiple subscales (Mehling et al., 2012; 16), which will be analyzed together in a multiple, parallel mediation analysis model and (2) *interoceptive abilities* (Garfinkel et al., 2015; Murphy et al., 2019), which will be measured using a psychophysiological measure of cardiac perception and related dimensions.

Interoception, mindfulness and wellbeing

There is growing evidence that a variety of contemplative practices such as mindfulness (Farb et al., 2007; 2013; 2015; Haase et al., 2016) enhances and improves interoceptive awareness. A growing literature suggests that interoceptive awareness is linked to mindfulness and its salutary outcomes, including subjective wellbeing (Ferentzi et al., 2019), pain attenuation (Gard et al., 2012) and reduced intensity of PTSD symptomology (Goldstein et al., 2018). Both mindfulness and IA are considered highly interrelated but contrasting mechanisms and it has been proposed that they are independently related to enhanced emotional wellbeing (Hanley et al., 2017). Some studies have revealed the clinical applicability of mindfulness training in reducing anxiety after both brief and extended exposure to mindfulness (Rodrigues et al., 2017). A brief mindfulness training was recently found to regulate psychophysiological responses typically associated with stress reactivity and emotional regulation, with objective interoceptive improvement mediating anxiety reduction (Sousa et al., 2021). Additional research into IA reveals a positive relationship between IA and emotional (Gross, 2015; Herbert & Pollatos, 2012; Dunn et al., 2010) and behavioural regulation (Herbert & Pollatos, 2014). Mindfulness training can be seen to cultivate interoceptive awareness by disengaging from thinking mode (thinking about bodily sensations) to sensing mode, or an immediate sensing of the bodily state (Farb et al., 2013; 2015; Mehling et al., 2017).

Interoception or interoceptive awareness (IA), with its sustained attention to bodily sensations, is believed to a core element of many mindfulness interventions and has been proposed as a primary mechanism by which practitioners obtain its benefits (Mehling et al., 2012; 2018; Farb et al., 2013; 2015; Holzel et al., 2011; Weng et al., 2021). Mindfulness and other forms of meditation have been shown to modulate the insula, which is the primary hub for interoception (Wen et al., 2021). In fact, it can be argued that the benefits of mindfulness can be described more accurately as the result of changes in neuroplasticity of the insula (Sharp et al., 2018) and surrounding neural circuits. These neural signatures are known to promote attentional and interoceptive capacities (see Chapter 1 for an overview of neurobiological evidence related to mindfulness and interoception; Gibson, 2019). Evidence suggests that the interoceptive cortex, including the insula, is responsible for additional functions beyond interoception including attention, awareness, and all subjective experiences, much of which has been linked to the mindfulness literature (Tang et al., 2015; Vig et al., 2022; Holzel et al., 2011; Schuman-Olivier et al., 2022).

A theory explaining the therapeutic effects of mindfulness training on wellbeing is that mindfulness enables a less avoidant and more willing stance toward unwanted internal (bodily) experience, thereby cultivating an adaptive relationship to interoceptive stimuli (Farb et al., 2022; Khalsa et al., 2018; Price & Hooven, 2018; Weng et al., 2021). Several authors have theorized that awareness of bodily information promotes the reduction of psychological distress (de Jong et al., 2016; Farb et al., 2015; Michalak et al., 2012). Farb and colleagues (2015) propose that endogenous bodily signals, and the emotional

signatures associated with them, can be managed by deploying different strategies. These strategies include efforts to control or change the sensation which corresponds to traditional psychological accounts of emotion regulation (distraction, reappraisal, and suppression) (Gross, 2002) or a contrasting strategy of modifying the attitudinal stance towards difficult sensations (Chambers et al., 2009; Desrosiers et al., 2014; Guendelman et al., 2017; Wheeler et al., 2017). This latter strategy is associated with contemplative and mindfulness accounts of regulation and involves concepts of acceptance, equanimity and noninterference (Farb et al., 2012; Feldman et al., 2007). By training practitioners to pay attention to their bodily signals within a stance of openness, acceptance and curiosity, mindfulness-based interventions (MBIs) may ultimately cultivate and promote an adaptive style of interoceptive awareness (Kabat-Zinn, 2013). IA is an essential element of the exercises taught in MBIs, which involve paying attention to the body at rest (e.g., body scan and breathing meditation) and in movement (e.g., yoga and mindful walking).

Interoception and alexithymia has been found to be linked in adults (Murphy et al., 2018; Trevisan et al., 2019). Additionally, interoception is related to emotion regulation which has been inversely associated with alexithymia (Brewer et al., 2016; Ernst et al., 2014; Herbert et al., 2011; Trevisan et al., 2019). A meta-analysis by Trevisan et al. (2019) demonstrated that alexithymia correlates with multiple subfacets of IA. The researchers observed that the strength of this relationship differed according to which interoceptive subscale was examined (Trevisan et al., 2019). Lower scores on the *noticing* and *emotional awareness* scales of the MAIA related to higher alexithymia symptoms. Mindfulness-based approaches may be promising for the reduction of alexithymia which had previously been considered a stable personality trait (Norman et al., 2019) due to its effectiveness in improving bodily and emotional awareness which is recognized as lacking in alexithymia (Trevisan et al., 2019). In fact, researchers propose that alexithymia essentially represents a core deficit in interoceptive accuracy (Herbert & Pollatos, 2012; Herbert et al., 2011; Bird et al., 2010), which has been evidenced by some studies but not by others (Trevisan et al., 2019). Differences in the relationship between alexithymia and IA may be due to mixed findings around the use of interoceptive accuracy measurements such as heartbeat perception (Zamariola et al., 2018).

There are only a few existing studies assessing the impact of MF training on IA and its mediational influence on psychological wellbeing and symptom reduction. De Jong and colleagues (2016) found that the beneficial outcomes of mindfulness training on depression were mediated by interoceptive awareness (measured by the MAIA) (Mehling et al., 2012), particularly non distracting from aversive bodily signals. Another study found that mindfulness training reduced depressive symptomology, which was mediated by a sequential process whereby increased IA was linked to a decentering capacity (Fissler et al., 2016), defined as an ability to step back from one's immediate emotional and cognitive activity and disidentifying from them (King & Fresco, 2019). Nevertheless, IA was not a unique mediating influence on symptom reduction (Fissler et al., 2016).

Subjective interoceptive awareness

In a recent review, Perez-Pena et al. (2022) found only four RCTs that examined the effects of mindfulness training on interoceptive awareness and its corresponding subfacets. It appears that only one study to date has used a longitudinal intervention design to examine specific interoceptive awareness variables and their mechanistic influences on psychological wellbeing (de Jong et al., 2016), with most of the literature relying on cross sectional investigations (Perez-Pena et al., 2022). A small number of longitudinal RCT studies have explored the positive effects of mindfulness interventions on self-reported interoceptive awareness (Fissler et al., 2016; Bornemann et al., 2015).

Interoception offers key insights into how the body and mind affect one another and has become a research interest in the fields of neuroscience, psychosomatic and psychiatric medicine, and psychology (Craig, 2003, 2008; Khalsa & Lapidus, 2016). Multidimensional constructs have been proposed whereby interoception is consciously experienced and amenable to change via training and regulation of psychological processes such as attention, affect and intention (Khalsa et al., 2017; Mehling et al., 2012). Mehling and colleagues (2012; 2016; 2018) identified a gap in the mindfulness literature for a body awareness instrument that could be used in intervention research and clinical settings. Mehling et al. (2009) analyzed the psychometric properties of key body awareness measures and found they lacked systematic development (Body Perception Questionnaire; Porges, 1993), did not reliably measure change via intervention (Body Responsiveness Questionnaire; Daubenmier, 2005), and did not encompass the attention styles and regulatory aspects of interoception (Body Awareness Questionnaire; Shields et al., 1989). Mehling and colleagues advanced a model of interoceptive awareness that is multidimensional and is measurable via self-report (Mehling et al., 2012).

The MAIA questionnaire comprises eight independent, though interrelated subscales, one of which is *noticing* physiological stimuli such as breath or heartbeat and is most aligned with models capturing interoceptive accuracy (Garfinkel et al., 2015) or attention (Murphy et al., 2019). The remaining subscales involve attentional and regulatory elements of bodily awareness, namely how felt sensations of the body can be deployed to regulate stress and attention and are intertwined with subjective emotional states that can be influenced by the degree to which the body is experienced as trustworthy and safe, used for insight and comfort (Mehling, 2017). The different attentional styles captured by the MAIA include: 1. maladaptive orientation associated with anxiety, hypervigilance and somatic amplification; 2. adaptive attentional orientation associated with mind/body therapies, acceptance, self-awareness and self-regulation (Bornemann et al., 2014; Mehling, 2016). As previously mentioned, bodily cues can influence psychological states at both conscious and unconscious levels. Conscious interoceptive awareness, whereby internal bodily experiences become available to explicit awareness, has been associated with beneficial impact on thoughts, feelings, behaviour and overall embodied experience (Cameron, 2001; Craig, 2009; Dunn et al., 2007; Guendelman et al., 2007). See Table 8 for a representation of the MAIA subscales and questions.

Table 8

*Interoceptive Awareness Subscales**

MAIA Subscale	Example Question
Attention Regulation	I can refocus my attention from thinking to sensing my body.
Body Trusting	I trust my body sensations.
Body Listening	I listen for information from my body about my emotional state.
Self-Regulation	When I bring awareness to my body, it brings a sense of calm.

Note. *Multidimensional Assessment of Interoceptive Awareness (MAIA: Mehling et al., 2012) to represent UFM's Step 1 process (attention regulation) and Step 2 processes (body listening, trusting and self-regulation).

The interoception literature has found some evidence for the claim that mindfulness practices improve self-reported interoceptive awareness as measured by the MAIA (Mehling et al., 2016; Perez-Pena et al., 2022). Several RCTs have demonstrated improvement in IA via mindfulness training in subjects with chronic pain and comorbid depression (de Jong et al., 2016) and depression (Fissler et al., 2016). Perez-Pena et al. (2022) suggest that this is promising evidence of the salutary effects of mindfulness training on self-reported interoceptive awareness, however they caution that these are preliminary findings, with underpowered studies that require replication. Notwithstanding, a non-randomized trial was found to significantly improve IA in a nonclinical population using a bodily focused mindfulness intervention, with particularly strong effects on the regulatory subscales of the MAIA (Bornemann et al., 2014). The relevant subscales are (1) self-regulation, involving regulating one's distress by attending to body sensations, (2) attention regulation, or regulating attention to and from body sensations, and (3) body listening, or listening to the body for important data and insights (Bornemann et al., 2014). Self-regulation has been revealed to be the interoceptive awareness dimension that changed the most with body-focused meditation training in healthy adults (Bornemann et al., 2014). Self-Regulation is similar to the concept of acceptance (Mehling et al., 2017) and may cooperate with nonreactivity to reduce stress arousal.

There is a consensus that the subjective element of IA is influenced by top-down cognitive processes such as memories, expectations, attitudes, and context (Mehling et al., 2012; Bornemann et al., 2015; Farb et al., 2015). The Multidimensional Assessment of Interoceptive Awareness (MAIA: Mehling et al., 2012) was developed to provide clarity on the construct of interoceptive (bodily) awareness and to be able to differentiate between adaptive and maladaptive aspects of subjective bodily focus. An inverse relationship has been found between higher interoceptive awareness, measured by the MAIA, and lower trait anxiety (Mehling et al., 2012), providing evidence that the MAIA constructs do not target anxiety-oriented hypervigilance and somatic amplification associated with maladaptive somatic and psychological disorders (Micheli et al., 2022; Mehling, 2016). On the contrary, Mehling et al., (2016) found that the attentional style toward bodily sensations as defined by the MAIA, particularly the regulatory subscales, is negatively correlated with anxiety. Conversely, there is evidence that higher anxiety is associated with greater interoceptive accuracy as measured by a cardioceptive task (Mallorquí-Bagué et al., 2014).

Ferentzi et al., (2019) assert that wellbeing depends more on subjective interpretation of interoceptive sensations and that interoceptive accuracy may not coincide with either a positive or negative impact on psychological wellbeing. Mehling (2016) identified an association between emotional vulnerability and interoceptive awareness, with vulnerable subjects commonly reporting more distress, worry about bodily sensations, and a heightened sense of bodily discomfort. In certain anxious or somatically vigilant populations, interoceptive enhancement without corresponding capacity to use bodily awareness to regulation one's emotional experience may intensify anxiety (Micheli et al.,

2022). Micheli and colleagues (2022) suggest that the mechanisms of mindfulness training are associated with effective emotional regulation, and that mindfulness is promising for individuals with somatic complaints. The authors argue that a deficit in emotional awareness and an overuse of maladaptive strategies of emotion regulation are core psychopathological features of 'somatic symptom disorder' (Micheli et al., 2022).

Interoception involves dual awareness of the body's physiological state, including attending to and regulating internal bodily signals, (Farb et al., 2015; Garfinkel & Critchley, 2016) and the simultaneous cognitive activity and emotions associated with said awareness (Craig, 2009; Farb et al., 2015; Mehling, 2016). Interoceptive awareness has been referred to as representing top-down perceptions (Cameron, 2001; Craig, 2009; Mehling et al., 2012) providing moment-by-moment emotional and cognitive representation of the body's endogenous state (Craig, 2009; Khalsa et al., 2019). The original version of the MAIA questionnaire (Mehling et al., 2012) comprises thirty-two items on eight scales, conceptually organized in five dimensions: (1) Awareness of body sensations (Noticing scale), (2) emotional reaction and attentional response to sensations (Not-Distracting and Not-Worrying scales), (3) capacity to regulate attention (Attention Regulation scale), (4) awareness of mind-body integration (Emotional Awareness, Self-Regulation, and Body Listening scales), and (5) trusting body sensations (Trusting scale). Interoceptive awareness as conceptualized within the MAIA is comparable has been conflated with the notion of interoceptive sensibility as proposed by Garfinkel et al. (2015) despite the sensibility construct typically defined as measured by self-rated confidence of one's ability to accurately detect internal signals such as heartbeats (Murphy et al., 2020). The MAIA has been used for clinical research into disordered eating (Brown et al., 2017), PTSD (Mehling et al., 2017), chronic pain (de Jong et al., 2016), depression (Fissler et al., 2016), and alexithymia (Muir et al., 2017; Zamariola et al., 2018). There is growing evidence that the MAIA can discern between a receptive versus anxiety-driven attentional style of interoception. The receptive style is considered adaptive, and it facilitates the processing of interoceptive sensations to regulate emotional experience more effectively (Maccharinho et al., 2018).

The developers of the MAIA do not recommend summing the subscales into a global score for use in clinical research, despite it being commonly used as a unidimensional score (Hanley et al., 2017). Yet in a recent study evaluating the psychometric properties of the MAIA questionnaire on a large sample, researchers uncovered a single MAIA 'g-factor' comprising six of the eight subscales (noticing, attention regulation, emotional awareness, self-regulation, body listening and trusting) (Ferentzi et al., 2020). The outlying two subscales, not distracting and not worrying, were found to strongly correlate with negative emotions. This development calls into question the claims of multidimensionality within the MAIA construct. It can be argued that this validates the adaptive versus maladaptive dialectic that is commonly referred to in the research literature (Farb et al., 2015), rather than multiple independent interoceptive factors (Ferentzi et al., 2020). Longitudinal studies have found that different MAIA subscales change according to differing research targets and identify the regulatory dimensions of the MAIA as most modifiable by mindfulness and

mind/body therapies (Bornemann et al., 2015; Mehling, 2016). Jones and colleagues (2021) recommend that researchers select and omit specific MAIA subscales according to their research hypothesis and questions (Jones et al., 2021).

Other researchers distinguish between interoceptive awareness and attention (Murphy et al., 2019), with attention involving the 'pure' detection and primary perception of interoceptive signals (Vig et al., 2021). Vig and colleagues (2021) differentiate between the IA construct, captured by the MAIA, and an 'interoceptive attention' construct. They argue for a narrow conceptualization of interoceptive 'sensibility', coined by Garfinkel and colleagues (2015), where only the 'noticing' subscale of the MAIA appears to represent 'sensibility' (Vig et al., 2021). According to Bogaerts et al. (2022), it is important to distinguish between the 'sensory-perceptual' aversus emotive components of a bodily or physiologic signal. The 'sensory-perceptual' conceptualization promotes the use of neutral language to describe an interoceptive sensation, while the emotive interoceptive concept can be described using language related to emotional valence or the aversive, negative connotations of sensory experience (Bogaerts et al., 2022). A new multidimensional questionnaire of interoceptive attention has been developed to address this discrepancy in the interoception taxonomy and to move away from the psychological, emotional connotation of the MAIA. This new self-report instrument is called the Interoceptive Sensitivity and Attention Questionnaire (Bogaerts et al., 2022) and is explicitly contrasted from the MAIA with its nonemotive focus on bodily sensations. To add further complexity to the debate on the operationalization of interoception, the one MAIA subscale that has been identified as closely related to non-emotive interoceptive attention or appraisal of interoception abilities, 'noticing', has also been found more recently to positively correlate with emotion regulation (Mehling et al., 2012; Schuette et al., 2021; Zamariola et al., 2019).

It can be posited that mindfulness and contemplative practices might affect limited or specific interoceptive dimensions measured by the MAIA (Mehling et al., 2012). One study found no discernible effects on the MAIA noticing scale after three months of body-based training, with significant effects found on the self-regulation and attention regulation scales (Bornemann et al., 2015). Attributed to prolonged interoceptive training, consisting of mindfulness practices such as the body scan and breath meditations, participants were able to better manage stress, regulate negative emotions and facilitate greater insight via their bodily states. Two more studies investigating the impact of body-focused mindfulness interventions found similar MAIA subscale findings (de Jong et al., 2016; Fissler et al., 2016). The quantitative findings are validated by participant feedback related to their experience of mindfulness-based training (Schure et al., 2014; Gibson, 2019; Paulus & Stein, 2010). Regarding the construct of interoceptive awareness, sensory abilities are not sufficient to capture the construct, with interoceptive sensory experience intertwined with a larger cognitive and emotional system (Mehling et al., 2018). Indeed, MAIA scores are often lower in people with chronic illnesses (Locatelli et al., 2023).

The self-report literature is supported by neuroscience evidence of increased insula activation, the neural signature representing interoceptive functioning (Khalsa et al., 2018; Young et al., 2018; Craig, 2003). The insula activation was present in meditation naive subjects from the general population after a standardized mindfulness intervention (Farb et al., 2007) and in more experienced meditators (Grant et al., 2010). A recent meta-analytic and systematic review validates these findings by highlighting that the insular cortex is the neural region most consistently activated by both interoceptive and mindfulness states and activity (Casals-Gutierrez & Abbey, 2020). On the other hand, studies assessing objective dimensions of interoception such as interoceptive detection and accuracy have found weak or no associations between mindfulness and interoceptive accuracy and detection (Khalsa et al., 2020; Treves et al., 2019).

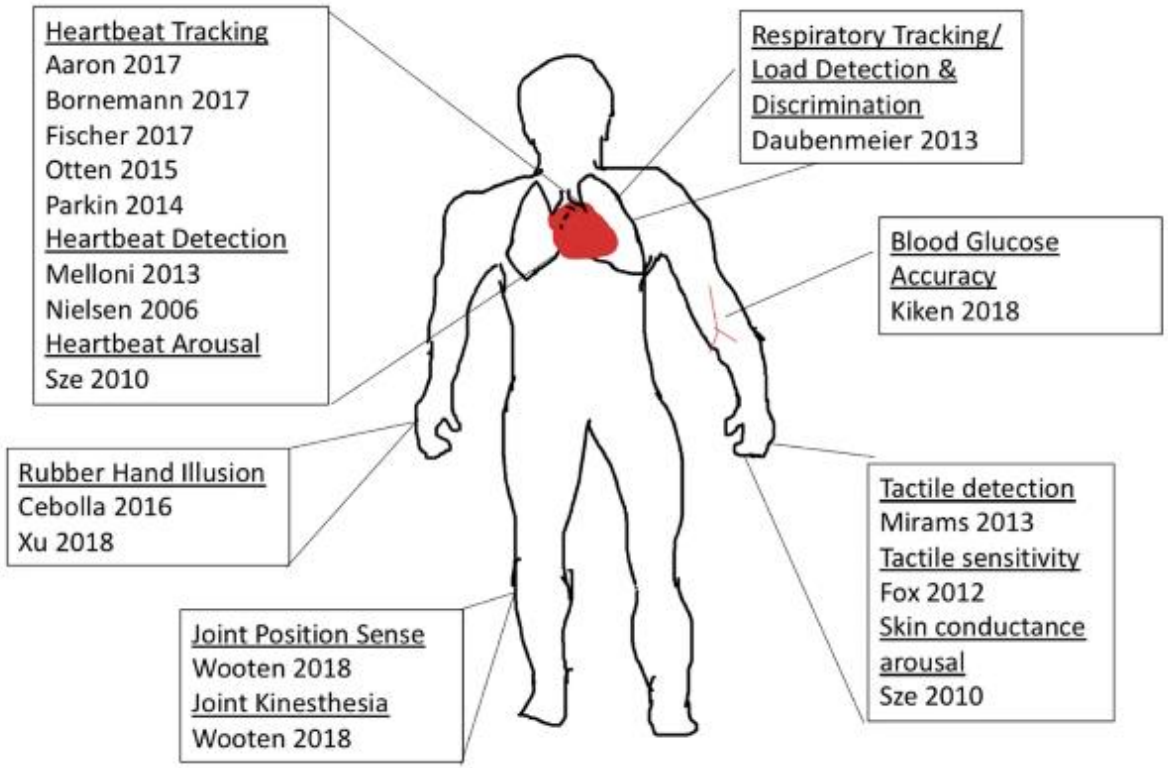
Psychophysiological Interoception

Research examining mindfulness and body awareness is still emergent, with only one meta-analysis so far examining the relationship between mindfulness and psychophysiological interoception (Treves et al., 2019). Despite the proposed mechanistic role of interoception, findings from studies directly examining the association between mindfulness and 'objective' measures of interoception have been mixed (Britton et al., 2022; Khalsa et al., 2020; Treves et al., 2019). This is the case for studies examining dispositional mindfulness (Parkin et al., 2014), the intervention effects of mindfulness training (Bornemann et al., 2017) and the association between mindfulness experience and induction (the intensity and degree of mindfulness practice) and psychophysiological measures of body awareness (Sze et al., 2010).

There is an ongoing debate as to how to define and measure interoception, both subjectively and 'objectively', and particularly how best to measure interoceptive changes induced by mindfulness-based practices (Locatelli et al., 2023). In the neurobiological literature, interoception is conceptualized as a complex body-mind interaction and experimental studies are typically designed to measure 'objective' or implicit outcomes from a range of interoceptive tasks. Given the role of interoception in regulating physiological homeostasis, in emotional and attentional regulation (Craig, 2008) as well as the integrity of the bodily self (Tsakiris & Critchley, 2016), clinical research and therapeutic interventions remain limited by conceptual and methodological discrepancies and there is a clear need for valid measures of interoceptive dimensions to evolve the science (Duquette, 2017). See Figure 15 for a graphical representation of 'objective' body awareness measurements and their approximate bodily locations.

Figure 15

Objective Measures of Body Awareness Mapped onto Body



Note. Biomarkers of body awareness and their approximate locations from a review by Treves et al. (2019).

Two axes of interoceptive awareness have been identified, *accuracy* and *sensibility*, encompassing multiple dimensions of interoception and corresponding measurements. These axes are seen to be valuable in promoting greater understanding of psychopathology (Barrett et al., 2004; Paulus et al., 2013; Mehling et al., 2016). Interoceptive accuracy, or sensitivity, is the common 'objective' method of investigation interoception. Poor interoceptive ability or accuracy can be a metric that connotes a range of somatic and emotional impairments (Trevisan et al., 2021; Brewer et al., 2016), including alexithymia which is associated with low interoceptive awareness and accuracy (Murphy et al., 2018; Herbert et al., 2011). Conversely, high thresholds of interoceptive accuracy can be indicative of psychopathology and wellbeing. Individuals with somatic anxiety may exhibit high interoceptive accuracy due to their hypervigilance (Dunn et al., 2010), while simultaneously experiencing maladaptive interoceptive subjective experience (sensibility) such as a pattern of catastrophizing physiological discomfort and pain (Paulus et al., 2013). The capacity to accurately detect interoceptive cues is thought to be critical in facilitating the experience of subjective emotional states (Herbert & Pollatos, 2012; Damasio, 2003).

Several authors have attempted to incorporate varying dimensions of interoception into a common classification (Cali et al, 2015; Garfinkel et al., 2016; Garfinkel et al., 2015; Khalsa et al., 2018; Mehling, 2016). The three-dimensional model of interoception introduced by Garfinkel and colleagues (2015) includes: 1. 'objective' interoceptive sensitivity (accuracy), 2. self-reported interoceptive sensibility (confidence) and 3. interoceptive insight, operationalised as metric of 'metacognition' (correspondence between interoceptive accuracy and confidence about accuracy). Murphy and colleagues (2019) extended the model to differentiate between interoceptive accuracy and attention, each of which can be assessed using either self-reported or more objective methods. Despite attempts at convergence, the terminology remains debated and the discussion about language and construct continues (Suksasilp & Garfinkel, 2022; Farb et al., 2015; Quadt et al., 2018; Garfinkel et al., 2016; Khalsa & Lapidus, 2016; Murphy et al., 2019). To avoid confusion about the 'interoceptive sensibility' domain of Garfinkel et al.'s (2015) three-dimensional model, an additional dimension is often specified to include validated measurements of interoceptive awareness such as the Multidimensional Assessment of Interoceptive Awareness (MAIA) (Mehling et al., 2012). See Figure 16 a graphical representation of the three dimensions of interoception (Garfinkel et al., 2015; Locatelli et al., 2023).

Figure 16

*Three-Dimensional Model of Interoception**

Note. Garfinkel and colleagues (2015) developed a three-dimensional model of interoception that proposes both objective and subjective definitions and measurements (Garfinkel et al., 2015; Locatelli et al., 2023)

Murphy and colleagues (2019) have defined interoceptive accuracy as equating the precise and accurate monitoring of bodily sensations and cues (Murphy et al., 2019). Heartbeat detection tasks are believed to be reliable, valid and quantitative measures of measures of interoceptive accuracy (Whitehead & Drescher, 1980; Schandry, 1981), in which the participants are instructed to focus on perception of their heartbeats without feeling for a pulse. Proponents of the heartbeat counting task suggest that the rationale to use heartbeat detection over other methods is it relatively easy to measure and is not resource intensive. Moreover, heartbeat counting is considered a reflection of a general sensitivity to visceral and endogenous signals (Bogaerts et al, 2008), and is said to be more easily perceived than other visceral processes (Kollenbaum et al., 1996). Higher objective interoceptive accuracy, via the heartbeat counting task, has been shown to facilitate effective downregulation of negative emotions (Füstös et al., 2013; Kever et al., 2015; Pollatos et al., 2015). However, this outcome is not consistently found in research designs using larger samples and self-report measures of emotion regulation (Schuette et al., 2021; Zamariola et al., 2019).

Though cardioception has recently been questioned as a valid biomarker of interoception (Brener & Ring, 2016; Lima-Araujo et al., 2022), the heartbeat tracking task remains a common method to objectively measure interoception or more precisely, accuracy (Critchley et al., 2004; Dunn et al., 2007; Fustos et al., 2012; Bornemann et al., 2015; Fischer et al., 2017). In fact, a recent meta-analysis found that heartbeat tasks were included in nine of the seventeen studies (Treves et al., 2019) There are other physiological tests said to measure interoception such as the water load test based on the sensation of gastrointestinal signals (Herbert et al., 2012) and the respiratory mask, muscular effort task and taste tasks, all affected by interoceptive deficits in alexithymia (Murphy et al., 2018). Nevertheless, the utility of the HCT has been questioned due to the ability of participants to estimate their heartbeats even sensations are not perceived (Desmedt et al., 2020). Interestingly, when participants are explicitly instructed to not estimate their heartbeats but to identify felt signals, accuracy reduced by fifty percent (Desmedt et al., 2018). The idea that heartbeat detection serves as an indicator of general interoceptive ability to sense bodily signals remains unclear (Herbert et al., 2012; Ferentzi et al., 2019).

Other studies propose that heartbeat perception tasks are less susceptible than self-report measurements to response set biases which has been routinely highlighted as a limitation in the mindfulness literature (Grossman, 2019). Schandry's (1987) heartbeat tracking task is conducted in a laboratory where participants are instructed to estimate how many times their heart beats over various time intervals. Simultaneously, their actual heart rate is measured using a tracking device, which allows for a comparison of estimated versus actual heartbeat information. An index of interoceptive accuracy is derived from the ratio of these values. Previous mindfulness research has found that interoceptive accuracy may

not readily improve by training (Borneman & Singer, 2017), whereas other styles of interoception such as attention may be cultivated by paying attention to the breath (Roemer et al., 2015). Interoceptive attention is acknowledged as a potentially useful therapeutic target for improving emotion regulation and wellbeing (Murphy et al., 2019), however it is understudied compared to interoceptive accuracy. Although interoceptive attention is likely a useful target for interventions aiming to improve emotion regulation ability and mental health, it has been less examined in this context compared to interoceptive accuracy.

Fisher et al. (2017) found evidence for interoceptive accuracy enhancement after a mindfulness training programme, with no corresponding improvements to self-reported sensibility. More recently, Lima-Araujo and colleagues (2022) found no improvement in interoceptive accuracy in a mindfulness training group or in an active control group, in line with studies indicating that neither mediation nor mindfulness practice is linked to improved accuracy (Khalsa et al., 2020; Parkin et al., 2014). Importantly, studies have shown that accuracy is negatively associated with mental wellbeing, whereas wellbeing is positively associated with subjective interoceptive awareness (Paulus & Stein, 2010; Ferentzi et al., 2019). Bornemann & Singer (2017) highlight that most studies that are unable to demonstrate improvements in heartbeat perception utilize cross-sectional designs with a small sample size. García-Cordero et al., (2016) report evidence from neuroimaging studies that improved accuracy via interoceptive training results in neuroplastic changes. Additionally, García-Cordero and colleagues (2017) found that when participants focused on exteroceptive stimuli rather than interoceptive cues, their heartbeat counting accuracy improved. The researchers propose that interoception and exteroception may deploy different neural actions, with exteroception being less neurologically demanding than interoception which requires an internal focus and attention that may be involve more cognitive load. Adding to the complexity, the somatosensory cortex tends to be included as part of the interoceptive brain network and is involved in processing external stimuli (Farb et al., 2007; 2013).

Interestingly, even in studies that specifically aim to assess interoceptive attention (Avery et al., 2015; Stern et al., 2017; Ferentzi et al., 2018), attentional capacity is rarely investigated. Measures of interoceptive accuracy tend to require endogenous, i.e., top-down attention. In everyday life, however, exogenous attention focusing on homeostatically relevant signals is at work. This is mainly because signals coming from the environment are usually more significant from an evolutionary perspective (Adam, 1998). This striking difference between the very nature of the measures of interoceptive accuracy and how interoceptive signals are generally processed in everyday life somewhat undermines the validity of the common measures of interoceptive accuracy, like the heartbeat counting task (Feruglio et al., 2021). Yet Vig and colleagues (2021) have not found a relationship between sustained attention and somatosensory amplification, interoceptive confidence/metacognition and mindfulness. Due to lack of consensus and

clarity, this study has chosen to include both the heartbeat counting and the sustained attention tasks to measure endogenous and exogenous forms of attention.

Interoceptive Metacognition

Studies have indicated that the objective measure of interoceptive accuracy does not easily correspond with self-report measures of interoceptive awareness measured by the MAIA (Ferentzi et al., 2018). Garfinkel and colleagues (2015) defined a third dimension of interoception to include 'metacognitive insight' of interoceptive accuracy, operationalised using a metric derived from the difference between self-rated confidence in one's interoceptive accuracy and the accuracy score (Rominger & Schwerdtfeger, 2024; Garfinkel et al., 2016; Suksasilp & Garfinkel, 2022). This metacognitive dimension has been criticized by Mehling and colleagues (2018) for lacking the capacity to capture the depth of one's lived experience (Mehling et al., 2018).
Nevertheless, Garfinkel and colleagues (2015) found that interoceptive metacognition (IMC) was improved by mindfulness practice and disposition (Khalsa et al., 2008; Parkin et al., 2014). IMC is characterized by greater confidence in one's cardiac detection abilities (Borg et al., 2018; Cali et al., 2015; DiLernia et al., 2016; Garfinkel et al., 2015; Murphy et al., 2019). Interoceptive metacognition (IMC) is considered essential to the non-causal predictive accuracy of interoceptive perception. Inaccurate, overestimation of the frequency of heartbeats can lead to emotionally-arousing interpretations that something frightening or exciting is occurring, whereas if there is insight that one's perception of heartbeats may be exaggerated, this is hypothesized as potentiating contributing to a lessening of fear and anxiety (Rominger & Schwerdtfeger, 2024). This theory aligns with a study by Garfinkel et al., (2016b) that found an inverse relationship between IMC and anxiety. There is evidence that individual differences in interoceptive accuracy capacities can vary greatly, and that low trait IMC is common (Garfinkel et al., 2015).

IMC can be summarized as accurately knowing when we are perceiving internal signals better or worse (Locatelli et al., 2022). As such IMC may be a useful metric for clinical research and health conditions (Khalsa et al., 2018; Nord & Garfinkel, 2022). It has been suggested that people whose confidence rating correlates with their interoceptive accuracy in either direction can more effectively monitor their actual interoceptive performance, indicating IMC abilities (Locatelli et al., 2022). IMC remains an understudied measurement despite its potential utility in clinical investigations of somatic conditions (Locatelli et al., 2023; Suksasilp & Garfinkel, 2022; Garfinkel et al., 2016; Rominger et al., 2021, Torregrossa et al., 2022). Locatelli and colleagues (2023) doubt the interrelatedness of the three subdimensions of objective and subjective interoception put forward by Garfinkel and colleagues (2015). Locatelli et al., (2023) found little evidence on how the three subdimensions of interoception interrelate and found only one study (Garfinkel et al., 2015) that investigated the three dimensions together. That study suggested that interoceptive accuracy and confidence were both positively associated with high clinical symptoms, while interoceptive metacognitive awareness was associated with reduced symptomology.

Locatelli et al. (2023) recommend that future studies investigating the association between interoceptive functioning and wellbeing should explore at least two of dimensions.

This study

There is growing evidence that mindfulness and other mind/body contemplative practices enhance interoceptive awareness capacities (Farb et al., 2007; 2013; 2015; Haase et al., 2016). Indeed, mindfulness and interoception are purported to be conceptually intertwined (Hanley et al., 2017). Despite the importance of bodily awareness to the mindfulness literature, there is ongoing disagreement about definition and measurement methods in assessing mindfulness-induced interoceptive changes (Locatelli et al., 2023). Considering how challenging it is to measure a multi-faceted construct like IA and taking into account the lack of association between self-report and objective measures of IA found in the literature (Garfinkel et al., 2015), this study will examine self-report, as well as accuracy, confidence and metacognitive ability.

Following on from the first study where global interoceptive awareness was not found to exert a unique mediational influence on wellbeing beyond overall mindfulness, this second study explored multiple IA subscales to examine their mediational effects on wellbeing. To date, only a limited number of studies have explored the positive effects of mindfulness-based interventions on self-reported IA (Fissler et al., 2016; Bornemann et al., 2015). In a recent review, Perez-Pena et al. (2022) found only four RCTs examining the effects of mindfulness training on IA subscales. It appears that only one study to date has used a longitudinal intervention design to examine specific interoceptive awareness variables and their mechanistic influences on psychological wellbeing (de Jong et al., 2016).

The hypotheses of this second study, exploring dimensions of interoceptive awareness, were that (1) mindfulness training would improve a psychophysiological measure of interoceptive sensitivity and related domains of confidence and metacognition; (2) MT would also improve IA subscales, particularly from the regulatory domains: self-regulation, body listening, emotional awareness and attention regulation; (3) specific IA subscales from mind/body awareness and attention dimensions will exert differential mediational influences on anxiety, distress, stress and alexithymia and (4) attention regulation will emerge as a unique mediator of change in distress, anxiety, stress and alexithymia when compared with more attitudinal regulatory dimensions of mind/body awareness. This hypothesis is in line with the UFM process model of mindfulness-induced psychological wellbeing, whereby attentional processes are proposed to be strengthened first before the strengthening of the attitudinal components (Rogge & Daks, 2021).

Method

Participants, research design and analyses

This longitudinal study used a randomised controlled trial (RCT) design with a repeated measures 2x2 factorial design. All participants from mindfulness and control conditions engaged in a 2-hour lab session before and after the 8-week period of the mindfulness based programme. See Chapter 1 for participant information and summary of main mixed RM ANOVAs (within and between groups) and bootstrapped multiple mediation analyses.

Procedure

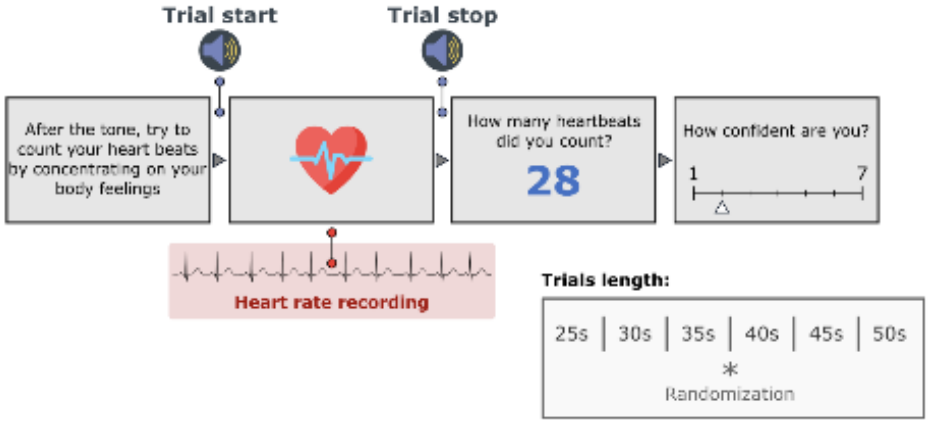
Heartbeat Tracking Task (Interoceptive Accuracy)

The heartbeat tracking task is a psychophysiological measure used to determine interoceptive accuracy (Schandry, 1981). In a lab, participants were instructed to look at the fixation cross on the monitor in front of them and count their heartbeats, without feeling their pulse, when the cross turned from red to green for four randomly intermixed intervals of 20, 35, 45 and 100 s. At the end of each interval, participants were asked to state the number of heartbeats counted. They were also asked about their confidence in their accuracy (see confidence description below). The heartbeat counting task was programmed in E-Prime 2 software. Participants' heart rate was recorded throughout the task with ADInstruments 247 PowerLab System (ML845) including a Bioelectrical signal amplifier (ML408 with 248 MLA2540 and MLA2505 5-lead shielded Bio Amp cables). Self-adhesive electrodes were attached to participants' abdomen, and a ground electrode to the elbow. LabChart 7 (v.7.3.1. 250 1994-2004; www.adiinstruments.com) was used to record and analyze the ECG signal from which heart rate (i.e. R-peaks) was derived. A trigger was sent from E-prime to the ECG trace to demarcate the onset and offset of each trial. Participants were given the following instructions: 'Without manually checking, can you silently count each heartbeat you feel in your body from the time you see the green cross and a beeping sound" to when you hear "stop"'. This task was repeated four times to form four trials, using time-windows of 15, 25, 35, and 45s, presented in randomized order. The HCT score was calculated by comparing the number of reported heartbeats with the number of actual heartbeats and then averaging the score of the three intervals. The following formula was used for each interval: (1−(|HRrecorded − HRcounted|)/HRrecorded).

See Figure 17 for a visual representation of the heartbeat counting task measuring interoceptive accuracy (Schandry, 1981; Garfinkel et al., 2015).

Figure 17

*Cardioception as an Objective Measure of Interoceptive Accuracy**



Note. * The heartbeat tracking task is a psychophysiological measure used to determine interoceptive accuracy (Schandry, 1981)

Confidence Rating of Interoceptive Accuracy

A subjective self-rating on participants' confidence related to their interoceptive accuracy derived from the mean confidence during the heartbeat tracking task (i.e. averaged over experimental trials to produce a global measure of mean confidence).

At the end of each trial (N = 4 for heartbeat tracking), participants immediately rated their confidence in their perceived accuracy of response. This confidence judgement was made using paper/pencil marked on a continuous visual analogue scale (VAS) that was 10 cm long. One end was marked "Total guess/No heartbeat awareness" while the other end was labelled "Complete confidence/Full perception ofheartbeat".

Interoceptive Metacognition

Interoceptive metacognition (IMC) was calculated according Rominger et al. (2022) who calculated the correspondence between confidence ratings and performance measure (i.e., IAcc). All interoceptive accuracy and confidence ratings were z-standardized within each participant for both pre and post time intervals. Then, a formula from Schraw (2009) was applied to assess the correspondence between the confidence rating and the IAcc, as a measure of *relative* correspondence *(IMC = (zCR - zIAcc*)^2*(−1)). A measurement of mean confidence-accuracy)

Mental Health Outcomes Measures

See Chapter 1 for descriptions of GHQ-12 (distress); GAD7 (anxiety); PSS (stress); BVAQ (alexithymia cognitive type).

Mediation Measure

Interoceptive Awareness (Mehling et al., 2012): see Chapter 1. The MAIA is a commonly used self-report questionnaire in interoception and clinical research. The eight scales for MAIA are scored as separate scales. Results from previous psychometric analyses indicate that creating a summary score over all the eight scales is inferior to keeping the scales separate (Mehling et al., 2012; Vig et al., 2022). Additional analysis of the MAIA psychometric properties uncovered a unidimensional factor, termed the MAIA 'g-score', consisting of six of the eight subscales. Depending on the research question, researchers are free to select scales that are expected a priori to be relevant for their research questions and may choose to drop scales less relevant to their a priori hypotheses and research questions (Jones et al., 2020). Most of the scales from the original MAIA have shown good reliability. In the original MAIA version, both scales Not-Distracting and Not-Worrying showed lower internal consistency (α = .66, α = .67, respectively), as confirmed in other cross-cultural adaptations (Abbasi et al., 2015; Bornemann et al., 2014; Cali et al., 2015; Lin et al., 2017; Valenzuela-Moguillansky et al., 2015).

Longitudinal data have shown that the MAIA scales change differentially. For example, the regulatory dimensions of interoceptive awareness can be expected to change the most in studies of mind-body interventions (Bornemann et al., 2015; Mehling, 2016). Researchers have found that six of the MAIA scales could be clustered into an overall Regulatory Awareness function (Hanley et al., 2017; Bornemann et al., 2015) and further the six MAIA scales identified in the regulatory awareness cluster were also found to be the MAIA scales longitudinally impacted by a mindfulness-based intervention (Bornemann et al., 2015). For this study we will focus on the regulatory awareness subscales of self-regulation, emotional awareness and body listening (representing awareness of mind/body integration) and the sub scales of attention regulation.

Results

Main Outcome Effects (within and between groups)

All within-subjects and between-groups effects were analyzed using a 2x3 mixed design repeated measures ANOVA, with a within factor of time (pre, mid and post) and a between factor of group (mindfulness and control) on the interoception outcomes (IAcc, IConf, IMC), mental health outcomes (see Chapter 1, with additional analysis of alexithymia subscales) and secondary mediator outcomes (analysis of specific IA subscales). A conservative estimate of degrees of freedom were corrected using greenhouse-geisser for violations to assumptions of sphericity. Follow on posthoc testing used bonferroni adjusted pairwise comparisons for group differences at pre, mid and post. As suggested by Field (2009), the correct degrees of freedom will be reported in the findings, rather than the rounded figure. **See Table 9 for a summary of means, standard deviations, main group by time outcome effects and posthoc group differences for all of the study variables.**

Table 9

*Main Interoception Outcomes Effects****

Variable	Time	Group		Results
		Mindfulness	Control	
Psychophysiological Outcome				
Cardiac Accuracy	Pre	.47 (.23)	.46 (.27)	
	Post	.55 (.22)	.42 (.25)	Main group x time interaction : *F(1.00,36.00) =2.08, p=.158, ηp² =.06** Between groups differences at pre, *p=.918* and post *p=.104***
Confidence	Pre	33.63 (24.70)	48.02 (26.77)	
	Post	53.41 (18.41)	48.73 (26.16)	Main group x time interaction effects: *F(1.00,36.00) =7.79, p= .008 np²=.18** Between groups differences at pre *p=.097* and post *p=.537***
Metacognition	Pre	33.17 (24.59)	47.57 (26.66)	
	Post	52.86 (18.33)	48.30 (26.08)	Main group x time interaction effects: *F(1.00,36.00) =7.74, p= .009, np²=.18** Between groups differences at pre *p=.095* and post *p=.547***
Self Report Interoception Outcome				
g Interoceptive Awareness	Pre	62.59 (22.59)	59.95 (16.44)	
	Post	94.24 (16.43)	64.27 (19.01)	Main group x time interaction effects: *F(1.82,67.34) = 25.06, p=.<001 np²=.40** Between groups differences at pre *p=.676* and post *p<.001***
IA - Self Regulation	Pre	7.82 (4.61)	8.95 (3.58	
	Post	14.41 (2.81)	10.09 (4.02)	Main group x time interaction effects: *F(1.94,71.82) = 17.90, p=<.001 np²=.33** Between groups differences at pre *p=.394* and post *p<.001***
IA - Trusting	Pre	6.76 (4.05)	6.95 (3.15)	
	Post	11.12 (2.39)	7.14 (3.26)	Main group x time interaction effects: *F(1.90, 70.46) = 13.37, p=<.001 np²=.27** Between groups differences at pre *p=.870* and post *p<.001***
IA - Attention Regulation	Pre	13.76 (7.30)	11.55 (5.75)	
	Post	23.18 (4.33)	13.68 (6.09)	Main group x time interaction effects: *F(1.96, 72.54) = 10.09, p=<.001 np²=.21** Between groups differences at pre *p=.295* and post *p<.001***
IA - Body Listening	Pre	5.29 (3.84)	5.50 (3.00)	
	Post	10.12 (2.91)	5.95 (3.80)	Main group x time interaction effects: *F(1.82, 67.25) = 13.90, p=<.001 np²=.27** Between groups differences at pre *p=.852* and post *p<.001***
IA - Noticing	Pre	12.76 (3.65	12.27 (2.73)	
	Post	15.24 (2.73)	11.73 (3.13)	Main group x time interaction effects: *F(1.81, 66.80) = 4.98, p=.012 np²=.12** Between groups differences at pre *p=.633* and post *p<.001***
IA - Emotion Awareness	Pre	16.18 (4.76)	14.73 (3.87)	
	Post	20.18 (3.40)	15.68 (4.32)	Main group x time interaction effects: *F(1.96, 72.44) = 4.48, p=.015, np²=.11** Between groups differences at pre *p=301* and post *p=.001***

Note. *partial eta squared for effect size (ηp²) and greenhouse geisser applied; **bonferroni adjusted, *****Means, SDs, Main Group by Time Interaction Effects and Simple Effects of Group Difference Across Time (Pre and Post Intervention)*

Main Mental Health Outcomes

See Chapter 1 for distress, anxiety, stress and alexithymia outcomes

H1: Psychophysiological Interoception

Psychophysiological Interoceptive Accuracy (IAcc)

For IAcc, there were no significant effects of time *(F(1.00, 36.00) = .39, p =.537 ηp² =.01)* or group *(F(1,36) = .99, p = .326, ηp² =.03)*, or group by time interaction *(F(1.00,36.00) = 2.08, p= .158 ηp² =.06)*. In addition, there was no significant group difference at pre *(p=.918)* or post *(p=.104)*.

Interoceptive Confidence Rating (IConf (of IAcc))

For IConf, there was a significant effect of time, *(F(1.00, 36.00) = 8.98, p =.005 ηp² =.20)* and no significant group effects *(F(1,36) = .45, p =.506, ηp² =.01)*. There was a significant group by time main interaction effects *(F(1.00,36.00) = 7.79, p=.008, ηp² =.18)*. There were no significant group difference at pre *(p=.097)* or post *(p=.537)*.

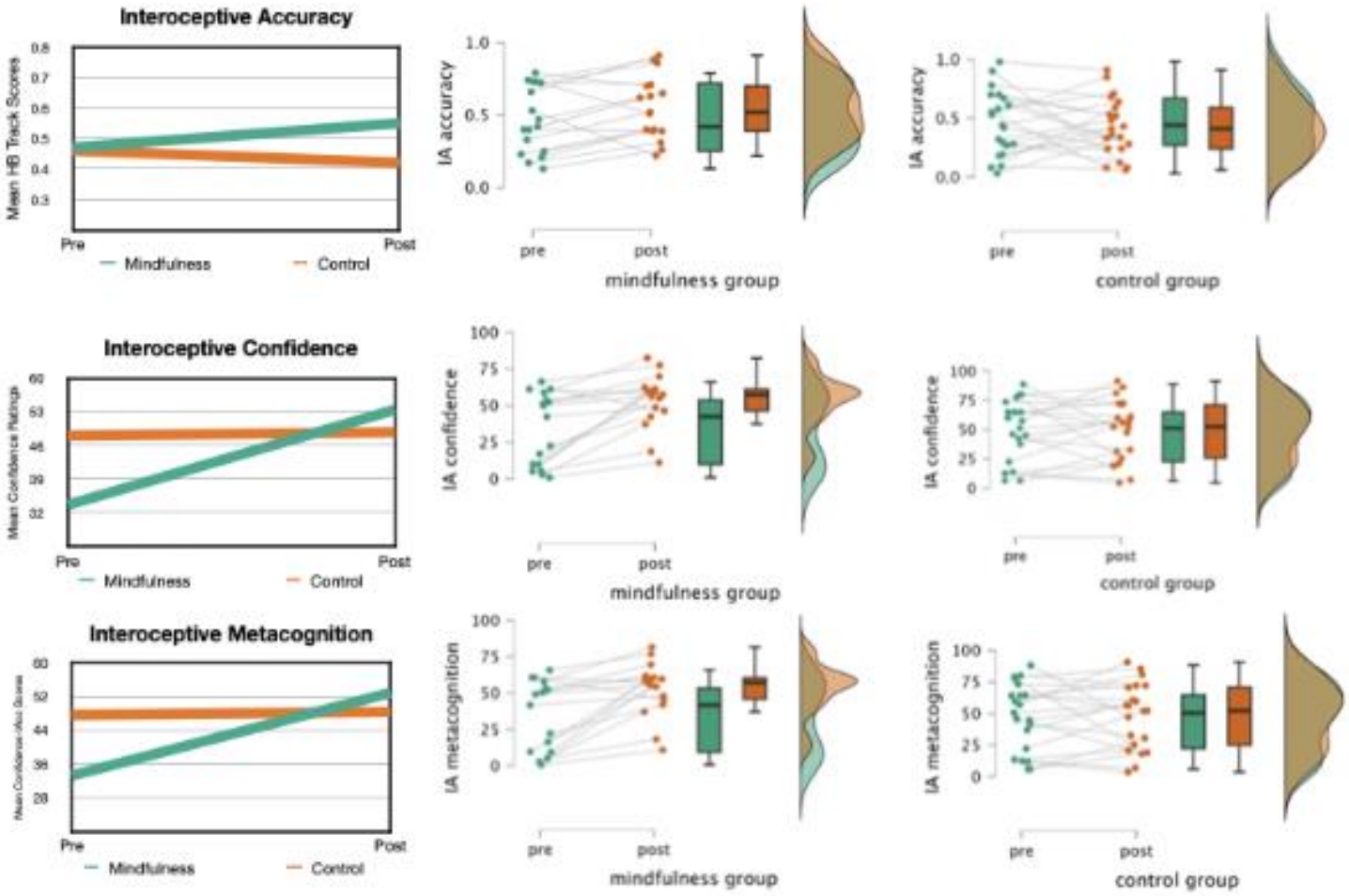
Interoceptive Metacognition (IMC=IConf-IAcc)

There was a significant effect of time, *(F(1.00, 36.00) = 8.99, p =.005, ηp² =.20)* but no significant group effect *(F(1,36) = .47, p =.498, ηp² =.01)*. There was a significant group by time main interaction effect *(F(1.00, 36.00) = 7.74, p=.009, ηp² =.18)*. There was no significant group difference at pre *(p=.095)* or post *(p=.547)*.

The mindfulness training group did not significantly improve on the psychophysiological measure of interoception (IAcc) or related confidence rating, above the control group. However in a raincloud plot, the mindfulness group showed a trend towards improvement over the control group. However the mindfulness group did improve over the control group on interoceptive metacognition. See Figure 18 for main group by time interaction effects for physiological interoceptive accuracy and related dimensions.

Figure 18

*Main Outcome Effects for Physiological Measurement and Related Dimensions**



Note. *mean and individual changes in interoceptive accuracy, confidence and metacognition between groups (mindfulness and control) at two time points (pre and post). Raincloud plots of individual participant level change, by group.

H3: Main Mediator Subscale Outcomes (IA)

global IA

There were significant effects of time, *(F(1.82, 67.34) = 43.40, p <.001 ηp² =.54)*, and group, *(F(1,37) = 10.16, p = .003, ηp² =.22).* The mindfulness group demonstrated significant group by time main interaction effects *(F(1.82, 67.34) = 25.06, p< .001 ηp² =.40)*. There were no significant group difference at pre *(p=.676)*, however there was a group difference at post *(p <.001)*.

Self-Regulation Subscale

There were significant effects of time, *(F(1.94, 71.82) = 32.39, p <.001 ηp² =.47)* and group, *(F(1,37) = 4.12, p = .050, ηp² =.10)*. The mindfulness group demonstrated significant group by time main interaction effects *(F(1.94, 71.82) = 17.90, p< .001 ηp² =.33)*. There was no significant group difference at pre *(p= .394)*. There was a group difference at post *(p<.001)*.

Trusting Subscale

There was a significant effect of time, *(F(1.90, 70.46) = 16.65, p=<.001 ηp² =.31)* but not group, *(F(1,37) = 3.87, p =.057, ηp² =.10)*. The mindfulness group demonstrated significant group by time main interaction effects *(F(1.90, 70.46) = 13.37, p=<.001 ηp² =.27)*. There was no significant group difference at pre *(p=.870)*. There was a group difference at post *(p<.001)*.

Attention Regulation Subscale

There were significant effects of time, *(F(1.96, 72.54) = 25.79, p=<.001 ηp² =.41)* and group, *(F(1,37) = 11.70, p =.002, ηp² =.24)*. The mindfulness group demonstrated significant group by time main interaction effects *(F(1.96, 72.54) = 10.09, p=<.001 ηp² =.21)*. There was no group difference at pre (*p=.295)*, however there was a significant group difference at post *(p<.001)*.

Body Listening Subscale

There were significant effects of time, *(F(1.82, 67.25) = 19.27, p=<.001 ηp² =.34)* and group, *(F(1,37) = 5.17, p =.029, ηp² =.12)*, qualified by significant group by time main interaction effect *(F(1.82, 67.25) = 13.90, p=<.001 ηp² =.27)*. There was no significant group difference at pre (p=.852), with a significant group difference at post *(p<.001)*.

Noticing Subscale

There was no significant effect of time, *(F(1.81, 66.80) = 1.85, p=.168, ηp² =.05)* however there was a significant effect of group *(F(1,37) = 6.97, p =.012, ηp² =.16)*. The mindfulness group demonstrated significant group by time main interaction effects *(F(1.81, 66.80) = 4.98, p=.012, ηp² =.12)*. There was no group difference at pre *(p=.633)*, but there was a group difference at post *(p<.001)*.

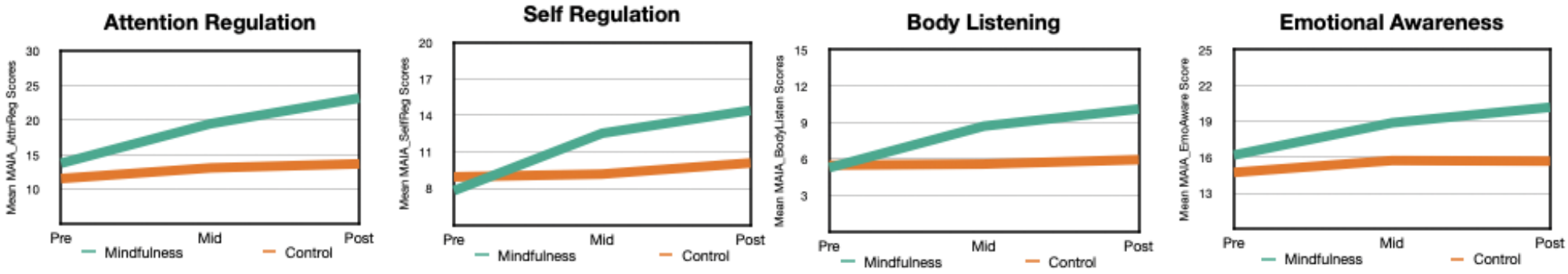
Emotional Awareness Subscale

There was a significant effect of time *(F(1.96, 72.44) = 12.77, p<.001 ηp² =.26)* and group *(F(1,37) = 6.53, p =.015, ηp² =.15)*. The mindfulness group demonstrated significant group by time main interaction effects *(F(1.96, 72.44) = 4.48, p=.015, ηp² =.11)*. There was no significant group difference at pre (*p=.301*) but there was a group difference at post (*p=.001*).

As hypothesized, the mindfulness condition (above the control condition) demonstrated significant improvements in the mediator variables (all IA subscales). For follow on multiple mediation analysis, the grouped variables will be organized by IA 'cluster': regulatory (attention regulation, self-regulation, trusting) and awareness cluster (emotion awareness, noticing, body listening). This is in line with the literature demonstrating differential and interrelated roles of attentional and attitudinal (regulatory) mechanisms implicated in mindfulness-induced emotional regulation and wellbeing (references). See Figure 19 for graphs of main interaction effects of IA subscales of attention regulation, self regulation, body listening and emotional awareness.

Figure 19

Main Outcome Effects for Interoceptive Subscales



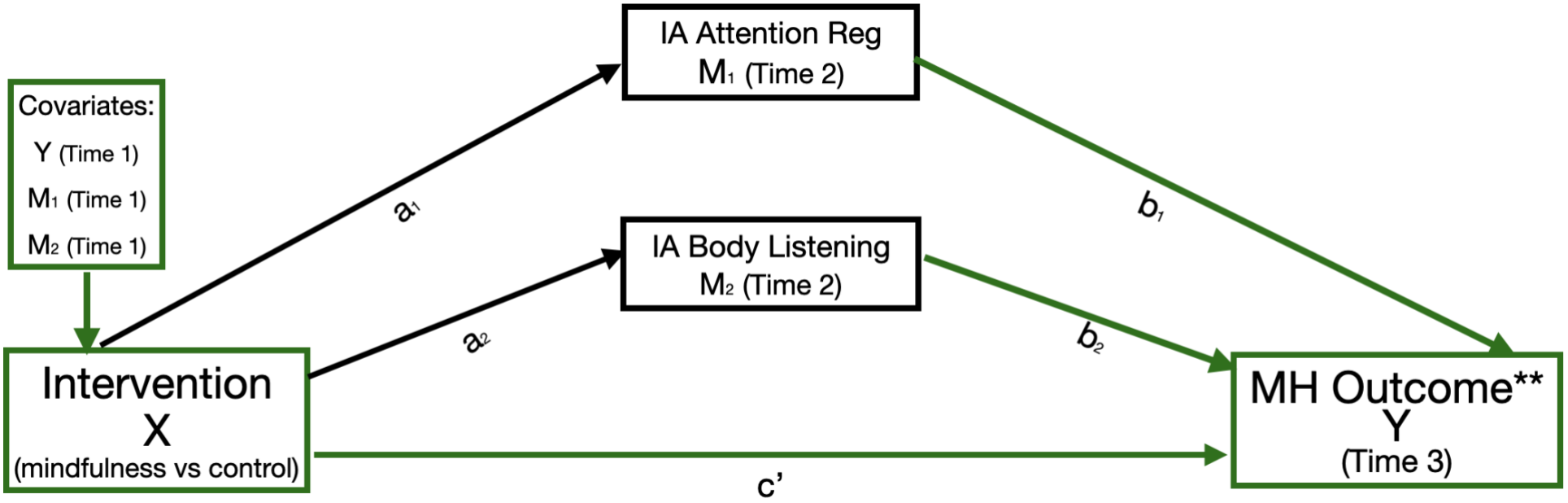
Note. main group by time interaction effects of MBSR by group (mindfulness and control) and time (pre, mid and post) on interoceptive awareness subscales

Multiple Mediation Effects

This study conducted two separate parallel multiple mediation analyses using PROCESS model 4 is SPSS (Preacher & Hayes, 2008). A defining feature of parallel multiple mediation analyses is that none of the mediating variables are modelled as influencing another mediator in model 4. This facilitates the estimation of a simultaneous testing of more than one mediator variable, while controlling for the shared variance between the different mediators (Goodall et al., 2020). The first analysis tested which of 4 interoceptive awareness subscales uniquely mediated the relationship between the exposure group (mindfulness intervention versus waitlist control) and individual mental health outcomes of psychological distress, generalized anxiety, perceived stress and cognitive alexithymia. The second subscale analysis tested the mediational influences of two cluster subscales representing ‘mind/body awareness’ and ‘attention regulation’ on mental health outcomes. See Figure 20 for a conceptual diagramme of the multi-mediator model of interoceptive awareness subscales.

Figure 20

*Parallel Multi-Mediation Model of Step 1 and Step 2 Interoceptive Processes**



Note. * bootstrapped parallel mediation, controlling for Time 1 (covariates), 95% confidence interval. Step 1 and Step 2 interoceptive processes are informed by the UFM mediation model (Rogge & Daks, 2021). **anxiety, distress, stress and alexithymia

H3: Multiple Interoceptive Subscale Mediation

To analyze IA subscales together, the 4 subscales corresponding to 2 core IA domains (mind/body awareness and attention regulation) were selected for multiple mediation analysis. These 4 IA subscales (self regulation, body listening, emotional awareness and attention regulation) were tested simultaneously in a bootstrapped subfacet multiple mediation model (Process Model 4) for total and specific indirect effects on the main outcomes of psychological distress, anxiety, stress and alexithymia. **See Table 3.3 for multiple subscale mediation summary.**

For the distress outcome, there were (ie., unique) indirect effects of the impact of MT on distress via *emotional awareness (b= -1.6062, BootSE= .8261, CI -3.5725, -.2997)* and *attention regulation (b= 3.4294, BootSE= 1.6842, CI .3180, 7.0441).* There were no specific indirect effect of mindfulness training on distress via body listening *(b= .7839, BootSE= 1.0195, CI -.6517, 3.4486)*, self regulation *(b= -.6540, BootSE= 1.3724, CI -4.3919, .7400)* or a total indirect effect *(b= 1.9531, BootSE= 1.4618, CI -1.5142,4.4088)*. **Attention regulation functions as unique mediators of change (for amelioration of distress), over and above the mediational influences of self regulation and body listening. Emotional awareness functions as an inverse mediator of psychological distress reduction.**

For perceived stress outcome, there was a specific indirect effect of *attention regulation (b= 8.0734, BootSE= 2.9783, CI 3.2056, 14.8380)*. In addition, there was a total indirect effect of the impact of MT on stress via all 4 IA subscales *(b= 7.5793, BootSE= 2.3198, CI 3.9039, 13.1342).* There were no specific indirect effects of mindfulness training on stress via body listening *(.1206, BootSE= 1.5820, CI -3.5036, 2.9301), emotional awareness (b= .4711, BootSE= 1.2862, CI -1.5933, 3.5385)* or self regulation *(b= -1.8508, BootSE= 1.7695, CI -5.3880, 1.9518).* **Attention regulation functions as a unique mediator of change (for the stress outcome), over and above the total mediational influences of self regulation, body listening or emotional awareness. There was a total mediation effect of all 4 IA subscales on stress reduction.**

For the anxiety outcome, there were no specific or total indirect effects of attention regulation *(b= 3.1860, BootSE= 3.1137, CI -2.2541, 10.1566)*, body listening *(b= -.0227, BootSE= 1.9168, CI -4.2109 3.4955), emotional awareness (b= -.3740, BootSE= 1.4007, CI -3.0864, 2.7014)* or self regulation *(b= .0052, BootSE= 2.1487, CI -5.8321, 2.8178).* There was no total indirect effect of the impact of MT on anxiety via all 4 IA subscales *(b= 2.745, BootSE= 2.4385, CI -2.2084, 7.5920).* **Interoceptive awareness dimensions, measured by the MAIA, do not function as mediators of mindfulness-induced anxiety attenuation.**

For alexithymia, there was a specific indirect effect of emotional awareness *(b= 2.0453, BootSE= 1.3050, CI .2909, 5.4076)*. There were no specific indirect effects of body listening *(b= 2.0239, BootSE= 1.5748, CI -1.4039, 4.9774), attention regulation (b= -*

1.5406,BootSE= 2.4555, CI -6.2086, 3.4835) or self regulation *(b= .4319, BootSE= 1.3354, CI -1.3940, 3.9832).* There was no total indirect effect of the impact of MT on alexithymia via all 4 IA subscales *(b= 2.9604, BootSE= 2.1640, CI -.9029, 7.7687).*

A Step 1 interoceptive process (attention regulation) demonstrates as a unique mediational influence via mindfulness training on improvements in anxiety and stress, beyond the mediational influence of Step 2 (body listening). Step 2 (body listening) functions as a unique mediational influence on improvements in alexithymic symptoms via mindfulness training, over and above the mediational influence of attention regulation. See Table 10 for parallel multi-mediation results for Step 1 (attention regulation) and Step 2 (body listening) interoceptive processes informed by the UFM model (Rogge & Daks, 2021).

Table 10

*Mediation Results for Step 1 and Step 2 Interoceptive Processes***

Total Effect (MT—>Outcome)	Direct Effect (MT—>Outcome)	Hypothesis: Mediation Relationship	Indirect Effect	SE*	Confidence Interval* Lower Bound	Confidence Interval* Upper Bound	Inference
Anxiety							
4.2826 (.0000)	1.1068 (.6114)	MT—>Total IA attention reg and IA body listen—>Anxiety	3.1758	2.0374	-0.6011	7.5309	
		MT—>IA attention regulation—>Anxiety	4.1785	2.0914	8.477	9.1828	**Mediation**
		MT—>IA body listening—>Anxiety	-1.0027	1.5792	-4.7725	1.4748	No Mediation
Distress							
2.7682 (.0019)	1.0456 (.4362)	MT—>Total IA attention reg and IA body listen—>Distress	1.7226	1.1494	-0.3016	4.2368	
		MT—>IA attention regulation—>Distress	2.2347	1.3807	-0.1831	5.3214	No Mediation
		MT—>IA body listening—>Distress	-0.5121	0.7527	-1.9858	1.0112	No Mediation
Stress							
8.2872 (.0000)	1.5052 (.4523)	MT—>Total IA attention reg and IA body listen—>Stress	6.2820	1.9670	3.1719	10.8931	
		MT—>IA attention regulation—>Stress	6.6791	2.1765	3.3573	12.0280	**Mediation**
		MT—>IA body listening—>Stress	-0.3970	1.3067	-3.3058	1.8894	No Mediation
Alexithymia							
7.5483 (.0000)	3.8207 (.1827)	MT—>Total IA attention reg and IA body listen—>Alexithymia	3.7276	2.6938	-1.8918	8.9406	
		MT—>IA attention regulation—>Alexithymia	-1.8431	2.2545	-7.0959	1.9724	No Mediation
		MT—>IA body listening—>Alexithymia	5.5707	2.1365	1.8810	10.1964	**Mediation**

*Note.***Step1 and Step2 processes are from the adapted UFM mediational model (Rogge & Daks, 2021)* * Estimated on 5,000 bootstrap samples using the SPSS PROCESS Model 4 Macro (Preacher & Hayes, 2004). Bold characters indicate unique indirect mediation effects. MT = Mindfulness Training IA= Interoceptive Awareness MF = Mindfulness Disposition SE = standard error; CI = confidence interval; SD = Standard deviation; ES = Effect size (ratio of the indirect effect to the total effect

Discussion

Interoceptive awareness has long been proposed as a core adaptive outcome and mechanism of mindfulness therapies and emotional wellbeing, particularly in the neuroscience literature (Gibson, 2019), however its mechanisms of action not well understood in the clinical and intervention research literatures (Khalsa et al., 2018; de Jong et al., 2016). In fact, there are few studies investigating the impact of mindfulness-based interventions on interoception awareness (Bornemann et al., 2016; Perez-Pena et al., 2022) and even less exploring the mediating influence of IA on mindfulness wellbeing outcomes (Tran et al., 2014). Regarding relevant biomarkers of interoception that can be enhanced by mindfulness training, there is conflicting evidence of the use of a psychophysiological marker to measure IA (Lima-Araujo et al., 2022). To address the gaps in the literature, this study explored the impact of mindfulness training on multiple dimensions of interoception including psychophysiological and self-report dimensions. Due to the lack of unique mediational influence of global interoceptive awareness compared with overall mindfulness on mental health outcomes, this study explored multiple interceptive dimensions, analyzing multiple MAIA subscales and their mediational roles. Four hypotheses were proposed.

The first hypothesis was that mindfulness training would improve a widely used psychophysiological measure of attentional accuracy as well as related domains of confidence and metacognition. This hypothesis was partially supported. A general improvement was found in interoceptive accuracy though not significant. In examining individual participant data (see Figure 18 for raincloud plot (Allen et al., 2021) for visualisation of individual interoceptive accuracy), there is a trend of improvement but with no uniformity. This suggests that greater effects may be found with larger samples and longer intervention exposure. There may also be useful indication that heartbeat accuracy and anxiety may may not be affected by mindfulness to the degree that was previously thought (Quadt et al., 2018). The insignificant relationship detected between mindfulness training and accuracy scores could represent the face that mindfulness does not favour any particular sensation or stimuli and can include perception and focus on internal and external cues as well as thoughts and feelings. Further, mindfulness practices do not involve any particular emphasis on the sensations associated with one's heartbeat and may instead change more distal processes associated with using heartbeat perception to appraise one's general arousal (Treves et al., 2019).

While IA accuracy demonstrated nonsignificant improvement, clear improvements were shown in the mindfulness group in interoceptive confidence and metacognitive insight about heartbeat detection abilities. IMC showed particularly strong effect, and again points to the change in how one attends to and relates to internal experience that appears to be strengthened by mindfulness practice. This is an interesting finding and calls into question the interrelatedness of the three subdimensions of objective and subjective interoception put forward by Garfinkel and colleagues (Garfinkel et al., 2015). In fact, Locatelli et al., (2023) most recently found little evidence on how the three subdimensions of interoception

interrelate. There seems to be considerable dissociation between perceived and actual body-related events (Ferentzi et al., 2017; 2019).

The second hypothesis was that mindfulness training would improve all relevant MAIA subscales, particularly from the regulatory domains including self-regulation, body listening, emotional awareness and attention regulation. This hypothesis was fully validated, with strong outcome effects found on these MAIA subscales. Bornemann et al. (2016) also found particularly strong effects were found for the regulatory strategies of interoceptive awareness: (1) regulating distress by attending to body sensations (self-regulation), (2) regulating attention to and from bodily sensations (attention regulation) and (3) listening to the body for important information (body listening). The strong MAIA outcome findings coincide with earlier meta-analysis and review studies (Hilton et al., 2019) that reported significant IA results after the practice of meditation.

The third hypothesis focused on change mechanisms and their relative mediational influences on mental health, hypothesizing that differing IA subscales from mind/body awareness and attention dimensions would exert different mediational influences on anxiety, distress, stress and alexithymia. This was mainly supported by parallel multiple mediation analyses where the mind/body awareness dimension of IA emerged as a unique mediator of alexithymia, and attention regulation emerged as a powerful unique mediator of mindfulness-induced amelioration of distress, stress and anxiety. Finally a fourth hypothesis was validated, finding that attention regulation emerged as a unique mediator of change in distress, anxiety, stress and alexithymia when compared with the combined attitudinal regulatory dimensions of mind/body awareness. This hypothesis is in line with the UFM process model of mindfulness-induced psychological wellbeing, whereby the attentional processes are proposed to be strengthened first before the strengthening of the attitudinal components (Rogge & Daks, 2021).

Conclusion

There is growing evidence that mindfulness and other mind/body contemplative practices enhance interoceptive awareness capacities (Farb et al., 2007; 2013; 2015; Haase et al., 2016). Indeed, mindfulness and interoception are purported to be conceptually intertwined (Hanley et al., 2017). IA, with its explicit attention to bodily data, has long been proposed as a primary adaptive product and mechanism of mindfulness training that is differentiated from core mindfulness mechanisms captured by the FFMQ such as attention and acceptance. The MAIA developers recognized a gap in mindfulness measurement tools, around the primacy of the body for regulatory and mood-enhancing capacities (Mehling et al., 2012). The FFMQ measurement lacks bodily specificity, apart from the observing facet that encompasses attention to both exogenous and endogenous stimuli (Baer et al., 2006). The mediation findings for the global MAIA and subfacet analyses were weaker than expected. Nevertheless, drilling down into multiple MAIA subscales revealed the significant role that IA attention regulation plays in mediating mental health benefits. It appears that

attentional abilities such as being able to focus, sustain, redirect and allow attention to rest on bodily cues exerts a unique mediational influence and is a skill that is actively enhanced by mindfulness. In support of this, Lima-Araujo (2022) reviewed the mindfulness and interoception literature and concluded that interoception seems to be modulated by enhanced attentional focus via mindfulness exposure (Lima-Araujo et al., 2022). Though longitudinal intervention research into mindfulness and IA is limited, there is some evidence of similar mindfulness-induced improvement in MAIA regulatory scales such as attention regulation, self-regulation of distress and using the body for insight (body listening) (Bornemann et al., 2015), which supports this study's findings.

A second mediational finding in this study was the role of the mind/body integration cluster (self-regulation, body listening and emotional awareness) in mediating the reduction in alexithymic symptoms associated with emotional awareness impairments (ie., the identifying and analyzing subscales of the BVAQ). This strengthens the proposition that alexithymia is essentially a transdiagnostic marker of poor interoception and emotion regulation functioning. These tentative mediational findings offer a theoretical correspondence to the previous RCT study whereby the 'what' skills of attention and the 'how' skills of acceptance may act as emotion regulation strategies that produce beneficial health outcomes. It also offers preliminary evidence that the dual regulatory and awareness components of interoceptive awareness (attention regulation/emotional awareness) exert their mediating influence differently on various measures of emotional wellbeing. In addition, these finding offer a theoretical correspondence to the Unified Flexibility of Mindfulness model (UFM), whereby Step 1 attention processes (IA attention regulation and emotional awareness) are strengthened prior to enhancing Step 2 acceptance processes (accepting, flexible) as interrelated emotion regulation strategies.

Concerning the measurement of 'objective' interoceptive accuracy, this study's findings contribute to the growing body of evidence that cardioception may not be a relevant psychophysiological marker implicated in mind/body therapies (Treves et al., 2019; Zamariola et al., 2018; Desmedt et al., 2018). In fact, studies suggest that heartbeat counting performance relies on non-interoceptive processes, including reliance on general *beliefs* about heartbeat rates that may be better measured by the metacogntive insight metric (Desmedt et al., 2018; Zamariola et al., 2018; 2019; Ring et al., 2015). The IMC finding appears promising as a form of insight into one's interoceptive abilities that could be mapped to mindfulness approaches that do not seek to control or strive for positive outcomes, but to change one's 'attitude' or perspective on difficult inner experience. Although the most common method for measuring interoceptive accuracy has been the heartbeat counting task (Schandry, 1981), there are other physiological tests may be used measure interoception such as the water load test based on the sensation of gastrointestinal signals (Herbert et al., 2012). There is inconsistent evidence of a relationship between mindfulness and interoceptive accuracy (Khalsa et al., 2020; Treves et al., 2019). This contradictory evidence may hinge on the type of mindfulness practice used and the depth and length of mindfulness 'dosage' (Todd & Aspell, 2022)

Limitations need to be acknowledged. Firstly, the use of the heartbeat counting task may be criticized, given the growing body of literature evidencing that interoceptive accuracy is not improved by mindfulness therapies and may be an inadequate physiological measure of adaptive interoceptive abilities (Brener & Ring, 2016; Ferentzi et al., 2019). Also, participants from this study were predominantly female. Regarding gender differences in interoception, women usually demonstrate poorer interoceptive accuracy but better emotional processing and recognition than men (Prentice et al., 2022). Divergent evidence reveals that mindfulness practice does not affect interoceptive accuracy (Khalsa et al., 2022; Parkin et al., 2014). This discrepancy may be due to differences in the operationalization and measurements of interoception which has been identified by a recent meta-analytic review by Treves et al. (2019) into the relationship between mindfulness and 'objective' interoceptive measurements. There is recent theorizing that the positive effects of mindfulness training on wellbeing can be attributed to improving the relationship with interoceptive signals by strengthening receptivity and acceptance towards physiological sensations and eliminating experiential avoidance (Weng et al., 2021; Farb et al., 2022; Price & Hooven, 2018; Khalsa et al., 2018). Accordingly, interoception seems to be modulated by enhanced attentional focus via mindfulness exposure (Lima-Araujo et al., 2022). There is no clear biomarker or objective test for anxiety and thus the ways it can be ameliorated might differ (Roseberry et al., 2023). The identification of a valid biomarker for anxiety, attenuated by mindfulness is worthwhile avenue of research, given the strong evidence that mindfulness reduces anxiety, including its somatic manifestations.

It appears that this doctoral investigation is one of only a few (or possibly only the second) longitudinal intervention studies to examine specific interoceptive awareness variables and their mechanistic influences on psychological wellbeing (de Jong et al., 2016). As such, this study aims to address a clear gap in the literature and offer a novel avenue of inquiry. There is some evidence that divergent mindfulness mechanisms mediating anxiety versus depression (Tran et al., 2014), with body awareness predicting the beneficial effects of dispositional mindfulness on anxiety symptoms (Tran et al., 2014). These findings offer preliminary evidence that the body-based attention regulation capacity is a particularly influential interoceptive change mechanism implicated in mindfulness practices and interventions. Taken together, findings imply that IA forms of emotion regulation are improved by mindfulness training and offer divergent mediational influences on stress, anxiety and distress versus alexithymia, while IA elements such as noticing bodily signals may not be associated with mindfulness benefits (Bornemann et al., 2015; de Lima-Araujo et al., 2022). An increasing body of research supports the relevance of interoception in mental health, showing strong associations with emotion regulation (Fustos et al., 2013), alexithymia (Trevisan et al., 2019) and psychopathology (Khalsa et al., 2018).

Chapter 4: Study 3

Investigating the psychological and psychophysiological processes of mindful and embodied emotion regulation strategies and their impact on mental wellbeing.

Abstract

Embodied and mindful emotion regulation (ER) strategies have been proposed as core outcomes and mediators of mindfulness induction and psychological health. There is limited research into the mediational influences of mindful versus interoceptive ER and the impact of MT on implicit, or 'objective', ER. This study is a novel exploration of psychological and implicit psychophysiological measures of mindful and interoceptive ER.

Method: A randomised controlled mixed 2x2 design was used, with multiple mediation analyses (see Chapter 1 for procedure and outcome measurements). Before and after a 2-month interval, participants were presented with emotionally valent images, whilst having their physiological arousal recorded via skin conductance and rating their arousal and valence responses. Participants also completed self-report measures of mental health and alexithymia (emotion dysregulation) and measures of 'interoceptive' and 'mindful' ER.

Results: The mindfulness training (MT) improved all mental health and ER measures including cognitive subscales of alexithymia. For psychophysiological arousal, there was a significant group by time interaction effect, with the mindfulness group's pattern of arousal distinct from the control group and reduced over time, compared with the control group's pattern of increased arousal. There was no simple effect of either time or group, however there was a crossover interaction. Mindful ER demonstrated a unique mediational influence (overriding IA ER) on mindfulness-induced attenuation of both anxiety and distress while IA ER demonstrated a unique mediational influence on mindfulness-induced alexithymia improvement. There was no unique mediational finding for the stress outcome.

Conclusion: The findings suggest that mindfulness training produced a differential effect over time compared to the control condition, via an objective measure of emotion regulation. The mindfulness group's psychophysiological arousal changed in the direction of reduced arousal, while the control group's arousal increased slightly. This finding offers a direction of research contributes to the mindfulness literature that MT improves interoceptive and mindful ER strategies. MT reduced emotion dysregulation (alexithymia), while mindful ER strategies mediated distress and anxiety above and beyond the mediational influences of interoceptive ER, with both mindful acceptance and interoceptive attention regulation mediated stress. Finally, IA mind/body awareness emerged as a unique mediator of alexithymia. Results suggest that mindful versus interceptive ER strategies exert differential influences on distinct mental health conditions. Further research is needed as there may be differing pathways and biomarkers through which mindfulness influences ER and wellbeing.

Introduction

In the last decades, an immense interest has surged towards the concept and applications of mindfulness as well as the concepts of 'mindful' emotion regulation (Chambers et al., 2009; Farb et al., 2012; Grecucci et al., 2015; Chiesa et al., 2013) and 'embodied' or 'interoceptive' emotion regulation (Guendelman et al., 2017). Research has demonstrated that mindfulness and emotion regulation are related, but the underlying processes are still not fully understood (Iani et al., 2019). It remains unclear which mechanisms, via mindfulness practice, contribute to emotion regulation and the association and dissociation between the two constructs (Heppner et al., 2015). To date, research has been mixed and has not provided clear answers (Iani et al., 2019). The present chapter aims to explore emotion regulation outcomes produced by mindfulness training, using an implicit psychophysiological measure and self-report measure of alexithymia, indicating the presence of emotional dysregulation. This chapter additionally explores change mechanisms, comparing multiple mediators representing mindful and interoceptive axes of emotion regulation. In short, this study examines whether mindful versus interoceptive emotion regulation strategies provide unique mediational influences on psychological health.

Mindfulness involves a style of attention that is anchored in the present moment and a attitudinal orientation of acceptance, nonreactivity and noninterference toward all emotional experience, which is proposed by mindfulness researchers to facilitate emotion regulation (Tan et al., 2023; Guendelman et al., 2020). The concurrent theory of emotion is that an emotional experience is a result of three components; a subjective experience, physiological changes, and behavioural activity in response to a stimulus or context (Scherer, 2005; Gross & Barrett, 2011; Jerath et al., 2015; Norman et al., 2014). Emotion regulation is a broad term that involves ways to process emotional responses, such as by consciously and unconsciously modulating the intensity and duration of positive or negative emotional states in the service of a particular goal (Holzel et al., 2011). Current psychological theories view the ability to regulate emotional states an essential component of emotional health, with emotional dysregulation identified as a transdiagnostic marker underpinning a number of mental health pathologies including borderline personality disorder, bipolar illness, schizophrenia (Preece et al., 2023; Sharmy & McClellan, 2021; Berenbaum et al., 2003; Kaiss et al., 2020; Rennin & Farach, 2007; Sloan et al., 2017). Emotional regulation deficits are also linked to alexithymia, a personality trait that is characterized by a lack of emotional awareness and clarity and impairment in the capacity to symbolise and describe emotional experience (Preece et al., 2023; Velotti et al., 2014).

According to a multidimensional model of emotion regulation developed by Gratz and Roemer (2004), three of the six factors are of particular relevance to this study, namely (1) inability or unwillingness to accept unwanted emotion, (2) limited emotional awareness and, (3) lack of emotional clarity. Trainings promoting interoceptive awareness, such as mindfulness-based approaches, have been utilized to promote increased capacity to process and cope with negative emotions. (Aaron et al., 2020; Remmers et al., 2016).

Mindfulness has been found to enhance emotion regulation by strengthening an attentional style rooted in present moment awareness and facilitating a stance of acceptance, receptivity and nonreactivity to challenging stimuli (Chambers et al., 2009; Preece et al., 2023).

Price and Hooven (2018) identified trends in the fields of clinical practice and neuroscience toward re-establishing the essential role of the body and interoception in processing, regulating and generating emotional experience. In the neuroscience literature, interoceptive awareness is viewed as a reflection of emotional states that offers access to adaptive mechanisms of emotion regulation (Khalsa & Lapidus, 2016). Researchers have also suggested that interoception may indicate early processes that lead to emotion regulation. This is achieved by promoting emotional awareness via the body, where one can actively attend to emotional cues located in bodily sensations (Fustos et al., 2013; Schuette et al., 2021). The extended process model of emotion regulation by Gross (2015) recognizes the relevance of interoceptive emotional awareness in stage one of the multistage sequential process. These constructs support the research of Aldao et al. (2010) who found that classic control strategies associated with emotion regulation, such as avoidance, rumination and suppression were correlated to anxiety, depression, and eating disorders (Aldao et al., 2010). Tan and colleagues (2023) call for research into how mindfulness training may influence choice of emotion regulation strategy deployed, possibly by choosing to reduce experiential avoidance of unwanted emotions rather than to distract or suppress the emotional experience (Ardi et al; 2021; Mehling et al., 2013; Villemure et al., 2014).

A working theory of mindfulness with regard to emotion regulation is that it may bypass effortful top-down control strategies in favour of more bottom up strategies of emotional awareness and acceptance (Guendelman et al., 2017; Preece et al., 2023; Grecucci et al., 2015; Tan et al., 2023). In sum, mindfulness based interventions may target emotion regulation deficits, such as nonacceptance and lack of emotional self-awareness implicated in emotion-related psychological disorders (Aaron et al., 2020; Chambers et al., 2009). This study is interested in exploring the meditational influences of both interoceptive (bodily) and mindful (attention and acceptance) forms of emotion regulation. It is also interested in implicit, bottom up forms of emotional regulation, exploring whether an intensive mindfulness training can reduce a biomarker of emotional reactivity represented by skin conductance response to emotionally arousing images (Noy & Noy-Sharav, 2013; Lang et al., 2004).

Mental health, mindfulness and emotion regulation

Research suggests overlapping processes between mindfulness practices and adaptive forms of emotional regulation (Chambers et al., 2019; Guendelman et al., 2017).
Mindfulness and emotion regulation are two psychological constructs that have shown a clear interrelationship, with the first potentially serving as a regulator of the second (Chiesa et al., 2013; Roemer et al., 2015). Higher trait mindfulness has been correlated with

deployment of effective emotion regulation strategies (Feldman et al., 2007) and inversely related to difficulties in emotion regulation (Roemer et al., 2009). Experienced mindfulness practitioners have also reported less emotion regulation difficulties than meditation naive subjects (Lykins & Baer, 2009). Some researchers advance the notion that mindfulness practice can promote top down regulatory control in beginner meditators, via focused attention practices, and bottom up regulatory capacity in experiences mediators, via open monitoring practices, leading to overall adaptive emotion regulation functioning (Chiesa et al., 2013).

Researchers have found that mindfulness is positively associated with emotional awareness and emotional regulation (Phillipot et al., 2009), as well as negatively correlated with anxiety, depression, alexithymia and other psychological issues (Hofmann et al., 2010; Williams et al., 2017). Poor emotion regulation functioning is identified as a component of emotional and psychiatric disorders (Aldao et al., 2010). Evidence from meta-analyses demonstrates that emotion regulation processes mediate the influence of mindfulness interventions on mental wellbeing (Gu et al., 2015) and that mindfulness interventions disruptive maladaptive emotion regulation strategies, conferring its beneficial effects on psychological health (Guendelman et al., 2017).The putative concept is that mindful states facilitate more effective emotional coping and dampening of negative reactivity to unwanted emotions (Wiesgloz et al., 2019). Mindfulness training has been found to repair emotion regulation capacities, leading to therapeutic gains (Guendelman et al., 2017; Khoury et al., 2013)

Mindfulness-based programmes, such as MBSR, have been shown to reduce rumination and other processes linked to emotional regulation (Gu et al., 2015) and to deactivate neural regions associated with self-referential processing and elaboration and connected to depressive rumination (Farb et al., 2007). MBSR has been shown to ameliorate anxiety, stress and depressive symptoms by modulating emotion regulation skills, yet there is no precise understanding of the nature and specificity of the relationship between emotion regulation and the beneficial outcomes of MBSR (Goldin & Gross, 2010). This may be a result of the multifaceted nature of both emotion regulation and mindfulness, whereby a range of strategies are activated at different stages of emotional processing, ultimately influencing which emotions are experienced and other qualitative experience such as intensity, duration, expression (Goldin & Gross, 2010). Emotion regulation can be described as a capacity to actively or explicitly modulate the quality and intensity of one's emotional experience (Gross, 1998).

Heppner and colleagues (2015) provide evidence of several distinct pathways through mindfulness exerts its influence on emotion regulation, including acceptance of negative emotional experience, nonreactivity to difficult emotional stimuli and experience, decentering or 'psychological distancing' and increased emotional stability. Of interest, there is some evidence that levels of nonacceptance, such as experiential avoidance (Kashdan et al., 2006) emotional nonacceptance (Yoon et al., 2018) and distress intolerance are linked to psychological symptoms (Lindsay & Creswell, 2019).

Accordingly, emotion regulation research indicates that acceptance is an effective strategy (Kohl et al., 2012). Therefore, a hypothesis can be advanced that mindfulness acts to target specific emotion regulation deficits of emotion-related disorders such as acceptance (instead of avoidance), present moment focus (instead of rumination) and bodily emotional awareness (instead of suppression).

Emotion Dysregulation - Alexithymia

Alexithymia is proposed as specifically an emotional regulation deficit based on limited ability to identify subjective emotional experience (lack of emotional awareness) and the affect of others (Edwards & Lowe, 2021). A cognitive type of alexithymia has been proposed by Vorst and Bermond (2001), which includes the identifying, analyzing and verbalizing subscale cluster. Cognitive aspects of alexithymia involve difficulties in verbalizing and identifying feelings (Taylor & Bagby, 2013; Fonagy et al., 2002). Cognitive alexithymia is linked to deficits in emotion awareness of others and empathy, connoting an externalized thinking style (Grynberg et al., 2010; Moriguchi et al., 2007). This study focused on participants with high baseline alexithymia as evidence suggests changes via mindfulness training are evident in those with high trait alexithymia (McGillivray et al., 2017; Norman et al., 2019). Alexithymia can be described as a transdiagnostic representation of emotional dysregulation and low interoceptive abilities (Brewer et al., 2016; Herbert & Pollatos, 2012; Trevisan et al., 2019), recently found to modifiable by mind-body therapies such as mindfulness (Norman et al., 2019). See Table 11 for alexithymia cognitive type subscales and example questions using the Bormund Vorst Alexithymia Questionnaire (BVAQ) (Vorst & Bormund, 2001).

Table 11

*Alexithymia Cognitive Type Subscales**

BVAQ Cognitive Subscales	Example Question
Identifying	When I feel lousy, I know whether I am afraid or dejected or sad. **
Analysing	There is not much to understand as far as emotions are concerned.
Verbalising	People often say that I should talk about my feelings.

Note. *Bormund Vorst Alexithymia Questionnaire (Vorst & Bormund, 2001).

Alexithymia is a personality trait encompassing difficulties in identifying, understanding and expressing emotions, and an externalized cognitive orientation (Bermond et al., 2007; Bagby et al., 2009), possibly generated by impairment in the neural processing of emotions (van der Velde et al., 2015). Alexithymia is present in about ten percent of the general population, with prevalence much higher in clinical populations (McGillivray et al., 2017). Psychological conditions, such as anxiety (Paniccia et al., 2017), depression (Honkalampi et al., 2000) and general psychological distress (Grabe et al., 2008) are all linked to alexithymic symptoms. The growing understanding is that alexithymia may present as relatively stable, rather than fixed, and as such can be ameliorated by therapeutic interventions such as mindfulness (Norman et al., 2019).

Norman and colleagues (2019) conducted a recent systematic review of the effects of mindfulness training on alexithymia, finding only four RCTs in the literature. They found that mindfulness training attenuated alexithymic symptoms, which is a promising finding. In these studies, the baseline level of alexithymia was low and below clinical threshold (Norman, 2019). It has been suggested that stronger effects may be found in clinical groups with higher alexithymia scores at baseline (McGillivray et al., 2017; Norman et al., 2019). Bornemann and Singer (2017) demonstrated more significant reductions in alexithymia in subjects meeting criteria for high alexithymia.

The association between alexithymia and risk for poor mental health seems to be related to emotion regulation deficits, including in emotional awareness (Edwards & Lowe, 2021; Van Bael et al., 2024). As previously stated, problems with emotion identification and clarity have been found to be mediators of psychological distress and negative emotions in the general population (Saxena et al. 2011). Previous studies on the effect of long-term mindfulness training reported significant reduction of negative emotions, implying that the skills of identifying and differentiating emotions, enhanced by mindfulness training, may represent meaningful emotion regulation functioning (Liu et al., 2008). A number of studies highlight that the accurate recognition or labelling of emotions (captured by the cognitive dimension of the Bermond Vorst Alexithymia Questionnaire, or BVAQ) (Bermond et al., 2014) may be the either: 1. first step in a process that enables the management of unwanted emotions (Goetz et al., 2020; Preece et al., 2017; Izard et al., 2011; Gross, 2015), or 2. an emotion regulation strategy by itself (Burkland et al, 2014).

Mindful Emotion Regulation

The concept of ‘mindful’ emotion regulation (Grecucci et al., 2015; Guendelman et al., 2017; Chambers et al., 2009) is of explicit and implied interest in the mindfulness research literature (Iani et al., 2019). Mindfulness and emotion regulation are interrelated concepts and mindfulness has been proposed to mediate emotion regulation outcomes (Chiesa et al., 2013; Roemer et al., 2015). The underlying emotion regulation processes implicated in mindfulness practices and concepts are still not fully understood (Iani et al., 2019).

There is no consensus on the definition of mindful emotion regulation, however it is recognized as an atypical emotion regulation strategy that employs awareness and

acceptance in order to promote a gentle exposure to a fuller range and intensity of emotional stimuli (Chambers et al., 2009; Farb et al., 2012; Chiesa et al., 2013; Grecucci et al., 2015). Some conceptualizations of a 'mindful' type of emotion regulation propose a unique feature involving bottom up, implicit regulatory capacities rather than typical top down effortful control strategies (Chiesa et al., 2013). Other studies challenge a unidimensional construct of mindful bottom up emotion regulation, suggesting that mindfulness training may also act via top down, cognitive control mechanisms of emotion regulation (Malinowski, 2013; Holzel et al., 2013; Goldin et al., 2013).

Grecucci and colleagues assert that different brain regions are activated by mindfulness, depending on intensity and depth of mindfulness experience and that this has been demonstrated in neuroimaging studies. In experienced mindfulness practitioners, a deactivation of medial prefrontal and posterior cingulate cortices was observed, with no activation of brain areas associated with emotional reactivity (Taylor et al., 2011). In contrast, beginner meditation practitioners appear to default to higher cortical neural regions to exert top down control of affective brain systems (Grecucci et al., 2015). In other FMRI studies, researchers found a downregulation of left amygdala (Taylor et al., 2011) and right amygdala (Brefczynski-Lewis et al., 2007) in meditation naive subjects with brief mindfulness exposure during tasks of emotion elicitation to unpleasant stimuli. These findings provide the rationale for suggesting that longer exposure to mindfulness results in a methods of emotion regulation that involves accepting of difficult emotional states and training present moment attentional focus. By contrast, beginner mindfulness practitioners continue to default to higher cortical brain regions exerting top down control of unpleasant emotional experience (Grecucci etc al., 2015).

Guendelman et al. (2020) found that participants engaging in mindfulness practice (MBSR) recruit neural systems associated with (1) emotion generation (anterior insula, subgenual-anterior cingulate cortex), (2) body awareness or interoception/exteroception (anterior insula, somatosensory cortex), (3) implicit bottom up emotion regulation (ventromedial prefrontal cortex) (4) emotional reactivity (amygdala, insula), (5) self-consciousness (posterior cingulate cortex, pons) and memory (hippocampus, cerebellum) (Guendelman et al., 2017). All of these systems have been found to be effectively activated or deactivated in the service of emotional regulation. None of the studies reviewed found changes in prefrontal cortex regions implicated in top down emotional regulatory control. This suggests that MBSR is primarily mediated by subcortical and cortical regions associated with bottom up or noneffective emotion regulation systems (Guendelman et al., 2017).

Chambers and colleagues (2009) differentiate mindfulness from other therapies such as CBT and psychoanalysis. Mindfulness is purported to alter how one relates to emotionally challenging states, whereas other treatments attempt to alter the actual content of emotional states (see Introduction Chapter for a summary of neuroscience evidence of a maladaptive narrative focus related to default mode overactivity linked to rumination and mind wandering: Tabibnia, 2020). Mindfulness changes the attitude towards emotional

experience by cultivating acceptance and curiosity about the bodily and mental stimuli (an experiential focus). This accepting, receptive orientation of mindfulness can be mapped to the emotional memory and learning theory of PTSD (Boyd et al., 2018) involving processes of exposure, extinction and reconsolidation. Mindfulness can be seen to cultivate a gentle exposure to certain challenging emotions or thoughts, then an extinction of adaptive responses and thoughts and finally a reconsolidation where a new relational pattern regarding subjective experience is established (Holzel et al., 2011). See Table 12 for mindfulness-based emotion regulation facets comprising acceptance (nonreactivity) and attention (acting with awareness).

Table 12

*Mindful Emotion Regulation Facets**

FFMQ Facet	Example Question
Attention	I don't pay attention to what I'm doing because I'm daydreaming, worrying or otherwise distracted**
Acceptance	When I have distressing thoughts or images I just notice them and let them go.

Note. * Five Facet Mindfulness Questionnaire (FFMQ: Baer et al., 2012) to represent mindful attention ('acting with awareness' facet) and mindful acceptance ('nonreactivity' facet). **reverse coded questions

Gross' influential process model of emotion regulation does not explicitly identify acceptance as a mechanistic strategy (Gross, 1998), however acceptance is present in other models (Gratz and Roemer, 2004; Berking et al., 2008). According to Gratz and Roemer's (2004) emotion regulation construct, three of the processes reflecting difficulties with emotion regulation are of particular interest in this study. They comprise (1) the nonacceptance of challenging emotions, (2) a lack of emotional awareness and (3) lack of emotional understanding or clarity. Using Gross' sequential emotion regulation model, some researchers propose including acceptance within the attentional deployment domain (Slutsky et al., 2017), while others consider acceptance to be as a reappraisal strategy (Webb et al., 2012).

Acceptance is put forward as a critical mechanism of mindfulness that enables the initial attentional focus on bodily, emotional and cognitive experience, which may be experienced as aversive in meditation naive practitioners, to be tolerated (Lindsay & Creswell, 2019). Acceptance may act early on in the initial stage of 'attentional deployment' (Gross, 2015), allowing practitioners to receptively attend to emotional stimuli, notice them as they emerge and allow them to pass. Slutsky and colleagues (2018) describe this process as an early engagement and disengagement of emotional cues, which reduces habitual emotional reactivity and the impulse to change, control or suppress the emotional experience (Quaglia et al., 2015; Slutsky et al, 2018).

Acceptance is markedly distinct from other recognized emotion regulation strategies in the research literature, commonly based on effortful, active modification of an unwanted emotional state at the level of quality, intensity, length or frequency (Gross, 2015). By definition, acceptance is an emotion regulation strategy that does not aim to change the quality of the emotional experience, but to present a stance of willingness, curiosity, receptivity and noninterference, allowing a full emotional experience despite its emotional valence (Hayes, 2004; Quaglia et al., 2015; Kohl et al., 2012). Despite the atypical orientation of acceptance, it is well studied in the psychological literature and is often compared with other regulatory strategies for effectiveness in different contexts and with different clinical conditions (Liverant et al., 2008; Aldao et al., 2010; Naragon-Gainey et al., 2017; Southward et al., 2019). See Table 13 for a Step 1 interoceptive subscale and a Step 2 subscale.

Table 13

*Interoceptive 'Emotional Regulation'**

MAIA Subscale	Example Question
Attention Regulation	I can refocus my attention from thinking to sensing my body
Body Listening	I listen for information from my body about my emotional state

Note. * Multidimensional Assessment of Interoceptive Awareness (MAIA: Mehling et al., 2012) to represent Step 1 process, bodily attention ('attention regulation'), and Step 2 process ('mind/body integration').

Interoceptive Emotion Regulation

Empirical evidence indicates a relationship between interceptive awareness and the regulation of emotions (Craig, 2015), with poor interoceptive awareness abilities associated with emotional pathologies (Paulus & Stein, 2010; Khalsa & Lapidus, 2016). A growing research literature validates the importance of interoception to mental wellbeing, specifically emotion regulation (Gross , 2014; Fustos et al., 2013), anxiety and depression (Hofmann et al., 2020; Williams et al., 2017), alexithymia (Trevisan et al., 2019), and other psychopathologies (Khalsa et al., 2018). This points to the applicability of bodily-focused emotion regulation interventions targeting entrenched psychological conditions such as depressive disorders, addiction and PTSD (Farb et al., 2015). Research has offered insights into traumatic stress effects, whereby brain and bodily changes occur in response to trauma exposure that affect internal emotional processing and awareness (Guendelman et al., 2017; Lupien et al., 2018; Ellis et al., 2011; 2013; Taylor et al., 2011). Posttraumatic stress produces physiological changes including hyperarousal and hypoarousal of the autonomic nervous system (Taylor et al., 2011). There is growing clinical and neuroscience interest in the fundamental role of the body and bodily awareness in emotional regulation and processing (Guendelman et al., 2017).

Emotional theories present a close association between interoception and the emotional experience. Specifically, in these theoretical frameworks, the perception of bodily signals is usually considered an underlying mechanism of the ability to recognize and regulate emotions (Damasio, 1994). Awareness of emotional states and the capacity to regulate them are intertwined. Emotional awareness can be purported to relay salient information to influence the selection of effective emotion regulation strategies (Barrett & Gross, 2001). An impairment in emotional awareness has been evidenced in conditions related to emotion regulation difficulties, including depression and anxiety (Kranzler et al., 2016; Novick-Kline et al., 2005; Sendzik et al., 2017), somatic disorders (Lane et al., 2011; Stonnington et al., 2013;), chronic pain (Baeza-Velasco et al., 2012) and disordered eating (Vander Wal et al., 2020). In populations vulnerable to depression, there is evidence of emotion identification deficits (Collin et al., 2013; Nyquist & Luebbe, 2020).

Significant evidence exists showing that interoceptive awareness is positively associated with the activation of the insula (Critchley et al., 2004; Fustos et al., 2013; Pollatos et al., 2005; 2007) and the anterior cingulate cortex (Pollatos et al., 2007). Both the insula and the anterior cingulate cortex are implicated in reappraisal of emotional experience (Goldin et al., 2008; Kanske et al., 2011), as such these structures may serve as interfaces between interoceptive awareness and emotion regulation. Bodily awareness, particularly of interoceptive signals, is recognised as involving increased insular and anterior cingulate cortex activation which enables the downregulation of distressing bodily sensations induced by negative emotional experiencing (Khalsa et al., 2018; Garfinkel & Critchley, 2016; Fustos et al., 2013; Pollatos et al. 2007).

Targeted therapeutic interventions that improve emotional awareness also reduce emotional dysregulation (Neumann et al., 2017) and ameliorate somatic symptoms linked to emotion dysregulation (Burger et al., 2016; Farnam et al., 2014; Thakur et al., 2017). Santarnecchi and colleagues (2014) conducted a longitudinal RCT with MBSR as the treatment and found substantial cortical thickness increases in interoceptive and somatosensory networks. These researchers found structural brain alterations in the right insula and decreased alexithymia symptoms, strongly indicating that bodily (interoceptive) awareness is a change mechanism influencing the beneficial effects of mindfulness interventions (Santarnecchi et al., 2014), with particular relevance for emotional awareness and regulation.

Finally, the explicit attending to, focusing on and sensing of the body and internal experience that is cultivated by mindfulness can be conceptualized as an embodied physicality that influences and promotes emotion regulation (Dunn et al., 2010; Mehling et al., 2012; Mehling et al., 2011; Sze et al., 2011). According to Critchley and Garfinkel (2017), this enhancement of bodily awareness exerts its influence on the detection, monitoring and regulating of emotions.

Psychophysiological Emotion Regulation

Mindfulness has been proposed to strengthen the capacity to disentangle from emotionally inducing stimuli and simultaneously to decrease emotional arousal, or reactivity (Desbordes et al., 2015). According to Cosme and Wiens (2015), an emotional response involves a range of physiological activity such as threshold for reactivity, peak amplitude of response, rise time to peak, and recovery time. Mindfulness is seen to enable dissociation from emotional arousal by reducing peak amplitude and promoting faster recovery (Cosme & Wiens, 2015). A nonmindful response typically involves prolonged engagement with the emotional trigger and a narrative self-referential processing that is associated with rumination and negative emotions (Nolen-Hoeksema et al., 2008). Mindfulness can promote habituation to an accepting stance toward difficult emotional experience (an emotion regulation strategy) and reduction of habitual stress reactivity, which in turn promotes greater psychological wellbeing (Ford et al., 2017). See Table 14 for a breakdown of physiological and behavioural emotion regulation measurements.

Table 14

Physiological and Behavioural Measures of Emotion Regulation

Measurement	Description
Emotional Visual Stimuli	Emotionally laden image set designed to elicit an emotional response from the research participant. Images are categorised as negative, positive or neutral and come from the International Affective Picture System (IAPS: Lang et al., 2008)
Physiological Arousal	Skin conductance responses (SCR) are recorded while viewing the IAPS images (Sze et al., 2010). Self-rated responses, using the Self-Assessment Manikin (SAM), a nonverbal pictoral self-rating tool.
Self-Rated Arousal	SAM rating of arousal, how affected one is by the images
Self-Rated Valence	SAM rating of valence, whether the image is experienced as negative, positive or neutral.
Self-Rated Dominance	SAM rating of dominance, or how dominated/controlled one felt by the images.

There have been a range of emotional theories in the scientific literature yet a converging notion is that emotional states are represented by bodily response to clearly detectable cues (Rodriguez-Torres et al., 2005). Research into emotional processing tends to involve provoking emotional arousal and measuring the corresponding cognitive and physiological reactions, with the most common method of emotion elicitation via presenting emotionally salient images (Noy & Noy-Sharav, 2013). The International Affective Picture system (IAPS) (Lang & Bradley, 2007) is a widely used database collection of visual stimuli (pictures) used to elicit emotions. To measure explicit impact of the emotional stimuli, self-assessment questionnaires such as the Self-Assessment Manikin (SAM) is commonly used (Bradley & Lang, 1996). The IAPS is distributed by the NIMH Center for the Study of Emotion and Attention, and it has been utilized in a wide range of emotional reactivity studies. See Figure 21 for an image of the IAPS pictures and SAM self-report measures, whereby emotionally laden visual stimuli are shown to participants and responses can be measured via self-report (eg, self-assessment manikin of arousal and valence) and physiological arousal (electrodermal activity, heartrate variability, respiration rate).

Figure 21

*IAPS Visual Stimuli Eliciting Emotional Reactions**

Note. Behavioural and psychophysiological task to elicit emotional reactions using the International Affective Picture System (IAPS; Lang et al., 2008). Visual stimuli (pictures) are shown to participants and responses can be measured via self-report (eg, self-assessment manikin of arousal and valence) and physiological arousal (electrodermal activity, heartrate variability, respiration rate).

In tandem with the self-assessment measures, psychophysiological and bodily arousal to the emotional stimuli are often recorded via brain imaging or autonomic signals (Nasoz et al., 2004). Given that neuroimaging experiments are resource intensive, researchers often focus on autonomic system responses. This approach does not require extensive hardware or resources and enables the recording of bodily data with a common physiological marker being skin conductance. Skin conductance is considered a direct correlate of 'autonomic sudomotor nerve activation' (Haag et al., 2004). High arousal via skin conductance response has been linked to emotional reactivity (Haag et al., 2004; Lang et al., 2014). Emotional states represented by elevated physiological arousal are associated with sympathetic nervous system 'fight or flight' response. In turn this activates the sudomotor nerve, triggering the release of sweat from the skin. This process of skin conductance response has been found to serve as a biomarker of sympathetic, or threat, arousal (Lang et al., 1993).

Implicit emotion regulation can be defined as the arc of recovery of the physiological systems after a negative or stressful emotion has been evoked. There is some evidence that mindfulness meditation can quicken the physiological recovery from the triggering stimulus (Davidson, 2010). Two studies have found that mindfulness contributes to reduced emotional reactivity as well as to self-rated valence of emotional pictures toward neutrality (Ortner et al., 2007; Taylor et al., 2011). One of the studies demonstrated decreases in skin conductance responses and subjective ratings of arousal and valence as a result of participation in mindfulness training (Ortner et al, 2007). This method of implicit emotion regulation requires further study. This chapter will examine the effects of mindfulness training (MBSR) on self-rated emotional experience and physiological arousal (skin conductance) when faced with negative emotional stimuli, using the IAPS emotion induction task. Skin conductance is arguably the most used physiological parameter to investigate participants' emotional activation (Lang et al., 2014).

This study

This third study will explore intertwined and possibly contrasting conceptualizations of emotion regulation that suggests there may be a distinction between embodied/interoceptive emotional regulation and mindful emotion regulation in exerting their mediational influences on psychological wellbeing. Measuring the clinical effectiveness of mindfulness training relies heavily on self-report in the research literature and does not tend to investigate change mechanisms explaining the salutary effects of mindfulness training. There are limited experimental intervention studies exploring the mediating role of embodied emotional awareness in mindfulness-induced wellbeing and the correspondence of self-report to psychophysiological measures of emotion regulation

This study has taken into account diverse psychological and clinical evidence, with a view to exploring an implicit psychophysiological (objective) measurement of emotion regulation that may be attenuated by a standardized mindfulness intervention. This study

incorporates a behavioural task (IAPS) and physiological data (skin conductance) with the aim to investigate whether a visual emotion inducing task can be utilized to objectively measure the impact of mindfulness training on implicit stress and emotional regulation strategies. Finally, this study will examine the mediational role of a 'mindful' versus 'interoceptive' form of emotion regulation in influencing mental health outcomes, including alexithymia, a metric of emotion dysregulation.

The hypotheses of this third study are therefore that: 1. mindfulness training will improve specific subscales of alexithymia (identifying, verbalizing, analyzing) which correspond to the emotional awareness component of emotion regulation (ie., cognitive alexithymia); 2. mindfulness will result in improved implicit emotion regulation (psychophysiological measure of arousal) and related arousal, valence and dominance self-ratings during an emotion elicitation task; 3. interoceptive attention regulation and mindful attention will emerge as a unique (ie., specific) emotion regulation mediators of mindfulness-induced wellbeing, above and beyond the meditational effects of interoceptive mind/body awareness and mindful acceptance. This hypothesis is informed by the findings from study 1 and 2 as well as the UFM framework asserting that attentional processes will be strengthened first before the strengthening of attitudinal processes (Rogge & Daks, 2021); and 4. mindful emotion regulation will emerge as a unique mediator beyond the mediational influence of 'interoceptive' emotion regulation. This hypothesis is yet again informed by the findings from the first two studies that mindfulness mechanisms exert stronger mediational effect on mental health outcomes than interoceptive mechanisms.

2. Method

Participants
See Chapter 1

Research Design and Analysis

This longitudinal study used a randomized controlled trial (RCT) design with a repeated measures 2x2 factorial design. All participants from mindfulness and control conditions engaged in a 2-hour lab session before and after the 8-week period of the mindfulness-based programme. See Chapter 1 for summary of main analysis (within and between groups) and mediation analysis.

Procedure

See Chapter 1 for recruitment and MBSR programme

Mental Health Outcome Measures

See Chapter 1 for descriptions of GHQ-12 (distress); GAD7 (anxiety); PSS (stress); BVAQ (alexithymia). For alexithymia, the focus was on the cognitive type identified by Vorst and Bermond (2001), which includes the identifying, analyzing and verbalizing subscale

cluster. Cognitive aspects of alexithymia involve difficulties in verbalizing and identifying feelings (Taylor & Bagby, 2013; Fonagy et al., 2002) and are consistently linked to deficits in emotion awareness of others and empathy, connoting an externalized thinking style (Grynberg et al., 2010; Moriguchi et al., 2007). This study analyzed participants with high baseline alexithymia as evidence suggests changes via mindfulness training are evident in those with high trait alexithymia (McGillivray et al., 2017; Norman et al., 2019).

Psychophysiological and Behavioural Outcomes

Emotion Elicitation Task - IAPS

For the experimental task, 44 images were chosen from the International Affective Picture System (IAPS; Lang et al., 2008) to represent a wide range of images corresponding to the nominal valence (*M* = 4.59; standard deviation (*SD*) = 2.16; range = 1.51-8.03) and arousal (*M* = 5.60; *SD* = 0.96; range = 3.56-7.15) ratings that constitute the IAPS database. Images were presented for 6 s each in one of two fixed pseudo-random orders. The IAPS is used widely in experimental investigations of emotion elicitation and attention, providing experimental rigour and control in the selection of emotional stimuli (Lang et al., 2005).

Arousal, Valence and Dominance Ratings

To assess the three dimensions of valence, arousal, and dominance, the Self-Assessment Manikin (SAM) was used as an emotional rating system (Lang, 1980). SAM employs a graphic figure to represent emotional reactions and values along each of the 3 dimensions on a continuously varying scale. For the valence dimension, SAM figures range from a smiling, happy figure to a frowning, unhappy one. For the arousal dimension, SAM ranges from an excited, wide-eyed figure to a relaxed, sleepy figure. And for the the dominance dimension, SAM ranges from a large figure (in control) to a small figure (dominated). The participant can select any of the 5 figures comprising each scale, or between any two figures, which results in a 9-point rating scale for each dimension. Ratings are scored such that 9 represents a high rating on each dimension (i.e., high pleasure, high arousal, high dominance), and 1 represents a low rating on each dimension (i.e., low pleasure, low arousal, low dominance)

Participants rated each of the 44 images presented to them based on how positive or negative it made them feel (the *valence* dimension) and how intense this emotional experience felt (the *arousal* dimension). Instructions were given whereby it was emphasized that ratings should reflect the participants' actual immediate feelings were in that moment, rather than a rating of what a so-called appropriate response should be.

Physiological Measure - Skin Conductance

Throughout the IAPS emotion elicitation experiment, skin conductance responses (SCRs) were monitored at 1 kHz using an ADInstruments PowerLab System through stainless steel bipolar SCR electrodes attached to the medial phalanges of the index and ring fingers of the non-dominant hand. LabChart 7 (ADInstruments, 1994-2011) was used for the recording and offline processing of the data. Following standard procedures (Bradley et al., 2001),

SCRs were quantified as the peak response within the 6-s picture presentation window, applying a log transformation (log(SCR + 1)) to normalize the distribution of the data.

Mediation Outcome Measures

Interoceptive Emotion Regulation
See Chapter 1 for MAIA description
For the interoceptive emotion regulation cluster, a summed score comprising the MAIA mind/body awareness dimension and MAIA attention regulation subscale was used.

Mindful Emotion Regulation
See Chapter 1 for FFMQ description. Various facets of the FFMQ are selectively involved in self-awareness, attention control and emotion regulation (Zhuang et al., 2017). For the mindful emotion regulation cluster, a summed score comprising the acceptance (nonreactivity) and attention (acting with awareness) facets were used.

3. Results

Main Outcome Effects (within and between groups)

All within-subjects and between-groups effects were analyzed using a 2x2 mixed design repeated measures ANOVA, with a within factor of time (pre, mid and post) and a between factor of group (mindfulness and control) for main mental health outcome (alexithymia subscales plus chapter 1 results of distress, anxiety and stress); main psychophysiological outcomes (SCR, IAPS arousal, IAPS valence, IAPS dominance) and mediator variables ('interoceptive emotional regulation' comprising IA mind/body awareness dimension and and 'mindful emotion regulation' variables of nonreactivity and acting with awareness). A conservative estimate of degrees of freedom were corrected using greenhouse-geisser for violations to assumptions of sphericity. Follow on posthoc testing used bonferroni adjusted pairwise comparisons for group differences at pre and post. As suggested by Field (2009), the correct degrees of freedom will be reported in the findings, rather than the rounded figure.

H1: Main Mental Health Outcomes
See Chapter 1 for main mental health outcomes of distress, anxiety, stress. The mindfulness training results in attenuation of the cognitive type of alexithymia, as well as of the 'analysing' subscale. **See Table 15 for main outcome effects** of all study variables related to emotion regulation, including a summary of means, standard deviations, main group by time outcome effects and posthoc group differences for all of the study variables. Emotion regulation variables include alexithymia (a measure of emotional dysregulation) and an objective, implicit psychophysiological measurement of emotional regulation (change in arousal while viewing emotion-eliciting pictures). **See Figure 22 for a graph showing main interaction effects** of improved mental health outcomes and cognitive alexithymia.

Table 15

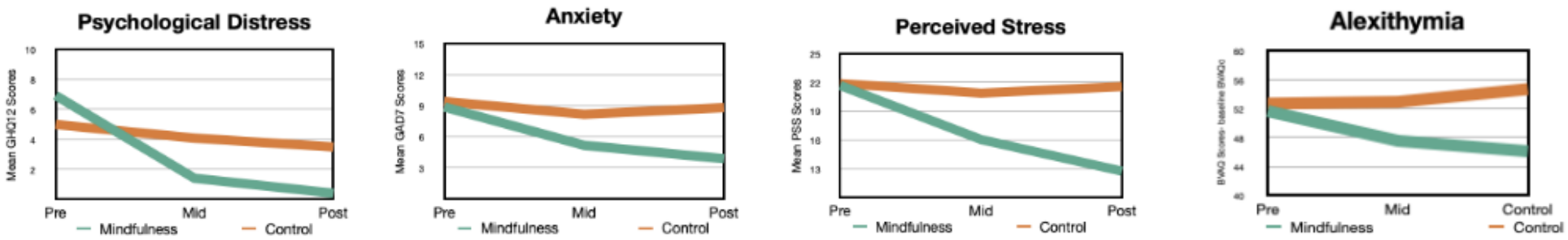
Main Emotion Regulation Group by Time Interaction Effects

Variable	Time	Group		Results
		Mindfulness	Control	
Emotion Dysregulation (Alexithymia)				
Alexithymia Cognitive Type	Pre	26.53 (6.47)	30.18 (7.35)	
	Post	23.76 (4.38)	32.64 (6.77)	Main group by time interaction effects: *F(1,37) = 9.57, p=.004, np²=.21** Between groups differences at pre *p=.114* and post *p<.001***
Identifying Subscale	Pre	9.82 (3.19)	11.27 (3.73)	
	Post	8.53 (2.83)	11.95 (2.94)	Main group by time interaction effects: *F(1,37) = 4.00, p=.053, np²=.10** Between groups differences at pre *p=.209* and post *p<.001***
Analyzing Subscale	Pre	7.00 (2.03)	7.36 (1.53)	
	Post	6.12 (1.90)	8.23 (2.41)	Main group by time interaction effects: *F(1,37) = 8.84, p=.005, np²=.19** Between groups differences at pre *p=.527* and post *p=.005***
Verbalizing Subscale	Pre	9.71 (2.87)	11.55 (4.11)	
	Post	9.12 (2.06)	12.45 (3.85)	Main group by time interaction effects: *F(1,37) = 2.97, p=.093, np²=.07** Between groups differences at pre *p=.125* and post *p=.003***
Psychophysiological Emotion Regulation				
Physiological Arousal (SCR) from IAPS	Pre	.25 (.14)	.21 (.15)	
	Post	.19 (.15)	.25 (.19)	*Group by time interaction effects: F(1,34) =4.62, p= .039 np²=.12** *Between group differences: pre p=.415 and post p=.278***
IAPS Arousal	Pre	4.56 (.99)	4.76 (1.29)	
	Post	4.43 (1.39)	5.04 (1.43)	*Group by time interaction effects: F(1,34) =1.50, p= .229, np²=.04** *Between group differences: pre p=.603 and post p=.215***
IAPS Valence	Pre	4.44 (.39)	4.66 (.57)	
	Post	4.46 (.34)	4.56 (.43)	*Group by time interaction effects:F(1,34) =.87, p= .357 np²=.03** *Between group differences: pre p=.210 and post p=.433***
IAPS Dominance	Pre	5.14 (.96)	5.25 (1.28)	
	Post	5.49 (1.21)	5.18 (1.48)	*Group by time interaction effects: F(1,34) =1.94, p= .173, np²=.05** *Between group differences: pre p=.796 and post p=.511***
Interoceptive Emotional Regulation				
IA Attention Regulation	Pre	13.76 (7.30)	11.55 (5.75)	
	Post	23.18 (4.33)	13.68 (6.09)	*Group by time interaction effects: F(1,37) =23.34, p< .001 np²=.39** *Between group differences: pre p=.295 and post p<.001***
IA Mind/Body Awareness Dimension	Pre	29.29 (12.14)	29.18 (8.93)	
	Post	44.71 (8.39)	31.73 (10.36)	*Group by time interaction effects: F(1,37) =33.38, p< .001 np²=.47** *Between group differences: pre p=.974 and post p<.001***
Mindful Emotion Regulation				
MF Acceptance (NR)	Pre	17.71 (4.69)	17.82 (4.51)	
	Post	24.41 (3.68)	19.27 (5.06)	*Group by time interaction effects: F(1,34) =15.71, p< .001, np²=.30** *Between group differences: pre p=.940 and post p=.001***
MF Attention (AWA)	Pre	21.29 (5.13)	22.72 (5.57)	
	Post	27.35 (6.20)	20.32 (6.28)	*Group by time interaction effects: F(1,34) =22.47, p< .001 np²=.38** *Between group differences: pre p=.415 and post p=.001***

Note. * partial eta squared for effect size (ηp²) and sphericity assumed; **bonferroni adjusted; SCR=skin conductance response; IAPS=emotion elicitation task via visual images. IA Mind/Body Awareness=MAIA subscales of body listening and trusting; NR=FFMQ nonreactivity facet; AWA=FFMQ acting with awareness facet. *Means, Standard Deviations, and Main Group x Time Interactions and Group Effects across 2 Time Periods (Pre and Post)*

Figure 22

Main Interaction Effects for Primary Mental Health Outcomes



Note. Main Interaction Effects by Group (Mindfulness and Control) and Time (Pre, Mid and Post) on Mental Health Outcomes

Cognitive alexithymia
There was no significant effect of time *(F(1,24) = 3.28, p =.083, ηp² =.12)*. There was a group effect *(F(1,24) = 7.88, p = .010, ηp² =.25)* and a group by time interaction *(F(1,24) = 13.40, p= .001, ηp² =.36)*. There was no group difference at pre *(p=.401),* however there was a significant group difference at post *(p<.001)*.

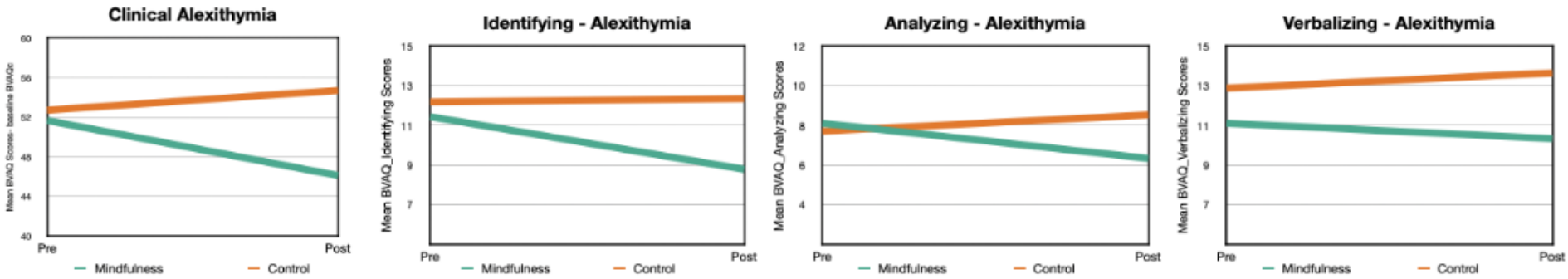
Identifying-Alexithymia
There was a significant effect of time, *(F(1,24) = 5.26, p =.031, ηp² =.03)* but no group effect *(F(1,24) = 3.69, p = .067, ηp² =.13)* and group by time interaction *(F(1,24) = 8.86, p= .015, ηp² =.22)*. There no group difference at pre *(p=.599)*, however there was a significant group difference at post *(p=.003)*.

Analyzing-Alexithymia
There were no significant effects of time, *(F(1,24) = .00, p =1.46, ηp² =.06)* or group effect *(F(1,24) = 2.25, p = .147, ηp² =.09).* There was a group by time interaction *(F(1,24) = 10.86, p= .003, ηp² =.31*. There no group difference at pre *(p=.504)*, however there was a significant group difference at post *(p=.013)*.

As hypothesized, the mindfulness group (above the control group) showed significant improvements in all mental health outcomes (psychological distress, anxiety, stress and cognitive alexithymia). With specific alexithymia subscales, there were significant group by time interaction effects on identifying and analyzing but not on the verbalizing scale. See Figure 23 for graphs showing main group by time interaction effects for alexithymia and relevant subscales.

Figure 23

Main Outcome Effects for Alexithymia and Subcales



Note. main group by time interaction effects of mindfulness training by group (mindfulness versus control) and time (pre, mid and post) on alexithymia subscales forming he cognitive type of alexithymia.

H2: Main Psychophysiological Outcome

H2: Physiological Arousal (Skin Conductance Response to IAPS)
There was a significant group by time interaction *(F(1,34) =4.62, p= .039 ηp²=.12), with the MBSR group showing decreased arousal and the control group showing increased arousal in a crossover effect.* There were no significant effects of time, *(F(1,34)=.13, p=.721, ηp² =.00) or group, (F(1,34)= .07, p= .801, ηp² =.00)* There was no significant group difference at pre *(p=.415)* or post *(p=.278)*.

H2: IAPS Arousal
There were no significant effects of time *(F(1,34)= .21, p=.647 ηp² =.01),* group *(F(1,36)= 1.32, p= .258, ηp² =.04) or* group by time main interaction effects *(F(1,34)= .87, p= .872, ηp² =.03).* There were no significant group difference at pre *(p=.210)* or post *(p=.433)*.

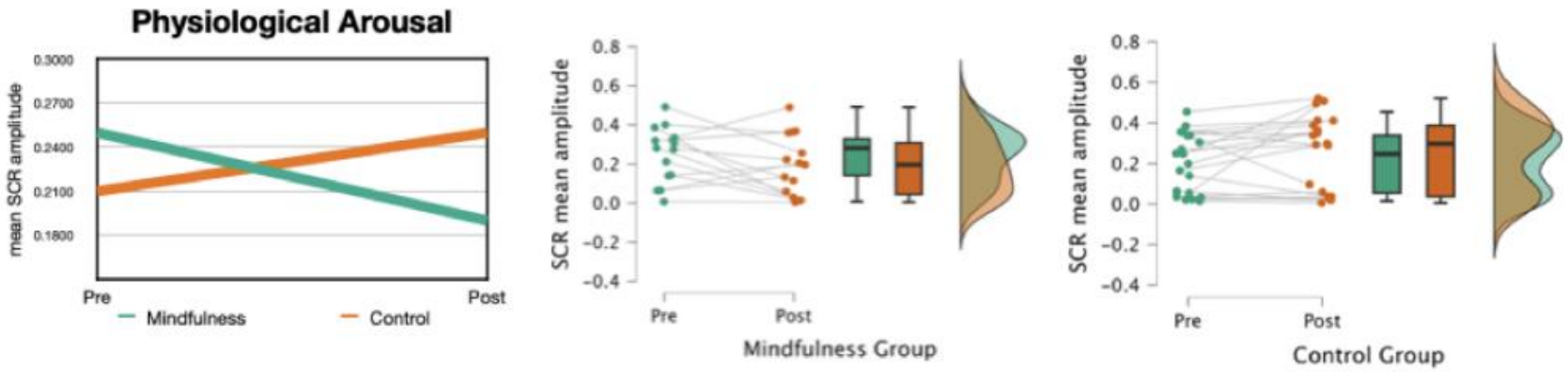
H2: IAPS Valence
There were no significant effects of time *(F(1,34)= .38, p =.543 ηp² =.01),* group *(F(1,36) = .99, p =.328, ηp² =.03)*. There was no significant group by time main interaction effect *(F(1,34) = 1.50, p= .229, ηp² =.04).* There were no significant group difference at pre *(p=.603)* or post *(p=.215)*.

H2: IAPS Dominance
There were no significant effects of time *(F(1,34)= .85, p =.362 ηp² =.03),* group *(F(1,36) = .07, p =.800, ηp² =.00)*. There was no significant group by time main interaction effect *(F(1,34) = 1.94, p= .173, ηp² =.05).* There were no significant group difference at pre *(p=.796)* or post *(p=.511)*.

There was a significant group by time interaction effect for the skin conductance response to the IAPS emotional elicitation task, with the MBSR group showing reduced arousal at post-intervention and the control group showing increased arousal in a crossover effect. However there were no group differences at pre or post which may be a feature of crossover effects. Finally, there were no effects of MT on self-rated arousal, valence or dominance during the IAPS emotion elicitation task. See Figure 24 for graphs of change on objective, implicit emotion regulation, including raincloud plots for individual results.

Figure 24

Mean and Individual Effects of Mindfulness Training on Psychophysiological Emotion Regulation



Note. Psychophysiological arousal is measured via skin conductance response amplitude. Raincloud plots show individual participant data, separated by group (mindfulness or control), a visual representation of trends toward change or no change and in what direction.

H3: Main Mediator Outcomes

Interoceptive Emotion Regulation

IA Attention Regulation
There were significant effects of time, *(F(1,37) = 58.80, p<.001 ηp² =.61)*, group *(F(1,37) = 10.94 p= .002, ηp² =.23),* which was qualified by a significant group by time main interaction effect *(F(1,37) = 23.34, p< .001 ηp² =.39)*. There was no group difference at pre *(p=.295)*, with a significant group difference effect at post *(p<.001)*.

IA Body Listening for Insight
There were significant effects of time, *(F(1,37) = 65.03, p<.001 ηp² =.64)*, group *(F(1,37) = 4.66, p= .037, ηp² =.11),* which was qualified by a significant group by time main interaction effect *(F(1,37) = 33.38, p< .001 ηp² =.47)*. There was no group difference at pre *(p=.974)*, with a significant group difference effect at post *(p<.001)*.

Mindful Emotion Regulation

MF Attention (FFMQ AWA)
There was a small significant effect of time, *(F(1,37) = 4.17, p=.048 ηp² =.10)* but no significant group effect *(F(1,37) = 2.85, p= .100, ηp² =.07).* There was a significant group by time main interaction effect *(F(1,37) = 22.47, p< .001 ηp² =.38)*. There was no group difference at pre *(p=.415)*, with a significant group difference effect at post *(p=.001)*.

MF Acceptance (FFMQ NR)
There was a significant effect of time, *(F(1,37) = 37.93, p<.001 ηp² =.51)* but no significant group effect *(F(1,37) = 3.67, p= .063, ηp² =.11).* There was a significant group by time main interaction effect *(F(1,37) = 15.71, p< .001 ηp² =.30)*. There was no group difference at pre *(p=.940)*, with a significant group difference effect at post *(p=.001)*.

There were significant group by time main interaction effects for two interoceptive subscales corresponding to Step 1 (attention regulation) and Step 2 (body listening) UFM processes. as well as the mindful emotion regulation variables (attention and acceptance). The mindfulness training significantly improved all emotional regulation variables in the mindfulness group, over the control group.

Multiple Mediation Effects

To reduce the influence of common method variance, change in mediators was assessed between pre-to-post, while change in outcome was also assessed pre-to-post. Results will be written up for pre-to-post change in indirect effects on the outcome measures. A

BVAQ score summing identifying and analyzing was used for mediation analysis due its significant outcome effects via factorial RM ANOVA.

H3: Multiple Mediation Analysis of Global IA and Global MF

To analyze the H4 mediators of overall interoceptive versus mindful emotion regulation, both overall variables were tested together in a bootstrapped mediation model (Process Model 4) for total and specific indirect effects on the mental health outcomes (alexithmia, distress, stress, anxiety). To reduce the influence of common method variance, change in mediators was assessed between pre-to-post, while change in outcome was also assessed pre-to-post. Results will be written up for pre-to-post change in indirect effects on the outcome measures.

For the alexithymic 'emotional awareness' outcome, results revealed a specific indirect mediation effect of overall interoceptive emotion regulation (b= 4.9211, BootSE= 1.7289, CI 1.4654, 8.4404). There was no specific indirect mediation effect for overall MF emotion regulation (b= -.8408, BootSE=1.2745, CI -2.9711, 2.1423). There was a total indirect mediation effect of both overall interoceptive and mindful emotion regulation (b= 4.0803, BootSE= 1.6006, CI 1.4463, 7.7233). **Global interoceptive emotion regulation functions as a unique mediator of change (for alexithymic deficit in emotional awareness), over and above the mediational influences of overall mindful emotion regulation. There is also a total meditational effect of both overall interoceptive and mindful emotion regulation strategies (for alexithymia).**

For psychological distress, results revealed a specific indirect mediation effect of overall mindful emotion regulation (b= 1.5476, BootSE= .8896, CI .0738, 3.5848). There was no specific indirect mediation effect for overall interoceptive emotion regulation (b= -.3414, BootSE=1.4404, CI -3.6414, 2.0216), nor was there a total indirect mediation effect of both overall interoceptive and mindful emotion regulation (b= 1.2062, BootSE= 1.1519, CI -1.2356, 3.3304). **Global mindful emotion regulation functions as a unique mediator of change (for psychological distress), over and above the mediational influences of overall interoceptive emotion regulation. There is no total meditational effect of both overall interoceptive and mindful emotion regulation strategies (for distress).**

For perceived stress, results revealed a specific indirect mediation effect of overall mindful emotion regulation (b= 5.6349, BootSE= 1.6574, CI 2.7412, 9.2801). There was no specific indirect mediation effect for overall interoceptive emotion regulation (b= 1.5400, BootSE=1.4007, CI -1.6328, 3.8758). There was a total indirect mediation effect of both overall interoceptive and mindful emotion regulation (b= 7.1749, BootSE= 1.8263, CI 3.5323, 10.8524). **Global mindful emotion regulation functions as a unique mediator of change (for perceived stress), over and above the mediational influences of global interoceptive emotion regulation. There is also a total meditational effect of both globalinteroceptive and mindful emotion regulation strategies (for stress).**

Finally for generalized anxiety, results revealed a specific indirect mediation effect of overall mindful emotion regulation (b= 3.0963, BootSE= 1.1329, CI .7818, 5.2503). There was no specific indirect mediation effect for overall interoceptive emotion regulation (b= -.2433, BootSE=1.8132, CI -4.2252, 3.2067), nor was there a total indirect mediation effect of both overall interoceptive and mindful emotion regulation (b= 2.8530, BootSE= 1.6304, CI -1.0593, 5.5337).

Global mindful emotion regulation functions as a unique mediator of change for 3 main mental health variables (anxiety, distress and stress) over and above the mediational influences of global interoceptive emotion regulation. See Table 16 for mediation analysis results for mindful versus interoceptive emotion regulation variables.

Table 16

Mediation Results for Mindful Versus Interoceptive Emotion Regulation

Total Effect (MT—>Outcome)	Direct Effect (MT—>Outcome)	Hypothesis: Mediation Relationship	Indirect Effect	SE*	Confidence Interval*		Inference
					Lower Bound	Upper Bound	
Alexithymia (Emotion Regulation)							
4.3451 (.0012)	.2648 (.8838)	MT—>Total global IA and MF—>Alexithymia	4.0803	1.6006	1.4463	7.7233	No Mediation
		MT—>global Interoceptive Awareness—>Alexithymia	4.9211	1.7289	1.4654	8.4404	**Mediation**
		MT—>global Mindfulness—>Alexithymia	-0.8408	1.2745	-2.9711	2.1423	No Mediation
Psychological Distress							
3.3074 (.0009)	2.1012 (.1562)	MT—>Total global IA and MF—>Distress	1.2062	1.1519	-1.2356	3.3304	No Mediation
		MT—>global Interoceptive Awareness—>Distress	-0.3414	1.4404	-3.6414	2.0216	No Mediation
		MT—>global Mindfulness—>Distress	1.5476	0.8896	0.0738	3.5848	**Mediation**
Anxiety							
4.6194 (.0031)	1.7669 (.4259)	MT—>Total global IA and MF—>Anxiety	2.8530	1.6304	-1.0593	5.5337	No Mediation
		MT—>global Interoceptive Awareness—>Anxiety	-0.2433	1.8132	-4.2252	3.2067	No Mediation
		MT—>global Mindfulness>Anxiety	3.0963	1.1329	0.7818	5.2503	**Mediation**
Stress							
8.7521 (.0000)	1.5772 (.3703)	MT—>Total global IA and MF—>Stress	7.1749	1.8263	3.5323	10.8524	No Mediation
		MT—>global Interoceptive Awareness—>Stress	1.5400	1.4007	-1.6328	3.8758	No Mediation
		MT—>global Mindfulness—>Stress	5.6349	1.6574	2.7412	9.2801	**Mediation**

Note. * Estimated on 5,000 bootstrap samples using the SPSS PROCESS Model 4 Macro (Preacher & Hayes, 2004).
Bold characters indicate unique indirect mediation effects. MT = Mindfulness Training IA= Interoceptive Awareness
MF = Mindfulness Disposition SE = standard error; CI = confidence interval; SD = Standard deviation;
ES = Effect size (ratio of the indirect effect to the total effec

4. Discussion

In the last decades, an immense interest has surged towards the concept and applications of mindfulness as well as the concepts of 'mindful' emotion regulation (Chambers et al., 2009; Farb et al., 2012; Grecucci et al., 2015; Chiesa et al., 2013) and 'embodied' or 'interoceptive' emotion regulation (Guendelman et al., 2017). Research has demonstrated that mindfulness and emotion regulation are related, but the underlying processes are still not fully understood (Iani et al., 2019). It remains unclear which mechanisms, via mindfulness practice, contribute to emotion regulation and the association and dissociation between the two constructs (Heppner et al., 2015). To date, research has been mixed and has not provided clear answers (Iani et al., 2019).

As an exploration of psychological and psychophysiological processes modulating mindfulness-induced emotion regulation, this study examined the impact of mindfulness training on (implicit) physiological and (explicit) self-rated arousal, valence and control induced by a visual emotion elicitation task, as well as on self-reported emotional dysregulation (alexithymia facets). This study further investigated the mediating roles of mindful versus interoceptive emotion regulation capacities using multiple mediation analyses. The hypotheses of this third study were that: 1. mindfulness training would improve specific subscales of alexithymia (identifying, verbalizing, analyzing) which correspond to the emotional awareness component of emotion regulation (ie., cognitive alexithymia); 2. mindfulness would improve implicit emotion regulation (psychophysiological measure of arousal) and related arousal, valence and dominance self-ratings during an emotion elicitation task; 3. interoceptive attention regulation and mindful attention would emerge as a unique (ie., specific) emotion regulation mediators of mindfulness-induced wellbeing, above and beyond the meditational effects of interoceptive mind/body awareness and mindful acceptance. This hypothesis was informed by the findings from study 1 and 2 as well as the UFM framework asserting that attentional processes are strengthened first before the strengthening of attitudinal processes (Rogge & Daks, 2021); and 4. mindful emotion regulation would emerge as a unique mediator beyond the mediational influence of 'interoceptive' emotion regulation. This hypothesis is yet again informed by the findings from the first two studies that mindfulness mechanisms exert stronger mediational effect on mental health outcomes than interoceptive mechanisms.

In the first hypothesis, the mindfulness training was expected to improve cognitive alexithymia, which included specific subscales of (identifying, verbalizing, analyzing). Cognitive alexithymia can be proposed to relate to deficits in emotional awareness, which has been shown in the literature to be an important early component of emotion regulation. This hypothesis was partially validated for participants with baseline clinical alexithymia before starting the mindfulness training. This cohort reported significant attenuation of the cognitive type of alexithymia (Taylor & Bagby, 2013) as well as the analyzing subscale of

cognitive alexithymia, though not on the identifying or verbalizing scale. The cognitive type of alexithymia identified by Vorst and Bermond (2001) was of particular interest in this study due to the association between alexithymia and poor interception and deficits in emotion regulation. Supporting the hypothesis, cognitive alexithymia was found to be attenuated in the cohort of participants who presented with high baseline alexithymia prior to the start of the mindfulness programme. Cognitive aspects of alexithymia involve difficulties in verbalizing and identifying feelings (Taylor & Bagby, 2013; Fonagy et al., 2002) which is linked to deficits in emotion awareness of others and empathy, connoting an externalized thinking style (Grynberg et al., 2010; Moriguchi et al., 2007). This study analyzed participants with high baseline alexithymia as evidence suggests changes via mindfulness training are evident in those with high trait alexithymia (McGillivray et al., 2017; Norman et al., 2019). As expected, cognitive alexithymia was ameliorated by mindfulness training in participants with high baseline alexithymia.

The second hypothesis proposed that the mindfulness training group would reduce skin conductance responses at the end of the 8-week training interval, when presented with emotionally-eliciting images. There was a small significant improvement in the (implicit) biomarker of emotion regulation, and at the individual participant level, raincloud plots revealed that a cohort of participants demonstrated significant reductions in SCR amplitude post mindfulness, compared to the control group. A limitation of this study that may have contributed to no significant change in self-reported valence and arousal was the small sample size.

The third hypothesis posited that interoceptive and mindful emotion regulation facets of attention (mindful attention and IA attention regulation) would emerge as unique emotion regulation mediators of mindfulness-induced wellbeing, above and beyond the meditational effects of the attitudinal components of emotion regulation (acceptance in mindfulness and mind/body integration in interoception). This hypothesis was informed by the findings from study 1 and 2 as well as the UFM framework asserting that attentional processes are strengthened first before the strengthening of attitudinal processes (Rogge & Daks, 2021). The hypothesis was only partially validated. In the stress outcome, both interoceptive and mindful attentional processes emerged as significant indirect mediators, above and beyond the mediational influences of the attitudinal processes related to acceptance and mind/body integration. In the psychological distress outcome, mindful acceptance emerged as a unique mediator of wellbeing, whereas mind/body awareness emerged as a unique negative mediator of distress. Finally mind/body integration was found to be a unique mediator of improved cognitive alexithymia, with no unique mediational influence emerging for anxiety.

The fourth hypothesis was that overall mindful emotion regulation would demonstrate a stronger mediational influence than overall interoceptive emotion regulation on mental health outcomes. This hypothesis was yet again informed by the findings from the first two studies that mindfulness mechanisms exerted stronger mediational effect on mental health

outcomes than interoceptive mechanisms. This hypothesis was mostly validated. Comparing mindful versus interoceptive emotion regulation (ER) strategies, ‘mindful ER’ emerged as a unique mediator of distress, anxiety and stress, while ‘interoceptive ER’ mediated alexithymia.

5. Conclusion

This third study explored the intertwined and possibly distinct conceptualizations of emotion regulation indicating that there may be a a slim yet clinically meaningful differentiation between embodied/interoceptive emotional regulation and mindful emotion regulation in exerting their mediational influences on psychological wellbeing. Indeed, there are limited longitudinal intervention studies exploring the mediating role of embodied emotional awareness and regulation in mindfulness-induced wellbeing and the correspondence of self-report to psychophysiological measures of implicit emotion regulation. This study considered diverse psychological and clinical evidence, with a view to exploring a psychophysiological measurement of implicit emotional reactivity (skin conductance responses to emotion-provoking images) that may be attenuated by a standardized mindfulness intervention. In addition, this study was concerned with the contrasting mediational influences of a ‘mindful’ versus ‘interoceptive’ style of emotion regulation in influencing mental health outcomes, including alexithymia (emotional dysregulation).

Further, alexithymia is proposed as specifically an emotional regulation deficit based on limited ability to identify subjective emotional experience (lack of emotional awareness) and the emotional states of others (Edwards & Lowe, 2021). Cognitive alexithymia is linked to deficits in emotion awareness of others and empathy, connoting an externalized thinking style (Grynberg et al., 2010; Moriguchi et al., 2007). This study focused on participants with high baseline alexithymia as evidence suggests changes via mindfulness training are evident in those with high trait alexithymia (McGillivray et al., 2017; Norman et al., 2019). This study validates this finding, with participants meeting threshold for clinical alexithymia showing significant improvement in emotional awareness and clarity. Results suggest that interoceptive emotional awareness (a key precursor of embodied emotion regulation) may be a core interoceptive emotion regulation mechanism mediating mindfulness-induced salutary benefits for the reduction of alexithymia.

Patterns of skin conductance response (SCR) have been associated with anxiety, emotional responses, and responses to threat (Craske et al., 2008). Evidence exists that MBSR can attenuate the degree of unconscious, implicit emotional arousal to visual affective stimuli via skin conductance measurement which can represent changes to emotional reactivity and regulation (Correira et al., 2023). This was borne out in this study, despite the small sample size and a limitation in this study of not focusing on skin conductance responses to negative images exclusively. Reduced emotional reactivity to aversive stimuli is a core acceptance and decentering skill cultivated by mindfulness. It is

worth highlighting that there is no clear biomarker or objective test for anxiety and thus the ways it can be ameliorated might differ (Roseberry et al., 2023). The identification of a valid biomarker for anxiety, attenuated by mindfulness trainings, would be a worthwhile avenue of research, given the strong evidence that mindfulness reduces anxiety, including its somatic manifestations. Further research is needed as there may be differing pathways and biomarkers through which mindfulness and interoception influences emotion regulation and emotional health.

Heppner and colleagues (2015) provide evidence of several distinct pathways through mindfulness exerts its influence on emotion regulation, including acceptance of negative emotional experience, nonreactivity to difficult emotional stimuli and experience, decentering or 'psychological distancing' and increased emotional stability. Of interest, there is some evidence that levels of nonacceptance, such as experiential avoidance (Kashdan et al., 2006) emotional nonacceptance (Yoon et al., 2018) and distress intolerance are linked to psychological symptoms (Lindsay & Creswell, 2019). Accordingly, emotion regulation research indicates that acceptance is an effective strategy (Kohl et al., 2012). Therefore, a hypothesis can be advanced that mindfulness acts to target specific emotion regulation deficits of emotion-related disorders such as acceptance (instead of avoidance), present moment focus (instead of rumination) and bodily emotional awareness (instead of suppression). According to a multidimensional model of emotion regulation developed by Gratz and Roemer (2004), three of the six factors are of particular relevance, namely (1) inability or unwillingness to accept unwanted emotion, (2) limited emotional awareness and, (3) lack of emotional clarity.

This study found that all three factors of the Gratz and Roemer (2004) multidimensional emotion regulation model were significantly targeted by the mindfulness training, as evidenced by improvements in the alexithymia subscales of identifying and analyzing. Further, this doctoral study found significant enhancement of the MAIA emotional awareness subscale as well as the nonreactivity facet of the FFMQ, which is a metric of acceptance and noninterference with difficult emotions and bodily sensations. Taken together, the results from this study offer a strong indication of the existence and mechanistic significance of mindful and interoceptive styles of emotion regulation that are divergent from one another and demonstrably distinct from top down control and avoidance strategies associated with habitual and effortful emotion regulation (Wiesglosz et al., 2019).

Furthermore, preliminary findings from this study indicate that mindful emotion regulation strategies mediate the beneficial outcomes of anxiety, distress and stress, whereas the interoceptive emotion regulation capacities mediate the positive alexithymia outcomes. In sum, it can be argued that mindful and interoceptive emotion regulation styles were validated by this study, and that they exert contrasting mediational influences on emotional health. Mindful emotion regulation appears to improve mental health, while interoceptive emotion regulation attenuates the emotional dysregulation implicated in alexithymia.

5. PhD Discussion/Conclusion Chapter

Key findings

This study considered diverse psychological, neurophysiological and clinical evidence, with a view to exploring psychophysiological measurements of implicit emotional reactivity (skin conductance responses to emotion-provoking images) and objective interoceptive accuracy (cardioception) that may be enhanced by mindfulness training and may correspond to self-reported emotional regulation (acceptance) and interoceptive awareness improvements. This study also explored core mindfulness change mechanisms, responding to calls for more NIH-defined Stage 3 efficacy trials in the community (Dimidjian & Segal, 2015) and MHR-guidance on pragmatic evaluation and process evaluation research in real world settings (Skivington et al., 2021).

In line with the MBSR literature, the mindfulness condition reported significant outcome effects in all self-report study variables (stress, distress and anxiety) as well as the secondary outcomes of (mindfulness and interoceptive awareness skills).

This study may have yielded promising evidence that mindfulness training promotes emotion regulation using an objective, implicit biomarker. The mindfulness condition demonstrated a small but significant reduction in sympathetic arousal while undertaking an emotion-eliciting behavioural task, while the control showed a trend toward increased arousal. This is an interesting finding, suggesting that the mindfulness group developed an enhanced ability to regulate their emotions. Skin conductance response is an objective physiological measure of sympathetic nervous system activity that indicates general implicit emotional arousal, both negative and positively valenced. Patterns of skin conductance response (SCR) have been associated with anxiety, emotional responses, and responses to threat (Craske et al., 2008). Evidence exists that MBSR can attenuate the degree of unconscious, implicit emotional arousal to visual affective stimuli via skin conductance measurement which can represent changes to emotional reactivity and regulation (Correira et al., 2023).

Interoceptive accuracy, using the heartbeat counting task, was not improved by mindfulness practice, however there was significant positive enhancement of interoceptive metacognition (IMC) as defined by Garfinkel and colleagues (2015) in their 3-dimensional model of interoception. IMC represents the higher order insight into whether one's detection of bodily signals such as heartbeat perception is accurate or not (Garfinkel et al., 2015) and this finding validates that heartbeat counting may not be an appropriate measurement of adaptive interoceptive awareness cultivated in mind/body therapies (Desmedt et al., 2016).

Mediation findings

Using the UFM sequential mediation framework, the Step 2 process **(acceptance)** emerged as a unique mediator, outperforming Step 1 process (attention) in mediating distress attenuation. Whereas for stress, both Step 1 (attention) and Step 2 (acceptance) each appear to have their own unique mediational pathway to stress reduction. No unique mediation was present in reducing anxiety. This is supported by the large body of evidence that present moment awareness and other attentional processes improve stress. A meta-analysis and systematic review (Pascoe et al., 2017) found strong evidence for the attentional facets of mindfulness improving physiological stress markers such as cortisol, heart rate, and blood pressure. Studies have found that high attentional control is associated with lower levels of anxiety and depression (Olafsson et al., 2011; Reinholdt-Dunne et al., 2013), thereby highlighting attentional control as a relevant therapeutic target.

Literature on acceptance as a powerful mindfulness mechanism is growing (Lindsay et al., 2018). Heppner and colleagues (2015) provide evidence of several distinct pathways through mindfulness exerts its influence on emotion regulation, including acceptance of negative emotional experience, nonreactivity to difficult emotional stimuli and experience, decentring or 'psychological distancing' and increased emotional stability. Of interest, there is some evidence that levels of nonacceptance, such as experiential avoidance (Kashdan et al., 2006) emotional nonacceptance (Yoon et al., 2018) and distress intolerance are linked to psychological symptoms (Lindsay & Creswell, 2019). Accordingly, emotion regulation research indicates that acceptance is an effective strategy (Kohl et al., 2012).

Led by the UFM step model, this study conducted parallel mediation analysis on interoceptive subscales that were indicated to be relevant to Step 1 and Step 2 processes (Hanley et al., 2017). The result was that 'bodily attention regulation' (Step 1) emerged as a unique mediator, outperforming 'body listening' (Step 2) in predicting the improvements in both anxiety and stress produced by mindfulness training. There was no unique mediation effect of interoceptive processes on psychological distress. Finally, 'body listening' (Step 2) emerged as a unique mediational influence on mindfulness-induced amelioration of alexithymia, overriding the mediational influence of attention regulation (Step 1).

These findings offers tentative insight into the potential psychological benefits of cultivating the capacity to move from thinking to sensing mode and sustaining attention to the body. Worry, a feature of anxiety, consists of two main components, the tendency to be reactive to perceived threats and difficulties in disengaging from self-referential processing (Johansenn et al., 2022), both of which have been shown to be improved by nonreactivity/acceptance (Step 2 process) and present moment awareness (Step 1 process) components of mindfulness (Simeone & Saldini, 2023). This suggests that MBSR may train the spotlight of attention to one's body with an attitude of listening, trusting and regulating, providing the necessary decentring, or 'psychological distance' from difficult inner experience to enable more adaptive emotion regulation processes to be deployed (Fissler et al., 2016; Perez-Pena et al., 2021). Awareness and attending to the body is an important mindfulness orientation cultivated in MBSR, enabling disengagement from automatic negative reactivity toward challenging inner experience in favour of a present moment, bodily awareness mode that gradually promotes a sensing and being mode that is less emotionally and cognitively biased and effortful. With regard to the alexithymia finding, this suggests that Step 2 acceptance-oriented interoceptive skills (listening to the body for insight) facilitate the attenuation of alexithymic symptoms. This may indicate that alexithymia is a transdiagnostic marker of poor interoception and emotion regulation functioning, rather than a personality trait (Preece et al., 2024).

The lack of overriding mediational finding for global interoceptive awareness over mindfulness skills in mediating the primary mental health outcomes conflicts with the evidence from neuroscience which has found direct neuroplastic changes in the activation of the interoceptive brain network, namely the insular cortex (Gibson, 2019). For the cognitive cluster of alexithymia, however, global IA uniquely mediated the reduction in alexithymic symptoms associated with emotional awareness impairments (ie., the identifying and analyzing subscales of the BVAQ). This strengthens the proposition that alexithymia is a transdiagnostic marker of poor interoception and emotion regulation functioning. A more unexpected potential finding was the improvement of emotional awareness in alexithymia (cognitive type) in subjects with clinical alexithymia at baseline. This is an interesting result as the traditional view of alexithymia is as a fixed personality trait (Preece et al., 2024). Cognitive aspects of alexithymia involve difficulties in verbalising and identifying feelings (Taylor & Bagby, 2013; Fonagy et al., 2002) which is linked to deficits in emotion awareness of others and empathy, connoting an externalised thinking style (Grynberg et al., 2010; Moriguchi et al., 2007). This study analysed participants with high baseline alexithymia as evidence suggests symptom reduction through mindfulness practice is more likely to be achieved by people with high trait alexithymia (McGillivray et al., 2017; Norman et al., 2019).

Finally it was surprising to find that nonjudging was only moderately improved by MBSR, as it is described in the literature as a strong acceptance process. An explanation may be that nonjudging takes longer to fully cultivate, and that the positive mediational effects of nonjudging as an acceptance factor would emerge with longer training than the standard MBSR, which is in line with UFM sequential mediation model (Rogge & Daks, 2021).

Answers to research questions

H1: MBSR led to significant improvements in all mental health and self-regulation variables

H2: Interoceptive accuracy did not improve, however a raincloud plot of individuals suggests a trend toward improve cardioception in the mindfulness group. In addition, there was a small but significant enhancement of metacognitive awareness, the capacity for insight about one's interoceptive ability.

H3: There was a significant interaction effect, with crossover pattern, indicating that objective emotion regulation, measured using a biomarker of sympathetic nervous system arousal, was slightly enhanced in the MBSR group and slightly decreased in the control condition.

H4: In the multi-mediation model of Step 1 and Step 2 UFM mindfulness processes, acceptance (Step 2) uniquely mediated the mindfulness-distress amelioration relationship, overriding the mediational influence of attention (Step 1). Both acceptance and attention each demonstrated a unique mediational influence on stress reduction via MBSR. There was no unique mediational finding for anxiety.

H5: In the multi-mediation model of Step 1 and Step 2 UFM interoceptive processes, attention regulation (Step 1) uniquely mediated mindfulness-induced anxiety amelioration and stress reduction, overriding the mediational influence of body listening (Step 2)

H6: In the multi-mediation model of mindful versus interoceptive emotion regulation, global mindfulness uniquely mediated the mindfulness - distress and stress reduction relationships, while interoception uniquely mediated the mindfulness-alexthymia improvement relationship

Theoretical Implications

A promising outcome of this study is that it may contribute to early validation of the sequential UFM mediational framework and further investigation of the mechanistic role of IA in mindfulness-based therapies.

The findings have several meaningful implications. First, they advance understanding of how two core mindfulness processes (attention and acceptance) and interoceptive processes contribute to psychological wellbeing in a real-world mindfulness programme, addressing a key gap concerning exploration of mechanisms in applied settings. Second, by incorporating objective psychophysiological measures (heartbeat awareness, skin conductance) alongside self-report, the research moves beyond self-report-only evidence to possibly demonstrate convergent validity for proposed pathways. Third, the study contributes to methodological best practices in mindfulness research by integrating laboratory tasks with community-based protocols, providing a template for future Stage 3 efficacy research in real-world communities. Taken as a whole, the work supports a mechanism-informed, ecologically valid understanding of how MBSR can reduce stress and improve self-regulation, with implications for scalable implementation and policy recommendations.

While there was no significant improvement in detecting interoceptive signals, the interoceptive metacognition finding appears promising as a form of insight into one's interoceptive abilities that could be mapped to mindfulness approaches that do not seek to control or strive for positive outcomes, but to change how to relate to difficult inner experience. In addition, this study adds to the inconsistent evidence base of a relationship between mindfulness and interoceptive accuracy (Khalsa et al., 2020; Treves et al., 2019). This contradictory evidence may depend on the type of mindfulness practice used and the depth and length of mindfulness 'dosage' (Todd & Aspell, 2022). With regard to the measurement of 'objective' interoceptive accuracy, this study's findings contribute to the growing body of evidence that cardioception may not be a relevant psychophysiological marker implicated in mind/body therapies (Treves et al., 2019; Zamariola et al., 2018; Desmedt et al., 2018). In fact, studies suggest that heartbeat counting performance relies on non-interoceptive processes, including reliance on general *beliefs* about heartbeat rates that may be better measured by the metacogntive insight metric (Desmedt et al., 2018; Zamariola et al., 2018; 2019; Ring et al., 2015).

Practical/Clinical Implications

Several important strengths of the present study are its ecological validity with a healthy, stressed sample with mixed clinical and nonclinical features and which contributes to the scarce literature on MRC complex intervention research guidance (Skivington et al., 2021) and NIH Stage 3 efficacy studies based in community settings of standardised MBIs (Onken et al., 2015) Secondly its external validity in comparison with other RCTs investigating MBIs as the sample reflects a population that would likely participate in mindfulness training in the community; thirdly its inclusion of multidimensional instruments and the assessment of interoceptive awareness as a change mechanism which is limited in the mindfulness literature; and finally its assessment of relevant mindfulness process

variables to advance the literature on the transdiagnostic nature of MBSR and the differential and interrelatedness of core mechanisms involved in explaining its positive mental health effects

The Medical Research Council's updated framework concerning complex intervention research, emphasises real world context and system change, which is relevant to this PhD. In fact, this doctoral work was co-funded by the mental health charity Mind, under a multi-agency Public Health/NHS partnership called the City and Hackney Psychological Therapies and Wellbeing Alliance, which commissions the East London City and Hackney Wellbeing Network and Mind's psychological therapies service to collaborate with other statutory and voluntary sector providers to deliver a widescale programme of clinical and psychosocial groups to enhance wellbeing and recovery from mental ill health. Partly through the partnership between City St. George's and Mind, a large programme of MBIs and other mindfulness, compassion-focused and acceptance-based interventions, as well as MBI teacher trainings, have been implemented and delivered by Mind and its partner agencies over the past few years.

Future community-based efficacy research should significantly increase sample size and consider a wider multi-site programme and should replace waitlist control with active controls such as CBT to improve study design and ensure that future participants do not have to experience long waits for treatment. Future research should also include follow up data and analysis of home practice data.

Original contribution to the field

Significance and contribution

The study advances theory-driven understanding by testing the Unified Flexibility and Mindfulness (UFM) framework (Rogge & Daks, 2021), which posits that core mindfulness processes, attentional focus and acceptance, operate in sequence, independently and interactively to mediate the beneficial outcomes of mindfulness-based interventions. Analyses were conducted within a parallel mediation framework to identify whether each mediator uniquely contributes to mental health outcomes, while also examining their combined, synergistic effects.

The UFM model was adopted because it offers a cohesive account of how mindfulness practice translates into clinically meaningful change through key mediators of mindful attention and acceptance. To address a notable gap in the clinical literature, two interoceptive awareness subscales were incorporated into a modified UFM framework, aligning interoceptive processes with mindfulness-mediated pathways. Shifting away from Step 3 values-based actions that are less central to MBSR and more relevant to Acceptance and Commitment Therapy, these modifications emphasise acceptance and attention led mechanisms more directly relevant to mindfulness-based stress reduction (MBSR) outcomes (Parker et al., 2024).

Physiological measurement of mindfulness processes

To expand understanding of the mechanisms beyond self-report, the study integrated objective physiological indices to capture mindfulness-related processes. Interoceptive accuracy was assessed with the heartbeat counting task, offering a behavioural index of bodily awareness that may reflect the body listening component of IA. Sympathetic arousal was indexed via skin conductance level (SCL) measured during an emotion-eliciting picture task, providing an objective marker of autonomic reactivity and regulation linked to affective processing and emotion regulation. Together, these exploratory physiological measurements enable future investigation of whether these biomarkers correspond to subjective indices of wellbeing and emotional health or whether other objective measurements such as HRV represent a more precise corresponding measure of mindfulness based emotional and physical functioning.

Context and scope

Recognising that community-based RCTs are relatively rare and embed additional resource, context, and logistical complexities, this study contributes methodologically and substantively beyond laboratory settings. The community trial design enhances external validity and informs real-world applicability, including considerations of recruitment, engagement, adherence, and programme delivery across diverse settings. The integration of interoceptive and autonomic indicators within a theory-driven mediation framework offers a template for future trials seeking to map multi-level mechanisms of mindfulness interventions in pragmatic contexts.

Mechanisms, significance, and implications for Stage 3 real-world efficacy

Mediation analyses using the UFM framework revealed distinct, mechanism-specific pathways. Acceptance (Step 2) uniquely mediated reductions in psychological distress, while bodily attention regulation (Step 1) uniquely mediated improvements in anxiety and stress, highlighting complementary roles for present-moment awareness and nonreactive acceptance be tested and deployed in real life settings. These findings echo contemporary theory on mindfulness as a dual process of attention and acceptance and suggest that different mechanisms may drive specific and divergent outcomes. The lack of a unique mediation for overall anxiety, and the limited interoceptive results (metacognitive gains without improved interoceptive accuracy) underscore the value of a mechanism-focused, multi-modal assessment in Stage 3 efficacy research. Overall, the study contributes to mechanism-informed, ecologically valid evidence for MBSR and offers practical guidance for real-world implementation and scalability in community settings.

Limitations of the study

Despite the promising signals, a number of limitations affect the precision and generalisability of these findings. The study's small, single-site sample (approximately n=43 at baseline; final n=17 in MBSR and n=22 in control after 9% attrition) reduces

statistical power and increases susceptibility to sampling variability, with potential baseline imbalances despite randomisation.

Although an a priori power analysis suggested adequate power under ideal conditions, real-world deviations (non-normal data, uneven group sizes, missing data) likely widened confidence intervals and inflated uncertainty. The absence of an active control limits control for nonspecific factors (e.g., group support, expectancy). The use of a wailist control condition also limits the attribution of effects to the mindfulness intervention. The sample's characteristics (predominantly female, stressed, heterogenous, nonclinical) constrain generalisability to more specific populations and broader settings.

Additionally, there was a lack of longer-term follow-up data to test durability of effects or to gain more specificity relating to the temporal sequencing of Step 1 and Step 2 mechanisms. Home practice data was not analysed, which precludes examining dose response relationships, and follow up assessments were not conducted to evaluate the durability of effects or causal sequences of mechanisms.

Finally, several mediation analyses may have been underpowered, and reliance on self-report measures (aside from select physiological indices) introduces potential biases such as social desirability. The reliance on self-report measures for many outcomes; limited objective markers beyond selected physiological indices. The findings are preliminary and require replication in larger, multi-site trials with preregistered analyses and more diverse samples.

Concluding statement

This body of work advances mindfulness science from controlled trials to real world impact by grounding analyses in the Unified Flexibility of Mindfulness framework and integrating multi-method evidence, including mediation analyses of attention and acceptance alongside objective physiological indices. Demonstrating that acceptance and attention processes independently and uniquely mediate stress reduction, with interoceptive and autonomic markers offering convergent validation, the study sheds light on how mindfulness-based interventions (MBIs) work but also for whom and in what contexts they are most effective. The work's trajectory, from theory to community practice, culminating in a large scale programme implemented within the City and Hackney Wellbeing Network, highlights the potential for MBIs to drive system level improvements in mental health and wellbeing. These findings carry meaningful implications for policy, service design, and scalable training, underscoring the value of multi-site, pragmatic research that informs sustainable, accessible interventions. Looking ahead, the study sets a rigorous agenda for future work: larger, multi-site trials with active comparators, preregistered mediation analyses, longer follow-ups, and continued integration of physiological and experimental data, with the aim to uncover the active ingredients of mindfulness-based emotional health to optimise real world impact.

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