Effect of Mindfulness-Based Interventions on Interoception: A Meta-Analysis

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Abstract

Background: There is increasing evidence that interoception - the ability to sense, appraise, or attend to changes in the physiological and emotional condition of the body – impacts on physical and mental wellbeing. The degree to which psychotherapies, such as mindfulness, target the mind-body connection and help to promote interoceptive functioning remains unclear. *Aim*: To systematically examine and quantify available evidence for the effectiveness of Mindfulness-Based Interventions (MBIs) on interoceptive ability, and to identify potential moderators of treatment effect. *Method*: A systematic search of the CINAHL, Embase, PsycINFO, PubMed, and Web of Science databases identified 12 randomised controlled trials evaluating interoception pre-post MBI for a pooled sample of 771 adults. Reporting quality was assessed with the Cochrane Risk of Bias tool (RoB 2.0), and Hedges' g effect sizes with 95% confidence intervals, p values and heterogeneity statistics calculated using a random effects model. *Results*: MBIs produced moderate to large, statistically significant improvements across subjective facets of interoception, particularly self-regulatory domains, relative to peers who accessed alternate therapies, standard care, or no treatment (g range = 0.634 to 1.315). Between-group differences for objective measures of interoceptive accuracy were small and non-significant (g_w = 0.126, 95% CI [-0.124, 0.377], p = .324). Longer term benefits could not be established (k = 2). Intervention intensity was identified as a significant moderator, indicative of a dose-response relationship. *Conclusion:* MBIs hold promise for improving several facets of impaired interoception implicated in the aetiology and maintenance of many high-prevalence mental health disorders.

Keywords: interoception, mindfulness, psychopathology, mind-body

Declaration

This thesis contains no material which has been accepted for the award of any other degree of diploma in any University, and, to the best of my knowledge, this thesis contains no material previously published except where due reference is made. I give permission for the digital version of this thesis to be made available on the web, via the University of Adelaide's digital thesis repository, the Library Search and through web search engines, unless permission has been granted by the School to restrict access for a period of time.

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Nina Marshall

27 September 2021

Contribution Statement

In writing this thesis, my supervisors and I collaborated to generate research questions of interest, and together we developed the study eligibility and screening criteria. I created the logic grids for each database, conducted the literature searches and study screening, extracted all data, completed the risk of bias assessment, and undertook all statistical analyses. A library research assistant reviewed the logic grids for completeness, and a post-graduate psychology student reviewed a sub-sample of abstracts to independently confirm reliability of study screening. Lastly, I wrote all aspects of the thesis, with review of the Introduction, Method, and Results shared between my supervisors.

Acknowledgements

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Finally, my sincere appreciation goes out to my family and friends, knowingly or unknowingly, you have helped me along the way; especially mum, I could not have started off on this journey without you.

Chapter 1

Introduction

Background

To increase the effectiveness of therapeutic efforts, and reduce the burden of mental ill-health, researchers have begun identifying modifiable factors contributing to shared symptoms of psychopathology across traditional diagnostic classifications (Caspi et al., 2014). Interoception, or the perception of one's internal bodily state, represents one such factor of interest, with increasing evidence finding impaired functioning is implicated in a range of mental health disorders (Paulus et al., 2019). Despite growing acknowledgement of the role of mind-body practices such as Mindfulness-Based Interventions (MBIs) in improving interoception (Gibson, 2019; Farb et al., 2015), no studies to date have systematically examined the available evidence base.

Interoception

Definition

Interoception is the sense of the internal condition of the body, giving rise to '*how one feels*' from moment to moment (Craig, 2002). Mapping both physiological and emotional states, interoception is an iterative process of the 'bottom-up' perception of bodily signals and the 'top-down' cognitive appraisal of such stimuli, helping to guide responses for the regulation of homeostatic and emotional states (Dunn et al., 2010, Critchley et al., 2004; Bechara & Naqvi, 2004). Fundamentally, it is a process connecting mind and body. Believed to develop early in life through infant-caregiver interactions (Koch & Pollatos, 2014; Garfinkel et al., 2015) interoception is shaped by learned associations, past experiences and expectations (Critchley et al., 2004), though appears to be moderated by factors such as age (Khalsa et al., 2009_b) and mindfulness-meditation training (Bornemann et al., 2014).

Measurement

There are various inconsistencies in how interoception is both conceptualised and measured (Khalsa et al., 2018). Principally, interoception has been distinguished along two dissociable dimensions: *interoceptive accuracy (IAc)* which, through the use of behavioural tests (e.g., counting one's heartbeats), quantifies the precision with which internal bodily signals are detected (Garfinkel et al.,2015), and *interoceptive awareness (IAw)*, which is measured by one's beliefs or appraisal about their own interoceptive tendencies (Mehling, 2016). Weak or non-significant correlations between objectively measured IAc and self-reported IAw substantiate their delineation, as does research demonstrating that IAw *may* be associated with an accurate perception of interoceptive stimuli, although such accuracy cannot be assumed (Garfinkel et al., 2016; 2019; Cali et al., 2015; Khalsa et al., 2008).

While objective measures of IAc are important to establish individual differences in the ability to detect bodily signals, measurement is not without its challenges. Cardiac-based measures, such as heartbeat perception accuracy (HBPa), are almost exclusively used as a generic indicator of IAc as they are less invasive than other modalities (e.g., gastric, respiratory; Gibson, 2019). Assessment of HBPa typically requires the participant to silently count the number of times they perceive their heartbeat during a specified interval, with performance then indexed against actual number of measured heartbeats (Schandry, 1981). While the reliability of these tests has been established (Jones, 1994), more recent findings have called in to question the validity of HBPa as a proxy for IAc. Indeed, most individuals appear to demonstrate chance performance (i.e., accuracy rates < 40%) when assessed by this measure (Khalsa et al.,2009; Brener & Ring, 2016). Additionally, it has not been established whether interoceptive ability can be generalised across modalities. That is, HBPa may not necessarily reflect accuracy in other sensory domains (Khalsa et al., 2018).

Beyond measures of objective accuracy, numerous self-reported scales have been developed to assess subjective interoceptive abilities (i.e., IAw), most of which reflect earlier unidimensional assessments of interoception and have application with distinct populations (e.g., primary care; Mehling et al., 2009). More recently, however, the 32-item Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012) has been developed. This instrument comprises eight scales distinguishing between regulatory and attention-related processes and provides a more nuanced conceptualisation of interoception (refer Table 1). While the MAIA is strengthened by its multidimensional nature, including its distinction between adaptive and maladaptive attentional styles toward interoceptive stimuli (e.g., anxiety-related hypervigilance toward physical sensations vs. a non-judgemental 'mindful' awareness of such stimuli), it is limited by its reliance on self-report and the potential biases therein (Stone et al., 2000).

Table 1

Scales of the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012)

Scale Name	Description
Noticing	Awareness of comfortable, uncomfortable and neutral body sensations
Not-Distracting	Tendency not to ignore or distract oneself from sensations of pain and discomfort
Not-Worrying	Tendency not to worry or experience emotional distress with sensations of pain and discomfort
Attention Regulation	Ability to sustain and control attention on body sensations
Emotional Awareness	Awareness of the connection between body sensations and emotional states
Self-Regulation	Ability to regulate distress by attention to body sensations
Body Listening	Active listening to the body for insight
Trusting	Experience of one's body as safe and trustworthy

Dysfunctional Interoception and Psychopathology

The delineation between IAw and IAc may have value in understanding psychopathology (Mehling, 2016). Indeed, there is evidence that wellbeing depends more on subjectively perceived states than on the actual accuracy of such experience (Ferentzi et al., 2019). It has been suggested that IAc below a particular threshold may explain certain disorders (e.g., alexithymia, or the inability to recognise or describe one's own emotions, is characterised by poor IAc which could underpin deficits in emotional processing; Herbert et al., 2011). However, when IAc is above threshold, IAw may become more relevant to psychopathology (Treves et al., 2019). An example is panic disorder where individuals typically demonstrate high IAc alongside dysfunctional IAw (e.g., catastrophising appraisals; Dunn et al., 2010).

Interoceptive dysfunction is suggested to operate via a discrepancy between actual sensed bodily state and the brain's expected state, resulting in a 'prediction error' requiring a behavioural response to re-instate homeostatic equilibrium (Seth, 2013). Whereas adaptive interoceptive functioning relies on successful corrective actions to resolve these prediction errors, persistent error signals can also occur due to an inadequate regulatory response. When this pattern persists over time, healthy functioning is compromised and may, ultimately, lead to psychopathology (Duquette, 2017).

Consistent with this view, a growing body of evidence suggests that disordered interoception plays a key role in the aetiology and maintenance of a range of mental health conditions (e.g., eating disorders, anxiety disorders, depression; Caspi et al., 2014; Murphy et al., 2017). For example, anxiety and panic disorders have been categorised as an oversensitivity or hypervigilance to interoceptive signals along with a negative bias in interpreting such signals, triggering symptoms of worry and avoidance often associated with these syndromes (Paulus & Stein, 2006). Conversely, depressive disorders are associated with atypically low interoceptive sensitivity, whereby individuals are thought to experience emotions less intensely, reducing their ability to use interoceptive feedback to guide decision making (Furman et al., 2013; Pollatos et al., 2009).

Dysfunctional interoception may manifest for different reasons. Examples include impaired quality of attention directed towards interoceptive signals (e.g., hypervigilant or dissociative tendencies), biased evaluation of such signals (e.g., catastrophised), distorted physiological sensitivity toward such signals (e.g., blunted or heightened in magnitude), and even limited meta-cognitive insight (i.e. poor confidence-accuracy correspondence; Schulz & Vögele, 2015; Khalsa et al., 2018). As such, mere awareness of interoceptive cues does not necessarily translate to adaptive functioning. Rather, how one appraises and then uses such awareness to reduce distress, together, are both seen to be critical to wellbeing (Mehling et al., 2012).

Disorders characterised by a deficit in a certain interoceptive domain (e.g., hyposensitivity to interoceptive stimuli) might especially benefit from the cultivation of that particular component (Brewer et al., 2021). Conversely, indiscriminate use of a therapeutic intervention to target interoception is unlikely to be effective, and even detrimental in some cases (e.g., catastrophised in the case of some anxiety disorders) unless more adaptive skills for relating to interoceptive stimuli are first established (Trevisan et al., 2021). Indeed, the idea that specific facets of interoception may be targeted through treatments aimed at changing bodily signal perception and interpretation is receiving increasing interest (Khalsa et al., 2018).

Mindfulness

Therapeutic approaches that include contemplative practices, most notably mindfulness-based interventions, have shown particular promise in the interoception literature (Farb et al., 2015; Weng et al., 2020). Much like interoception, mindfulness is an umbrella term that is characterised by a broad range of practices. In general, mindfulness is conceptualised as a mental faculty that emerges through the intentional paying attention to present-moment experience with an attitude of non-judgemental acceptance (Kabat-Zinn, 2003; Bishop et al., 2004). In order to cultivate this attentional style, mindfulness practices typically involve explicit direction of attention toward interoceptive sensations as well as the noticing of interoceptive appraisal tendencies (Bishop et al., 2004).

Mindfulness-Based Interventions

Central to their theorised efficacy, MBIs emphasise the suspension of appraisal tendencies (i.e., detachment) as a means to decouple habitual reactions, behaviours or thought patterns and, in turn, improve interoceptive awareness and self-regulation (Bishop et al., 2004; Carmody et al., 2009; Hölzel et al., 2011). MBIs are thought to moderate interoceptive processing habits by improving awareness and understanding of what *is* happening in the body rather than trying to change bodily experience to fit cognitive expectations of what *should* happen in the body (Farb et al., 2015). This heightened acuity is believed to enable more precise sensory representations, ultimately facilitating a more nuanced, adaptive response that contributes to improved health promoting behaviours (Weng et al., 2020).

Accumulated evidence supports the effectiveness of MBIs, such as Mindfulness Based Stress Reduction (MBSR) and Mindfulness Based Cognitive Therapy (MBCT), in improving psychological functioning for a broad range of clinical populations. Specifically, randomised controlled trials (RCTs) examining MBIs have shown promising effects, outperforming waitlist controls and performing on par or better than other active therapies (e.g., relaxation training), in significantly reducing levels of anxiety, stress, chronic pain, and depressive relapse for those most at risk (Teasdale et al., 2000; Khoury et al., 2013; Goldberg et al., 2018). However, despite widespread evidence for the clinical efficacy of mindfulness-based methods, the specificity of mechanisms through which such benefits accrue is still unclear (Shapiro et al., 2006).

Mindfulness and Interoceptive Change

There is some suggestion that mindfulness enhances the ability to effectively process body-state information. Specifically, mindfulness training has been associated with increased grey matter volume and functional activation in brain regions connected to interoception (e.g., insula and anterior cingulate cortex; Tang et al., 2015; Sharp et al., 2018; Hölzel et al., 2011). Lending further support to this conjecture, those experienced in mindfulness demonstrate heightened accuracy between subjective and objective measures of interoceptive sensitivity (Fox et al., 2012) along with greater coherence between physiological and subjective states (Sze et al, 2010).

Critically, MBIs ameliorate symptoms of psychopathology characterised by atypical interoception (Baer, 2003; Creswell, 2017). Indeed, it has been proposed that interoceptive awareness is one of the 'mechanisms of action' of MBIs (Hölzel et al., 2011_b). In particular, the cultivation of mindfulness has shown improvement in self-focused attention of a non-reactive manner and a reduction in rumination and experiential avoidance - processes relevant to the development and maintenance of psychopathology (Baer, 2007).

While mindfulness is reported to cultivate greater attention to, and awareness of bodily states (Baer, 2003), performance on heartbeat perception tasks is generally not improved. Cross-sectional and controlled trials, alike, have found that practicing sustained attentional focus toward internal sensations – a core feature of mindfulness programs – does not enhance IAc, including under induced conditions of cardiac arousal (Khalsa et al., 2020; Parkin et al., 2013; Fischer et al., 2017; Melloni, 2013).

This contrasts with findings from qualitative research wherein mindfulness practitioners attribute a heightened perceptual acuity of their bodily states to their mindfulness practice (Hölzel et al., 2006; Ekici et al., 2020), and with longitudinal research demonstrating that MBIs increase IAc, although the effects are not immediate (i.e., 6 months post-MBI; Bornemann & Singer, 2017). However, it is important to note that the latter results were from a non-randomised sample of healthy volunteers and, as such, may not be generalisable to clinical populations.

Regarding subjective measures of IAw, MBIs have produced noticeable changes across several domains. In another study of healthy participants, substantial improvements in the Self-Regulation and Attention Regulation dimensions of the MAIA were observed after three months of mindfulness training (Bornemann et al., 2015). The suggestion is that mindfulness can help to strengthen one's ability to direct attention inwardly to gain insight, and then use that knowledge to self-regulate. However, no significant changes for the 'Noticing' dimension of the scale; a measure which most closely aligns with IAc, have been noted (e.g., Mehling, 2016).

Collectively, the aforementioned findings highlight differential effects for MBIs across the various aspects of interoceptive functioning. It therefore remains unclear whether mindfulness strengthens the ability to accurately perceive, interpret, and/or adaptively respond to bodily signals. It is plausible that MBIs may only affect certain dimensions of interoceptive ability.

Factors Contributing to MBI Effectiveness

Consideration should also be given to intervention-related factors that may maximise the impact of mindfulness training for interoceptive awareness and processing. A key concern is the maintenance of benefits over time. Across many types of treatments, including MBIs, observed effects are typically larger immediately post-intervention than at follow-up (Morone et al., 2016; Kearney et al., 2013; Creswell et al., 2017). Yet, in some cases treatment-related gains have been maintained for up to five years, supporting the temporal durability of mindfulness as a clinical intervention (Munshi et al., 2013; Reibel et al., 2001). Such growth is thought to be indicative of participants integrating mindfulness tools into their everyday life (Bishop et al., 2004). Whether meaningful improvements in measures of interoception can be sustained post-intervention, or if regular training is required, remains unknown. Such knowledge would highlight potential limitations of treatment effects and, potentially, the need for regular, ongoing management.

A further factor is the dose-dependent treatment effect, or the likelihood of increased intensity and duration of mindfulness instruction leading to greater treatment effects. In the case of MBIs, MBSR and MBCT have strong empirical support for their effectiveness. Notably, both were developed as eight-week intensive programs involving weekly two-hour sessions followed by a full day retreat in order to embed skills into everyday life (Kabat-Zinn,1990; Segal et al., 2000). Program intensity and duration may therefore be an important determinant of their efficacy. However, more recent MBIs have modified their programs to suit populations for whom standard time commitments pose a barrier to participation (e.g., chronic pain patients; Carmody & Baer, 2009). Brief MBIs, ranging from single session to multi-session programs lasting two weeks or less, have demonstrated improved mental health outcomes, albeit with small effects (g = 0.21; Schumer et al., 2018), while programs of longer durations have shown moderate to large and positive impacts (Carmody & Baer, 2008; Shapiro et al., 2008; Khoury et al., 2013). By contrast, Carmody and Baer (2009) found no evidence for a link between in-class hours and psychological outcomes, suggesting reduced treatment dose may not necessarily compromise outcomes.

Current Study

In sum, dysfunctional interoception is thought to play a key role in the aetiology and maintenance of a broad range of psychiatric conditions (Brewer et al., 2021; Hölzel et al., 2011;

Paulus et al., 2019). Similarly, accumulated evidence supports the trans-therapeutic effectiveness of MBIs across a variety of populations (Greeson et al., 2014). To date, however, evidence for the effectiveness of MBI on measures of interoception remains unclear. Whether treatment effects are sustained over time or if dose-response relationships exist also remains to be determined.

The current study systematically reviews and consolidates the available evidence base for mindfulness interventions on both subjective and objective measures of interoception. To our knowledge, this is the first meta-analysis to do so and therefore provides much needed clarity within this burgeoning field. The specific aims were to:

1. quantify and evaluate available evidence for the effectiveness of MBIs on interoceptive ability, as applied to adults across a spectrum of clinical, sub-clinical and healthy populations
2. identify potential moderators of treatment effect, distinguishing between facets of interoceptive change post MBI.
3. evaluate whether noted improvements (if any) are sustained once mindfulness interventions have ceased.
4. determine whether a dose-response relationship exists between mindfulness intensity and interoceptive change

In addressing these aims, the combined findings of this review may guide the development of targeted interventions to treat interoceptive deficits and, in turn, mitigate psychopathology.

Chapter 2

Method

Literature Search

The CINAHL, EMBASE, PsycINFO, PubMed (MEDLINE) and Web of Science databases were searched up until 19 March 2021. Eligible studies examining interoceptive outcomes in mindfulness interventions were identified using a comprehensive list of terms, synonyms and proximity operators developed in consultation with a senior research librarian and adjusted for each database interface (refer Appendix A). A manual search of the reference lists of included studies and relevant narrative reviews (Farb et al., 2015; Khalsa et al., 2018; Gibson, 2019; Mehling et al., 2016) was also performed, along with citation searching in Scopus. This process identified one additional paper (Gawande et al., 2018).

Study Criteria and Screening

In addition to being peer-reviewed articles published in the English language, or with English translation, studies had to the following eligibility criteria, organised according to the Population Intervention Comparison Outcome Study design (PICO-S) framework (Agoritsas et al., 2012).

Population

Studies that recruited adult participants ($\geq$17 years), consistent with a phased transition model from adolescent to adult care for health services, were eligible (Government of South Australia, 2020; Signorini et al., 2018; 2014; Singh et al., 2008).

Intervention

Studies had to evaluate a mindfulness-based intervention (MBI), operationalised as ‘mindfulness’, ‘mindfulness skills’, ‘mindfulness training’, or ‘mindful attention’ within the description of the primary intervention. This included programs that emphasised formal meditation practices, such as MBSR and MBCT, as well as programs involving brief mindfulness-based body-scan exercises. Interventions that incorporated an attitudinal stance of mindfulness as a sub-component of a wider program (i.e., Dialectical Behaviour Therapy, Compassion-Focused Therapy, movement-based practices such as yoga and tai-chi) were excluded. To maximise fidelity of outcome, only those interventions delivered in-person by a qualified practitioner (e.g., psychologist, psychiatrist, nurse) were considered. Self-management programs or those delivered exclusively via telecommunication technology with no face-to-face contact (e.g., smartphone applications) were ineligible (Moncher & Prinz, 1991).

Control or Comparison

To mitigate against extraneous biases nonspecific to the intervention, such as group membership or general time effects (Lindquivist et al., 2007; Brigham et al., 2009), only those studies comparing MBI to an inactive control condition (e.g., waitlist), usual care (e.g., pharmacotherapy), or active comparison treatment (e.g., relaxation course without a mindfulness-based component) were eligible.

Outcomes

Studies needed to include a validated measure of interoception with available psychometric data, whether administered by a clinician or via self-report. Interoception was operationalised as the inner sense of the body's physiological condition (e.g., heartbeat, respiration, satiety) and autonomic nervous system sensations relating to emotions (Craig, 2002; Garfinkel & Critchley, 2013; Farb et al., 2015). This included four measurement types (see Table 2). Studies which measured the effectiveness of MBIs on body awareness or somatic awareness more generally (i.e., the sense of position and movement of the body; Craig, 2002) were excluded.

Table 2:

Operationalisation of Interoceptive Terms

Construct	Definition	Measurement
Accuracy	Objective measure of the precision with which interoceptive sensations are detected	Heart-beat detection task (Schandry, 1981)
Sensibility	Subjective measure of confidence in interoceptive accuracy performance	Self-reported confidence judgements (e.g., Likert scale)
Coherence	Correspondence between interoceptive accuracy and interoceptive sensibility	Within-participant correlation (*r*) between sensibility and accuracy scores
Awareness	An individual's personal account of their awareness of interoceptive sensations and how they are experienced (i.e., includes attention and appraisal tendencies, attitudes, thoughts and emotions)	Self-report questionnaire (MAIA; Mehling et al., 2012)

Study Design

To moderate selection bias and discern the true effects of MBIs, participants needed to be randomly assigned to a control or intervention condition (Doll, 1998; Schulz et al.,1995). In addition, studies had to employ a repeated measures design with interoception measured at baseline, immediately post-intervention and (if possible) at follow-up. Studies also had to provide parametric data to calculate Hedges' *g* effect sizes (e.g., means, standard deviations, one-way ANOVA). Where subscale MAIA data were not reported, corresponding authors were contacted, with follow-up emails issued after three weeks. Three of six authors responded. For the remaining three studies total or sum-score data were still available to calculate pre- and post-treatment effects (Duncan et al., 2017; Gawande et al., 2018; Price et al., 2020). Given the focus of this paper was on the calculation and comparison of effect size data from primary studies, qualitative data and review papers were excluded.

Study Selection

Screening was conducted by the student researcher (N.M.) using Covidence systematic review software (Veritas Health Innovation). To ensure reliability of the screening process, a random subsample of full-text records (*n* = 35, 10%) was independently examined by a postgraduate psychology student. Inter-rater reliability was high with reviewers agreeing in all but one case, which was then resolved through consensus discussion (Viera & Garrett, 2005)

Data Extraction and Organisation

In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines (PRISMA; Page et al., 2021), key data were retrieved from each study using a pre-piloted Microsoft Excel spreadsheet. These data included: 1) study characteristics (e.g., sample size, country, interoceptive measure); 2) sample demographics (e.g., age, gender, health comorbidities, recruitment source); 3) intervention characteristics (e.g., MBI format, session duration and frequency, home practise requirements); and 4) parametric data to calculate Hedges' *g* (i.e., group pre-and post-treatment means, standard deviations, sample sizes). No data conversion was required, with all studies providing requisite effect size information.

Risk of Bias Assessment

Methodological bias was assessed for each study using the revised Cochrane Collaboration Risk of Bias 2 tool (RoB 2; Sterne et al., 2019). The RoB 2 tool measures five sources of methodological bias common to RCTs: issues with the randomisation process (i.e., resulting in baseline imbalances between groups on prognostic or socio-demographic variables), deviations from intended interventions (i.e., poor adherence to protocols), missing outcome data (often due to study attrition), purposely designed or invalid outcome measures, and selective reporting of results (i.e., exclusion of non-significant findings; Higgins et al., 2021). Studies were assessed as having "low", "high", or "some concerns" against each domain based on answers to signalling questions (see Appendix B). In addition to rating each study against each domain, studies received an overall risk of bias score. A "low" rating was achieved when a study was considered to have a relatively low risk of bias across all domains, an overall rating of "some concerns" was applied if a study was judged to have some concerns in at least one domain, whilst "high risk" reflected a high rating on any domain.

Data Synthesis

Raw data were entered into Comprehensive Meta-Analysis Version 3.3.070 (CMA; Borenstein et al., 2013) for analysis. Owing to its correction for small sample bias (Rosenthal, 1991), Hedges' *g* was the most appropriate effect size estimate. For each *g*, 95% confidence intervals (95% CI) and *p* values were calculated to assess precision and statistical significance, respectively. For studies with a repeated-measure design, a pre-post correlation is required to calculate *g*. Given this statistic was not reported by included studies, an estimate of $r = 0.7$ was applied; considered conservative for studies with a repeated-measures design (Estrada et al., 2019; Rosenthal, 1993).

Effect estimates were calculated in two stages. First, short–term (i.e., baseline to immediately post-MBI) and sustained effects (i.e., immediately post MBI to follow-up) were calculated. Second, individual effect sizes were grouped by the interoceptive construct they represented (i.e., awareness, accuracy, sensibility and coherence). Prior to pooling, each *g* was weighted by that study's inverse variance (g_w). A random effects model was used for this analysis - on the basis that selected studies were not identical in design nor did they target a similar population (Borenstein et al., 2010). In cases where a study contributed more than one effect estimate (e.g., active and inactive control/comparison groups), individual *g*s were averaged before being pooled to ensure data independence (Cohen, 1988).

Effect sizes were interpreted with reference to Cohen's (1992) guidelines, whereby values of 0.2, 0.5 and ≥.8 reflect small, medium and large to very large effects, respectively. For ease of data interpretation, the direction of *g* was standardised such that positive values indicated improved interoception following mindfulness, relative to controls.

The degree of heterogeneity between studies was assessed by calculating Tau (τ); or the standard deviation of the mean effect, and I^2; the proportion of variation observed in the true effect (that is, the ratio of true heterogeneity relative to total variance; Borenstein et al., 2009). Higher I^2 values reflect greater levels of between-study variance (Higgins et al., 2003).

Publication Bias

Selective publication of statistically significant results is a key methodological concern of meta-analyses, potentially over-stating conclusions drawn from published research and undermining the validity of results (Rothstein et al., 2006). As an indication of robustness against publication bias, a funnel plot analysis of all included studies was conducted. A funnel plot graphs the distribution of effect sizes (*x*-axis) against standard error (*y*-axis). As large samples provide more accurate estimates of the 'true' effect than do smaller samples, a symmetrical 'reversed funnel' distribution is expected to emerge (Egger et al., 1997). Deviations from that pattern are indicative of irregularities and biases, including publication bias, whereby smaller studies with low effect sizes may be under-represented. This assumption was statistically tested using the trim-and-fill method, an iterative algorithm which imputes the number of hypothetical studies required to correct for any asymmetry (Duval & Tweedie, 2000)

For each subsequent meta-analysis involving three or more studies, Orwin's fail-safe *N* (N_{fs}; Orwin, 1983) was calculated. N_{fs} signifies the number of hypothetical studies required to reduce the overall effect size to a meaningless, non-significant level (i.e., < 0.2; Orwin, 1983). For the mean-effect reported to be validly regarded as robust against publication bias, the N_{fs} value needed to exceed the total number of studies (*k*) in this meta-analysis.

Sensitivity and Moderator Analysis

Statistical outliers were identified using a one-study removed sensitivity analysis. This involved re-running each meta-analysis with all included studies and then removing one study at a time, to observe whether this changed the magnitude of the overall effect size or level of significance (Borenstein et al., 2009).

To gauge the potential effect of intervention intensity on interoceptive outcomes (i.e., a quasi dose-response analysis), a univariate meta-regression was performed using a random effects model. 'Intensity' was operationalised as a continuous variable (i.e., treatment time x number of sessions per week x intervention duration in weeks). Both *Q* model and *Q* residual statistics were considered, which indicate variability associated with the regression model and variability unaccounted for by the model, respectively (Borenstein et al., 2010).

A post-hoc analysis was considered to test whether the type of control condition (i.e., no treatment vs. treatment as usual vs. active treatment) moderated the observed effect sizes, however there were insufficient studies per sub-group (i.e., < 4 studies) to warrant this analysis (Fu et al., 2010). Moreover, studies employing an inactive control typically employed a body scan intervention delivered at low intensity (i.e., < 30 minutes). Given this, a subgroup analysis would not be able to meaningfully distinguish whether resultant effects were associated with intensity, or control condition, or even the type of MBI applied.

Chapter 3

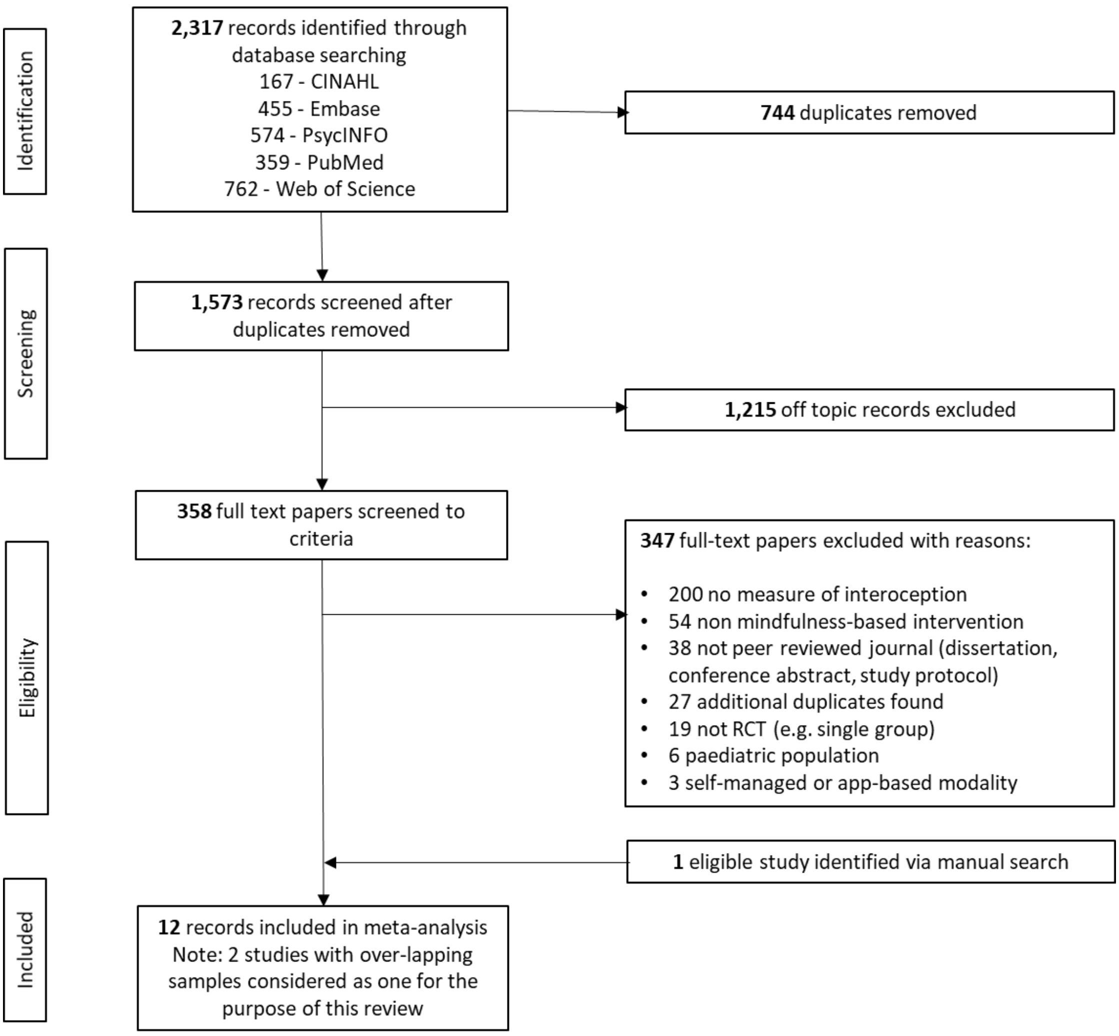
Results

Study Selection

A total of 2,317 studies were identified from the search process, with 744 duplicates automatically filtered by Covidence (refer Figure 1). Each title and abstract (n = 1,573) were screened, following which 358 full texts were re-screened against the eligibility criteria. In sum, 12 independent studies (*k*) met all eligibility criteria. Two studies reported separate data points (i.e. post-intervention and follow-up effects) for the same sample (Price et al., 2019; Price et al., 2019_b). These studies were considered as one for the purpose of this review.

Figure 1.

Flow Diagram Outlining Study Selection Process (adapted from PRISMA; Page et al., 2021)



Study Characteristics

Commensurate with recent interest in the concept of interoception, included studies were all published within the last decade and originated from two high income countries: the United States (*k* = 10) and Germany (*k* = 2; refer Table 2). Most (*k* = 8) examined self-reported interoceptive awareness using the MAIA (Mehling et al., 2012), with the remainder (*k* = 4) focusing on interoceptive accuracy using an objective heartbeat perception test (Schandry, 1981). Less commonly, interoceptive sensibility was reported (*k* = 3) as was the correspondence between sensibility and accuracy scores (i.e., interoceptive coherence; *k* = 1).

Six full scale RCTs targeted efficacy of MBI, with the remaining six studies described as pilot or 'stage 1' trials to examine intervention feasibility. Accordingly, sample sizes varied considerably (range: 10 – 187; *M* = 64.2; *SD* = 49.6), with four studies having sufficient power to reliably detect a moderate between-group difference (*n* ≥ 35 per group; Cohen, 1992).

Sample Characteristics

The pooled sample comprised 771, mostly (74%) female adults with an average age of 37 years (*SD* = 7.84, range 17 to 76). Of those studies reporting race (*k* = 8), most participants identified as Caucasian (72%). Further sociodemographic details were either not reported (*k* =2) or reported inconsistently (e.g., years of education vs. educational attainment; percent in paid employment vs. family income bracket; *k* = 8).

A wide spectrum of clinical populations (e.g., Major depressive disorder, Post-traumatic stress disorder, Substance use disorder; *k* = 6; 61.2%), primarily recruited by way of clinician referrals (*k* = 5; *n* = 260), were represented. Sub-clinical and healthy participants accounted for 10.5% and 28.3% of the pooled sample, respectively, and were either respondents to public advertisements or research volunteers.

Table 2

Study and Sample Characteristics

Lead author (date)	Country	Design	Target Outcome	Outcome Measure	Baseline N [I,C_1,C_2]	Age (years)		Gender (% F)	Race (% Cauc.)	Participant characteristics		MBI Format	Control Condition(s)
						Mean (SD)	Range			Clinical Status	Recruitment		
Aaron (2020)	USA	Pilot RCT	IAc; IS	HBT	76 [38,38]	19.7 (.95)	[-]	66%	54%	Healthy	University student volunteers	MBBS	NTC (story listening)
deJong (2016)	USA	Pilot RCT	IAw	MAIA	40 [26,14]	51.11 (10.64)	[-]	74%	90%	Chronic pain + comorbid depression	Outpatient clinic referals	MBCT + TAU	TAU (medical prof. + pharmacotherapy)
Duncan (2017)	USA	Pilot RCT	IAw	MAIA	30 [15:15]	[-]	[-]	100%	59%	Fear of labour-related pain	Provider referals + respondents to ads	Mind in Labour (adapted MBSR)	TAU (childbirth course)
Fissler (2016)	Germany	RCT	IAw	MAIA	74 [38, 36]	41.52 (12.30)	[-]	40%	[-]	Current MDD diagnosis	Respondents to ads	Mindfulness training (adapted MBCT)	Active (relaxation training)
Gawande (2018)	USA	RCT	IAw	MAIA	136 [92,44]	40.50 (12.50)	[-]	65%	77%	Primary care patients with DSM-V diagnosis	Primary care referals	MTPC (adapted MBSR & MBCT)	Low Dose Comparator (self-managed mindfulness)
Mehling (2018)	USA	Pilot RCT	IAw	MAIA	47 [21, 26]	46.80 (14.93)	24 - 69	19%	40%	PTSD (DSM-IV)	Unknown	Integrated Exercise with MBSR	Inactive WLC
Meyerholz (2019)	Germany	RCT	IAc	HBT	49 [25,24]	25.28 (5.67)	17 - 44	74%	[-]	Healthy	University student volunteers	MBBS	NTC (video)
Parkin (2014_a)	USA	RCT	IAc; IS; IC	HBT	40 [20,20]	43.17 (14.49)	18 - 65	60%	[-]	Healthy	Medical research volunteer panel	MBBS	Active (external meditation)
Parkin (2014_b)	USA	RCT	IAc; IS; IC	HBT	60 [20,20,20]	43.79 (17.20)	[-]	72%	[-]	Healthy	Medical research volunteer panel	MBBS	1. Active (external medit'n) 2. Inactive re-test
Price (2019)	USA	RCT	IAw	MAIA	187 [74,46,67]	35*	22 - 61	100%	75%	Outpatients, Substance Use Disorder	Respondants to ads	TAU + MABT	1. TAU + health education 2. TAU (meds. & psychoed.)
Price (2020)	USA	Pilot RCT	IAw	MAIA	10 [5,5]	46.6 (12)	30 - 61	30%	60%	Opiod Use Disorder	Primary care referals	TAU + MABT	TAU (medication & psychoed.)
Thomas (2019)	USA	Pilot RCT	IAw	MAIA	51 [26,25]	57.92 (10.04)	29 - 76	100%	96%	Overweight/obese breast-cancer survivors	Oncologist referals	Exercise/Nutrition counselling + Mindfulness	TAU (exercise + nutrition counselling)

Note: I = intervention; $C_{1,2}$ = control condition(s); IAc = interoceptive accuracy; IS = interoceptive sensibility; IC = interoceptive coherence; IAw = interoceptive awareness; MAIA = multidimensional assessment of interoceptive awareness; HBT = Heartbeat tracking task (Schandry, 1981); [-] = not reported; NTC = no treatment control; TAU = treatment as usual; WLC = waitlist control; MBCT = mindfulness based cognitive training; MBSR = mindfulness based stress reduction; MABT = mindful awareness in body-oriented therapy; MBBS = mindfulness based body scan; * Median

Intervention Characteristics

Eight different interventions were evaluated across the twelve RCTs (refer Table 3). In keeping with the core philosophy of MBI, all studies emphasised the practice of mindfulness (i.e., purposefully directing attention to present moment experience, non-judgementally), although differed in their attentional focus. This included Mindfulness-Based Body Scan (MBBS) and Mindful Awareness in Body-oriented Therapy (MABT) interventions that directed present-state awareness to felt bodily sensation (*k* = 6). The remaining six studies extended this focus to include meta-cognitive awareness of cognitions and emotions as they arose – the ultimate aim being the amelioration of mental health symptoms (e.g., depression, anxiety, PTSD; *k* = 3) and/or management of health and illness behaviours (e.g., obesity, pain; *k* = 3). Aside from MBBS, all interventions included a psychoeducational component tailored to their target population, with MBCT and MBSR programs adding a formal meditation and mindful-movement practice (i.e., yoga poses). Mehling et al. (2017) combined an integrated exercise program into their movement practice, extending MBSR principles to this training. Only Price et al., (2019, 2020) examined MABT. This manualised approach involved therapist touch to direct participant's attention to specific areas in the body as a method of accessing interoceptive awareness, thus placing greater emphasis on 'bottom-up' processing (i.e., toward bodily sensory experience as opposed to conscious mental activity; Price & Hooven, 2018).

MBIs varied in their delivery, format and intensity, although were typically delivered by certified clinicians or therapists with extensive mindfulness training. This included individual (*k* = 3) and group formats (*k* = 5). The remaining studies involved audio-recorded, guided body-scan meditations delivered in a lab setting (*k* = 4). For eight studies, in-session learning was supplemented with home practice to reinforce and embed mindfulness skills in daily life.

Excluding Thomas et al., (2019) where the participant drop-out rate was 41% (25% occurring prior to trial commencement), attrition rates were generally low (*M* = 11%, *SD* = .11; see Figures 2 and 3). This low rate likely reflected the brief interventions typically examined in this review, including single sessions of 30 minutes or less (*k* = 4). In particular, Duncan et al's (2017) compressed MBSR program of three sessions, totalling 18 hours over a single weekend, had no dropouts. Studies that recruited healthy participants also reported low dropout rates (*k* = 4). Where reasons for withdrawal were reported, scheduling and logistical challenges were most commonly cited (*k* = 4).

Intervention engagement (i.e., the average rate of program completion for those who commenced treatment) was generally high (M = 90%, SD = .11, range 70 - 90%; *k* = 9), indicating good acceptability. Highest engagement rates were likewise associated with less intensive programs and studies involving healthy participants. A single study reported adverse effects associated with MBI: one participant experienced a flashback while another reported feelings of anxiousness during meditation (Gawande et al., 2018). In both instances those affected continued their participation within the program.

Figure 2

Intervention Intensity and Attrition

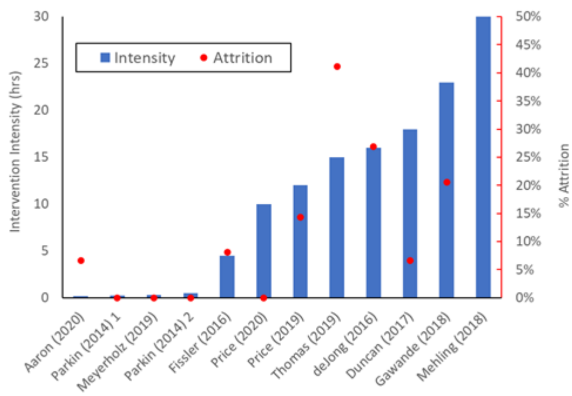
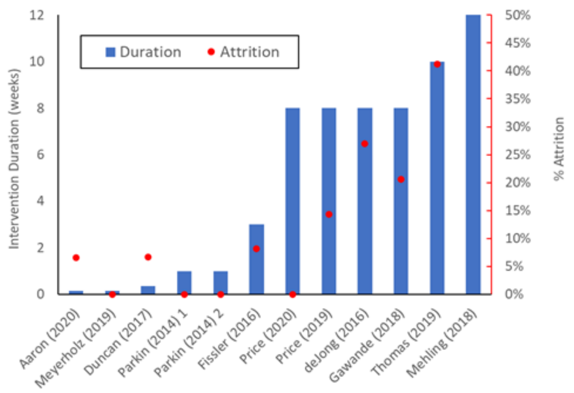


Figure 3

Intervention Duration and Attrition



Control Conditions

Studies typically compared MBIs to treatment as usual (TAU), involving evidence-based therapies such as pharmacotherapy, psychoeducation and counselling (*k* = 5). While these studies did not account for non-specific therapeutic effects within their experimental design (e.g., amount of treatment contact, degree of support), they provided superior control for expectancy effects compared to those employing inactive (i.e., waitlist, re-test; *k* = 3) or attention controls (i.e., video- or audio-based material; *k* = 2). Three studies compared MBIs to active controls (i.e., relaxation

Table 3

Intervention characteristics

Lead Author (date)	Intervention characteristics				Attrition	Adherence	Follow-up
	MBI Format	Mode (delivered by)	Sessions / Duration	Home Practice			
Aaron (2020)	MBBS	Individual (lab-based audio recording)	10 mins, once	[-]	7%	100%	No
deJong (2016)	MBCT	Group based (clinical social worker; psychologist)	2 hrs weekly over 8 weeks	daily, unspecified duration	27%	-	No
Duncan (2017)	Mind in Labour (adapted MBSR)	Group based (mindfulness teacher; certified nurse midwife)	18 hrs over 2.5 days	[-]	7%	90%	No
Fissler (2016)	Mindfulness training (adapted MBCT)	Individual (Clinical Psych)	1.5 hrs weekly over 3 weeks	50 mins daily	8%	93%	No
Gawande (2018)	MTPC (adapted MBSR & MBCT)	Group based (psychologists, psychiatrists, social-workers)	2hrs weekly over 8 weeks+ full day retreat	30 - 45 mins daily	21%	70%	6 months
Mehling (2018)	Integrated Exercise with MBSR	Group based (qualified instructors)	3 x 50 mins over 12 weeks	[-]	-	-	No
Meyerholz (2019)	MBBS	Individual (lab-based audio recording)	20 mins, once	[-]	0%	100%	No
Parkin (2014_a)	MBBS	Individual (lab-based audio recording)	15 mins, once	15 mins daily	0%	100%	No
Parkin (2014_b)	MBBS	Individual (lab-based audio recording)	15 mins, twice (1 week apart)	15 mins daily	0%	100%	No
Price (2019)	MABT	Individual (trained therapists)	1.5 hrs weekly over 8 weeks	daily, unspecified duration	14%	36% (≤ 5 sessions) 64% (6-8 sessions)	6,12 months
Price (2020)	MABT	Individual (trained therapists)	75 mins weekly over 8 weeks	daily, unspecified duration	0%	>80%	No
Thomas (2019)	MORE	Group based (clinical social worker)	1.5 hrs weekly over 10 weeks	15 mins daily	41%	82%	No

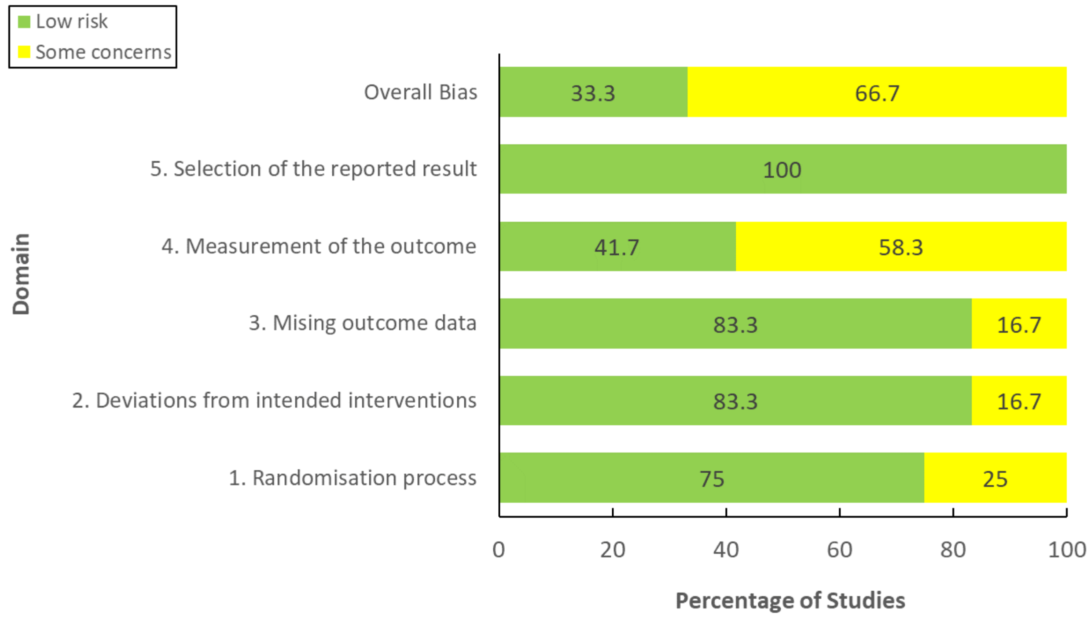
Note: MBBS = midfulness based body scan; MBCT = mindfulness based cognitive training; MBSR = mindfulness based stress reduction; MTPC = mindfulness training for primary care; MABT = mindful awareness in body-oriented therapy; MORE = mindfulness-oriented recovery enhancemenet; [-] = no home practice requirement; '-' = not reported training, external-focussed meditation) wherein treatment format, delivery, and credibility were comparable between the two experimental conditions, therefore allowing researchers to draw stronger causal inferences (Mohr et al., 2009). Gawande et al., (2018) was the only study to use a low-dose comparator in the form of a 60-minute introductory mindfulness course coupled with informational resources, available online or through local third-party providers. Importantly, both control and intervention groups were attention-matched in terms of participant-outreach engagement calls aimed at encouraging practice, minimising attrition, and maximising survey completion (Gawande et al., 2018).

Risk of Bias in Studies

Most studies (67%) were characterised by some methodological concerns (refer to Figures 4 and Appendix C for between and within group scores, respectively). Three studies did not specify whether the allocation sequence was concealed from participants or investigators (domain 1). However, the absence of significant baseline differences between the intervention and control groups suggests the randomisation procedure was adequate. Fidelity of intervention delivery was audited and verified through established protocols in five studies (e.g., use of session-specific checklists or standardised treatment manuals; domain 2). Missing outcome data was appropriately managed using either intent-to-treat (ITT) or modified forms thereof, whilst reasons for participant drop-out (where detailed) were not ascribed to the trial itself (domain 3). Not unexpectedly, the reliance on self-reported data increased the risk of response biases (domain 4), however there was no evidence to suggest that outcomes were influenced by knowledge of the intervention received (Podsakoff et al., 2003; Munder & Barth, 2018). While studies did not typically report an a-priori analysis plan, there was no indication that reported outcomes were selected from multiple eligible outcomes. That is, a single standardised measure was applied, and reported results compared unadjusted pre/post scores (domain 5).

Figure 4

Proportion of Included Studies Meeting Each Criterion of the RoB 2 Tool for RCTs



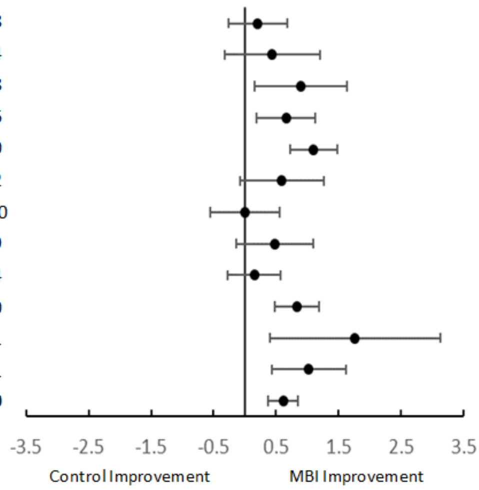
Short-Term Effects

Individual and pooled effect size data for each study are listed in Table 4. Six studies produced significant and moderate to very large group differences, resulting in a pooled and weighted effect that was medium to large: participants reported improved interoception immediately post-mindfulness, compared to peers who accessed alternate therapies, standard care, or no treatment. An effect size of this magnitude translates to approximately 73% of the scores from the control group falling below the mean of the intervention group (Cohen, 1988). The pooled effect estimate was robust (i.e., $N_{fs} > N_{studies}$) with 26 hypothetically missing studies required to be added to the analysis before the cumulative effect would be considered trivial (i.e., $g < 0.2$). The validity of these findings was confirmed by funnel plot analysis, with Duval and Tweedie's (2000) trim and fill method revealing one imputed study - the addition of which did not significantly change the magnitude of the overall effect (i.e., g_w reduced from 0.617 to 0.585; Figure 5).

Table 4

Pre-Post Standardised Mean Group Differences (Hedges' g) by Study with Forest Plot

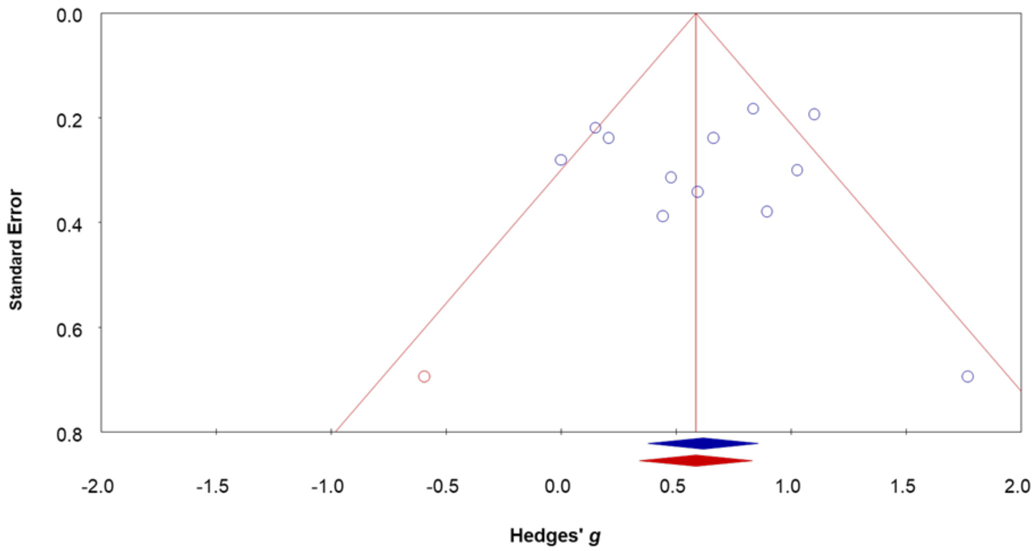
Lead author (date)	Construct	Measure	*N*	*g*	95% CI Lower	95% CI Upper	*p*	Forest Plot
Aaron (2020)	IAc; IS	HBT	69	0.207	-0.262	0.676	.388	
deJong (2016)	IAw	MAIA	33	0.442	-0.318	1.203	.254	
Duncan (2017)	IAw	MAIA	30	0.895	0.151	1.640	.018	
Fissler (2016)	IAw	MAIA	68	0.662	0.193	1.131	.006	
Gawande (2018)	IAw	MAIA	136	1.102	0.721	1.482	.000	
Mehling (2018)	IAw	MAIA	38	0.595	-0.076	1.265	.082	
Meyerholz (2019)	IAc	HBT	49	0.000	-0.551	0.551	1.000	
Parkin (2014a)	IAc; IS; IC	HBT; SRA; C	40	0.478	-0.139	1.094	.129	
Parkin (2014b)	IAc; IS; IC	HBT; SRA; C	60	0.150	-0.280	0.580	.494	
Price (2019)	IAw	MAIA	187	0.836	0.477	1.194	.000	
Price (2020)	IAw	MAIA	10	1.768	0.406	3.129	.011	
Thomas (2019)	IAw	MAIA	51	1.028	0.439	1.616	.001	
Overall g_w			**771**	**0.617**	**0.376**	**0.858**	**.000**	



Note: IAw = interoceptive awareness; IAc = interoceptive accuracy; IS = interoceptive sensibility; IC = interoceptive coherence; HBT = Heartbeat tracking task (Schandry, 1981); MAIA = multidimensional assessment of interoceptive awareness (Mehling et al., 2012); SRA = self rated assessment of IAc confidence on Likert scale; C = correlation between IAc and IS scores; *N* = total sample size; *g* = effect size (Hedges' *g*); 95%CI = 95% confidence interval; *p* = significance value for g / g_w

Figure 5

Funnel Plot of Standard Error by Hedges' g



accuracy, as measured by the Schandry heartbeat counting task (Aaron et al., 2020; Meyerholz et al., 2019; Parkin et al., 2014_a and Parkin et al.,2014_b). Conversely, the eight MAIA studies had moderate to large effects - although two studies included wide CIs, possibly reflecting their small and under-powered samples (deJong et al., 2016; Mehling et al., 2018).

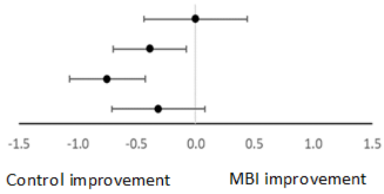
Longer-Term Effects

Two studies provided sufficient data to examine sustained effects of MBIs, based on total scores of the MAIA (Table 5). The pooled effect estimate was negative, indicating a trend for reduced interoception skills over time. Individual study results were, however, mixed (I^2 = 80%, τ = .36). Specifically, improvements reported by primary-care patients receiving MBI were comparable at 6 months to peers who received a low-dose comparison (Gawande et al., 2018). In comparison, those who received as-usual treatment for substance abuse disorder *improved* over the intervening period (i.e., 6 to 12 months post-intervention), whereas their MABT counterparts did not (Price et al., 2019). However, no firm conclusions can be drawn in lieu of the small number of studies contributing to these findings (*k* = 2).

Table 5

Longer Term Standardised Mean Group Differences (Hedges' g) on Interoceptive Awareness

						95% CI			
Lead author (date)	**Construct**	**Measure**	**Follow-up**	***N***	***g***	**Lower**	**Upper**	***p***	**Forest plot**
Gawande (2018)	IAw	MAIA	6 months	84	0.00	-0.44	0.44	1.00	
Price (2019)	IAw	MAIA	6 months	125	-0.39	-0.70	-0.08	.01	
Price (2019)	IAw	MAIA	12 months	121	-0.75	-1.07	-0.43	.00	
Overall g_w				**330**	**-0.32**	**-0.86**	**0.23**	**.26**	



Note: IAw = interoceptive awareness; MAIA = multidimensional assessment of interoceptive awareness; *N* = number of participants contributing to data; *g* = effect size (Hedges' *g*); 95%CI = 95% confidence interval; *p* = significance value for g/g_w

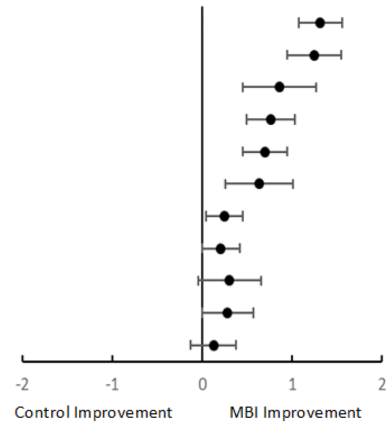
Effect Sizes Grouped by Interoceptive Construct

Studies were grouped by interoceptive construct to explore the differential effects of each measure and/or MAIA subscale (see Table 6, below, and Appendix D for individual study results). MBIs had a moderate to large impact on interoceptive awareness for six of the eight MAIA subscales: self-regulation, body listening, attention regulation, trusting, emotional awareness, noticing. Conversely, group mean differences were either small or non-significant and trivial for accuracy, sensibility and coherence scores, although these latter results were susceptible to publication bias ($N_{fs} \leq 2$).

Table 6

Pre-Post Standardised Mean Group Differences (Hedges' g) by Construct, with Forest Plot

Constr.	Subscale	Measure	*k*	*N*	*g*	95% CI Lower	95% CI Upper	*p*	Forest Plot	I^2	τ
IAw	Self Regulation	MAIA	5	377	1.31	1.07	1.56	.000		9.79	0.09
IAw	Body Listening	MAIA	4	309	1.25	0.95	1.55	.000		31.51	0.17
IAw	Attention Regulation	MAIA	5	377	0.86	0.46	1.27	.000		54.33	0.34
IAw	Trusting	MAIA	4	309	0.76	0.49	1.03	.000		26.83	0.15
IAw	Emotional Awareness	MAIA	5	377	0.70	0.46	0.94	.000		18.34	0.12
IAw	Noticing	MAIA	5	377	0.63	0.26	1.01	.001		61.86	0.33
IAw	Not Distracting	MAIA	5	377	0.25	0.05	0.45	.015		0.00	0.00
IAw	Not Worrying	MAIA	4	309	0.21	0.00	0.42	.052		0.00	0.00
IC		C	2	100	0.31	-0.05	0.66	.088		0.00	0.00
IS		SRA	3	169	0.29	0.00	0.57	.047		0.00	0.00
IAc		HBT	4	218	0.13	-0.12	0.38	.324		0.00	0.00



Constr. = Construct; IAw = interoceptive awareness; IAc = interoceptive accuracy; IS = interoceptive sensibility; IC = interoceptive coherence; MAIA = multidimensional assessment of interoceptive awareness (Mehling et al., 2012); HBT = Heartbeat tracking task (Schandry, 1981); SRA = self rated assessment of IAc confidence on Likert scale; C = correlation between IAc and IS scores; *k* = number of studies providing this data; *N* = total sample size; *g* = effect size (Hedges' *g*); 95%CI = 95% confidence interval; *p* = significance value for g/g_w; I^2 = proportion of between-studies variance; τ = tau or estimated standard deviation of underlying effects across studies

Self-Regulation

The largest improvements were noted for the MAIA self-regulation sub-scale. All studies (k = 5) revealed significant and large group differences (i.e. $g > 0.6$; $p < .01$), resulting in low heterogeneity. That is, mindfulness participants reported noticeable improvements in their ability to use interoceptive insight to regulate distress relative to waitlisted peers, those receiving usual care (i.e., psychotherapy, pharmacotherapy, exercise and nutrition counselling) or comparative treatments (i.e. relaxation training).

Body Listening

Four studies evaluated the impact of MBIs on participants' abilities to listen to, and gain insight from, their emotional and motivational states, with all reporting significant and very large effects in favour of mindfulness (Thomas et al., 2019; Price et al., 2019; Fissler et al., 2016; Mehling et al., 2017). Whilst this finding was unlikely to be characterised by publication bias ($N_{fs} > k$), individual study results exhibited wide confidence intervals, suggesting some imprecision in these estimates.

Attention Regulation

Of the five studies measuring the attention-regulation facet of interoception, three reported significant and very large improvements translating to a pooled effect that was robust: MBIs improved the ability to sustain and control attention towards bodily sensations (Fissler et al., 2016; Price et al., 2019; Thomas et al., 2019). Between-study variance was evident (I^2 > 50%; τ = .34). Principally, individuals experiencing chronic pain and comorbid depression revealed lower scores, on average, following MBCT compared to peers receiving usual medical or pharmacological treatment (*g* = 0.084, 95%CI [-0.663, 0.831],*p* = .825; deJong et al., 2016). Notably, the removal of this study reduced the overall heterogeneity (I^2 = 9.9%; τ = .10).

Trusting

Four studies examined the impact of MBIs using the MAIA trusting subscale (i.e., the degree to which inner sensations are considered trustworthy). Three reported large improvements (*g* > 0.70; *p* < .01,Fissler et al., 2016; Price et al., 2019; Thomas et al., 2019). In comparison, participants enrolled in an integrated MBSR program for the treatment of PTSD reported small, albeit non-significant gains immediately post-intervention (*g* = 0.219, 95% CI [-0.430, 0.869], *p* > .5; Mehling et al., 2018).

Emotional Awareness

Of the five studies targeting emotional awareness, three revealed improvements which translated to a large effect, notwithstanding the non-significant small to moderate between-group differences noted by deJong et al., (2016) and Fissler et al., (2016) for their chronic pain (*g* = 0.511, 95% CI [-0.248, 1.271], *p* = .187) and major depressive disorder samples (*g* = 0.313, 95% CI = [-0.141, 0.766], *p* = .177), respectively.

Noticing

The subjective ability to perceive inner sensations was targeted by five studies, with mixed results. Large improvements were reported for participants completing Mindfulness Oriented Recovery Enhancement (*g* = 1.308, 95% CI [0.711, 1.906], *p* = .000; Thomas et al., 2019) or MABT (*g* = 0.855, 95% CI [0.549, 1.161], *p* = .000; Price et al., 2019) relative to those receiving usual care (i.e., exercise, nutrition counselling and/or pharmacotherapy).

The effects associated with MBCT were comparable to usual care for the management of chronic pain (*g* = 0.129, 95% CI [-0.618, 0.877], *p* = .734; deJong et al., 2016). Small group differences were also found for MBSR versus integrated exercise (*g* = 0.337, 95% CI [-0.315, 0.990], *p* = .311; Mehling et al., 2017) and MBCT relative to waitlisted peers or those receiving relaxation training (*g* = 0.364, 95% CI [-0.091, 0.819], *p* = .117; Fissler et al., 2016).

Not Distracting and Not Worrying

Five studies evaluated the not-distracting dimension of interoception, a measure of bodily connection. Small and non-significant (or comparable) effects were reported (*k* = 4), as well as a large (albeit imprecise) effect estimate associated with MBCT (i.e., *g* = 0.816, 95% CI [0.037, 1.595], *p* = .040; deJong et al., 2016). A similar pattern of results was noted by three of the four studies that examined the not-worrying subscale: MBI participants reported a similar degree of improvement to controls. Price (2019) was the exception, revealing greater improvements above and beyond that reported by peers who received usual-care for substance-use-disorder (*g* = 0.314, 95% CI [0.028, 0.600], *p* = .032). Further research is required to confirm these findings ($N_{fs} \leq 2$).

Interoceptive Accuracy, Sensibility and Coherence

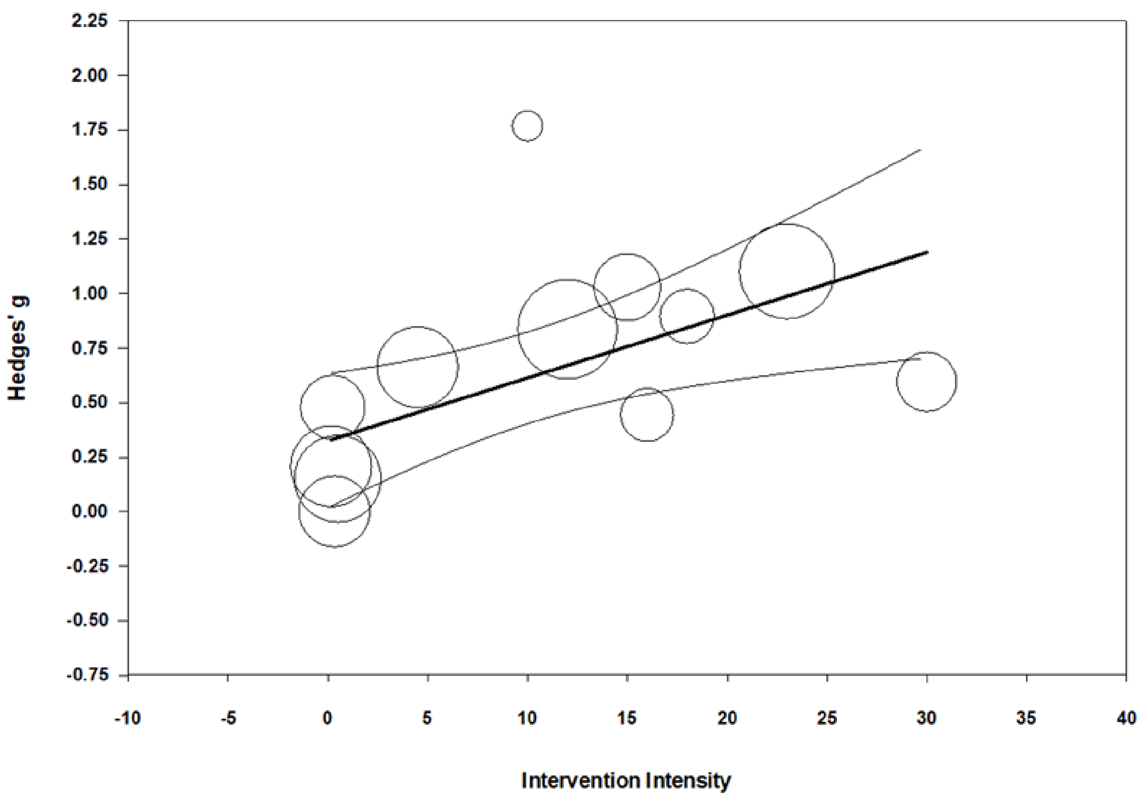
Four studies measured the impact of MBIs on objective IAc, with all reporting non-significant findings: participants' precision in detecting interoceptive signals (i.e., heart-beat counts) did not improve post-MBI (Aaron et al., 2020; Parkin et al., 2014_a, Parkin et al., 2014_b; Meyerholz et al., 2019). The pooled effect for interoceptive sensibility was also small, although characterised by significant within-study variation (i.e., wide CIs). The two studies that examined interoceptive coherence also reported small and non-significant group differences (Parkin et al., 2014_a, Parkin et al., 2014_b). The likelihood of publication bias was high across each of the aforementioned domains ($N_{fs} \leq 2$).

Sensitivity Analysis and Meta-Regression

A 'one study removed' sensitivity analysis revealed no statistical outliers: the combined effect across the 12 studies increased from 0.549 to 0.671 and remained significant ($p < .01$). A random-effects univariate meta-regression, with intervention intensity as the predictor variable was, however, significant (refer Figure 6). Intervention intensity explained 85% of the inter-study variance in observed pooled effects ($Q_{model} = 10.2$, df = 1, $p = .001$, $k = 12$). That is, more intensive MBI programs led to increased interoceptive ability, regardless of the measure used ($Q_{residual} = 11.91$, df = 10, $p = .29$, $I^2 = 16\%$, $\tau = .12$). It is recognised this estimate may be imprecise given the few studies in this meta-analysis (Thompson & Higgins, 2002).

Figure 6

Univariate Meta-Regression Scatterplot: Regression of Hedges' g on Intervention Intensity



Chapter 4

Discussion

Key Findings

The present review consolidates the evidence base for the effects of MBIs on interoception. Twelve RCTs, comprising 771 adults of diverse ages and clinical profiles, contributed to pooled effect size data. Across included studies, MBIs revealed an immediate and moderate to large treatment effect, indicating significant interoceptive improvements; a finding that was robust to publication bias and a one-study removed sensitivity analysis. Too few studies reported effects at follow-up preventing conclusive evidence from being drawn on the maintenance of treatment effects longer-term. However, intervention intensity emerged as a significant predictor of post-treatment effect. Findings are critically reviewed in this chapter alongside implications for practice and future research.

Effectiveness of MBIs

Interoceptive Awareness

Across six RCTs we found strong evidence that MBIs induce immediate, medium to large improvements in IAw. Our findings extend the current evidence base supporting the utility of MBIs in alleviating symptoms of psychopathology across common psychiatric disorders, wherein previous meta-analyses report small (g = 0.29) to moderate (g = 0.55) treatment outcomes for RCTs relative to active controls and no treatment controls, respectively (Goldberg et al., 2018; Khoury et al., 2013). They also align with RCTs showing moderate to large treatment effects post-mindfulness training for self-reported IAw (Bornemann et al., 2015; Duncan et al., 2017).

Of note, two of the examined studies did not find an effect for IAw (deJong et al., 2016; Mehling et al., 2018). There are several possible explanations for this. Firstly, as pilot studies evaluating feasibility of intervention delivery as opposed to efficacy of treatment effect per se, results likely reflect small, under-powered sample sizes (Cohen, 1992). Alternatively, discrepant findings may point to variability in intervention modality. While the majority of MBIs are meditation-based (Chisea & Malinowski, 2011), Mehling and colleagues (2018) did not incorporate formal meditation within their program, instead embedding mindfulness within an exercise practice - potentially limiting the extent to which this skill was internalised and integrated into daily life (i.e., beyond the exercise setting). While interventions vary in how they teach mindfulness (Chisea & Malinowski, 2011), a defining feature underpinning their therapeutic benefit may be sustained training in formal meditation practices (Kabat-Zinn, 1990; Crane et al., 2017). Lastly, null findings may reflect divergent participant clinical profiles. Studies for which an effect was not found involved participants with chronic pain and co-morbid depression (deJong et al., 2016) and PTSD (Mehling et al., 2018); populations that have shown variation in treatment outcomes, including adverse effects (e.g., intrusive thoughts; Lustyk et al., 2009; Lakhan & Schofield, 2013). While neither study reported the presence (nor absence) of adverse effects, such aspects may have contributed to the wide CIs noted for these studies and would support recommendations that more complex mental health presentations require specialist intervention (Cloitre et al., 2011; Bower & Gilbody, 2005) .

Sub-Facets of Interoceptive Awareness

Compared to controls, MBI participants showed improvement on seven of the eight dimensions of IAw as measured by the MAIA. No changes were evident for the *Not Worrying* subscale, indicating MBIs do not reduce the tendency to react to sensations of discomfort with distress, a finding mirrored elsewhere (Bornemann & Singer, 2017). Despite this, the small effect found for MABT is interesting (Price et al., 2019). As the only study utilising a body-oriented MBI, programs which emphasise ‘bottom-up’ processing, like MABT, may yield greater effects on the Not Worrying scale than programs, like MBCT, that are more heavily focused on present-state conscious mental activity, suggesting an avenue for future study.

While our findings indicate MBIs cultivated the ability to sustain attention toward unpleasant sensations (i.e., *Not Distracting*) - a result congruent with prior research demonstrating a negative association between experiential avoidance and mindfulness (Riley, 2014) - this scale’s suboptimal internal consistency needs to be noted (Cronbach’s alpha = 0.53; Mehling et al. 2018).

As avoidant behaviours are implicated across a broad spectrum of psychopathology (Hayes et al., 1996), and non-avoidant coping strategies lead to better mental-health outcomes (Williams et al., 2010), further research to elucidate the role of MBIs in facilitating this coping style is warranted.

A moderate effect found for the *Noticing* subscale suggests MBIs improved participants' ability to notice interoceptive stimuli; a key skill taught within the mindfulness framework (Crane et al., 2017). While an intuitive result, this subscale is not typically associated with practice-related changes (Bornemenn et al., 2015), although large differences have been found within chronic pain populations between those who practice mindfulness and those who do not (Mehling et al., 2012). Inconsistent findings on this subscale may therefore reflect methodological differences between studies, divergent participant populations, or differences in intervention modalities, possibly explaining the heterogeneity observed. The largest benefits were associated with RCTs characterised by adequately powered samples (Cohen, 1992) as well as programs promoting health-related behavioural change (i.e., MORE; Thomas et al, 2019) and interoceptive exposure (i.e., MABT; Price et al., 2019) for exclusively female populations. As females report significantly higher scores on this scale, tending to notice bodily sensations more often than males (Grabauskaite et al., 2017), gender may well have been a moderating factor and may therefore represent a particular group of interest for the development of targeted interventions.

We found large between-group differences for the MAIA sub-components of *Self-Regulation, Body-Listening,* and *Attention-Regulation,* collectively described as the 'regulatory' aspects of IAw (Mehling et al., 2012). Through mindfulness practice, participants strengthened their ability to deliberately focus attention on their body to regulate emotional-motivational states; a finding similarly echoed in qualitative (Landsman-Dijkstra et al., 2004; Morone et al., 2010) and longitudinal studies (Bornemann et al., 2015). Moreover, those who had received a mindfulness intervention reported significantly greater increases in the extent to which they trust their interoceptive sensations (*Trusting*) in informing their emotional state (*Emotional Awareness*); together the 'belief-related' aspects of IAw. Given these are key processes explicitly trained in MBIs, our findings underpin a hypothesised link between mindfulness and improved attention regulation (Hölzel et al., 2011), non-reactivity (Shapiro et al., 2006), emotional awareness (Bishop et al., 2004) and, in turn, self-regulation (Baer, 2003). As these behavioural changes play a central role in reducing symptoms of psychopathology and, relatedly, in improving clinical outcomes across a variety of mental-health conditions (Baer, 2007; Schuman-Olivier, 2020), such findings have important clinical implications. That is, MBIs induce significant improvements in aspects of interoceptive awareness associated with positive health-related behavioural change and therefore represent opportunities for application to those experiencing difficulties with IAw (e.g., clinically anxious populations; Paulus et al., 2019).

Interoceptive Accuracy

The lack of an effect found for *interoceptive accuracy* suggests MBIs did not improve the precision with which internal bodily signals were detected. Our findings parallel a previous meta-analysis examining the influence of mindfulness on objective measures of body awareness where no effect was found for heartbeat-related tasks (g = 0.13, 95% CI [-0.03, 0.29]; Treves et al., 2019). While our lack of evidence for an effect strengthens the current evidence base suggesting increases in IAc are unrelated to the benefits of mindfulness (Khalsa et al., 2020; Parkin et al., 2013; Fischer et al., 2017; Melloni, 2013), several reasons lend caution to this conclusion. Firstly, estimates of the failsafe-N indicate results are not robust to publication bias, and relatedly, our total number of samples (k = 4) and participants (n = 218) were modest. Secondly, it may be that large-scale, longitudinal trials are required to detect such changes, should they exist (Bornemann & Singer, 2017). Moreover, all studies within our sample relied on heartbeat-detection tasks as a marker of IAc, a measure criticised for its poor construct validity, limited test-retest reliability, ability to be influenced by cognitive strategies, and which may not generalise to other sensory modalities (Khalsa et al.,2009; Brener & Ring, 2016; Khalsa et al., 2018). As mindfulness practices do not direct attentional focus toward the heart specifically, but rather a diffuse array of internal stimuli, it remains an open question whether MBIs promote IAc in other sensory domains (e.g. musculature or respiratory activity; Khalsa et al., 2018).

Interestingly, a small effect was found for *interoceptive sensibility,* indicating that confidence improved despite no objective improvement in accuracy, which translated to a small and non-significant effect for *interoceptive coherence* (i.e. the degree of correspondence between accuracy and sensibility scores). Taken together, findings support the notion that mindfulness is associated with the subjective perception of cardiac interoceptive ability as opposed to accuracy per se (Parkin et al., 2014). It follows that mindfulness training, in isolation, is not a strong candidate for interventions aimed at promoting IAc.

Longer Term Effects

Meaningful improvements were not sustained at follow-up, although the small number of studies contributing to this data (k = 2) prevents conclusive evidence. Notwithstanding, our results correspond with previous RCTs showing diminishing post-treatment-effects for mindfulness (Morone et al., 2016; Kearney et al., 2013) and support the belief that sustained daily practice is required for the benefits of mindfulness to prevail (Kabat Zinn, 1990). To better understand the temporal stability of treatment effects for interoception, RCTs that assess outcomes at follow-up time-points are necessary. Moreover, with research demonstrating that ‘booster’ sessions and continued self-practice of skills taught within the formal MBI setting moderate treatment outcomes at follow up (Mathew et al., 2010), consideration for the individual factors contributing to continued self-practice of mindfulness skills (e.g., trait conscientiousness; Tang & Braver, 2020) would facilitate targeted application in treatment settings to those for whom mindfulness best serves longer-term.

Intervention Intensity

As a skill, mindfulness takes time and commitment to learn (Kabat-Zinn, 1990). MBIs of a longer duration may therefore provide more opportunity to acquire skills, embed them into daily life and consequently lead to greater improvement in interoception. Our meta-regression results support this notion. This finding is consistent with those of earlier studies (Carmody & Baer, 2008;

Shapiro et al., 2008; Khoury et al., 2013) and offers insight to clinicians considering abbreviated MBIs for populations where time commitments pose a barrier; results may be compromised. Importantly, our findings provide credible evidence that the substantial time commitment and effort required of participants in typical (i.e. 8-week long) mindfulness programs does appear to yield incremental benefit over less intensive programs, as appears to be the case for psychotherapy interventions generally (Cuijpers et al., 2013). It is plausible this relationship is partly driven by the increased opportunity for participants to seek advice and discuss concerns with an experienced practitioner and may also explain better outcomes typically derived from therapists with more rigorous training (Crane et al., 2010), although self-help modalities do show promise (Cavanagh et al., 2014). That said, lengthy mindfulness practices have been associated with high levels of attrition (Strohmaier, 2020), a trend evident in our sample. Therefore, identifying pre-existing variables, (e.g., individual preferences for practice style; Burke, 2012, positive beliefs about mindfulness; Langdon et al., 2011), that may indicate differential ability or willingness to engage in MBIs has clear therapeutic relevance and serves as a question for future research. Importantly, it is acknowledged that higher doses may not always be universally beneficial as dose-response is unlikely to be a linear relationship (Britton; 2019), therefore the over-arching framework of future research should consider inflection points (i.e., optimal verse ineffective or harmful doses; Baer et al., 2019).

While our results contrast with Carmody and Baer (2009) who did not find a significant relationship between in-class hours and reductions in psychological distress, such divergence may be a function of what was measured. That is, in-class hours appears to be an important moderator of interoceptive outcomes but less so for measures of psychological distress.

It is plausible that other study characteristics in our sample were highly correlated with intensity thus confounding results, namely intervention modality, with body-scan practices significantly less intensive than MBSR- and MBCT-based programs. As the number of studies fell short of the ten-per-co-variate criterion recommended for adequate power (Borenstein, 2009), this hypothesis was not able to be tested in the present study and so represents an avenue for future research. Moreover, consideration for the extent to which home practice influenced intervention outcomes was not considered although evidence suggests there is a small, positive association (Parsons et al., 2017).

Limitations

As is the case with meta-analyses, we were limited by the published literature. While our study was strengthened by its restriction to RCTs, substantiating stronger causal claims for observed changes, in some cases (*k* = 6) the relatively small number of participants per study puts effect size estimates at risk for small sample bias (Sterne et al, 2000) - a concern for mindfulness-based research generally (Dimidjian & Segal, 2015). Moreover homogeneity of sample demographics (i.e., mostly female, Caucasian participants from two high-income countries) limits the generalisability of results. Notably, gender has been found to moderate outcomes in response to mindfulness, with women typically experiencing more favourable results (Katz & Toner, 2013) - a finding that supports further examination.

Due to the scarcity of available studies, we inevitably included RCTs with varying levels of quality, including brief, single-session interventions which is likely to have underestimated the pooled effect. The main methodological shortcomings included the inability to conduct MBI studies under a double-blind condition, insufficient information regarding participant drop-out, therapist competence, the incidence of adverse events, as well as the scarcity of actively controlled studies to control for nonspecific factors such as group support or therapists care – a concern repeatedly raised in the literature (Goldberg et al., 2017). The evidence base would profit from future studies comparing MBIs against other first-line treatments to better delineate the specificity of intervention effects, and ultimately answer a key question facing clinicians (i.e., how do mindfulness-based therapies compare to other evidence-based psychotherapies?). Unfortunately the paucity of published literature precluded us from being able to address this question. Moreover, it was not possible to analyse variation of results between common mental-health disorders nor across control comparison groups (i.e., WLC, TAU, active treatments). It is likely that MBIs may result in different outcomes across dissimilar patient groups and/or control conditions (Hedman-Lagerlöf et al., 2018). Our inability to examine such effects is therefore recognised as a limitation on what can reliably be concluded.

Lastly, validity of findings are limited by our conceptualisation of MBIs which omitted other forms of contemplative practices aimed at improving awareness of a mind–body connection (e.g., yoga, tai-chi) or those incorporating an attitudinal stance of mindfulness as part of a multi-component program (e.g., Dialectical Behaviour Therapy; Linehan, 1993). It remains to be determined whether these practices induce similar post-treatment effects to MBIs examined within the present study, as suggested in recent reviews highlighting the role of contemplative practices in improving interoception (Gibson, 2019; Farb et al., 2015).

Conclusion

These limitations notwithstanding, the overall pattern of findings underscores the potential promise of MBIs for improving several facets of impaired interoception implicated in the aetiology and maintenance of many mental-health disorders. It appears that the strongest recommendation can be made for MBIs improving the regulatory and belief-related aspects of IAw. The finding that intervention intensity significantly moderated treatment effect indicates the potential efficacy of more intensive programs. However, benefits of MBIs at follow-up and on measures of interoceptive accuracy are less clear. Future RCTs examining the efficacy of these approaches relative to other evidence-based therapies are needed in order to meaningfully inform targeted clinical applications.

References

Aaron, R. V., Blain, S. D., Snodgress, M. A., & Park, S. (2020). Quadratic relationship between alexithymia and interoceptive accuracy, and results from a pilot mindfulness intervention. *Frontiers in Psychiatry*, 11, 132. https://doi.org/10.3389/fpsyt.2020.00132

Agoritsas, T., Merglen, A., Courvoisier, D.S., Combescure, C., Garin, N., Perrier, A., Perneger, T.V., 2012. Sensitivity and predictive value of 15 PubMed search strategies to answer clinical questions rated against full systematic reviews. *Journal of Medical Internet Research 14*, e85. doi:10.2196/jmir.2021

Akl, E. A., Briel, M., You, J. J., Sun, X., Johnston, B. C., Busse, J. W., Mulla, S., Lamontagne, F., Bassler, D., Vera, C., Alshurafa, M., Katsios, C. M., Zhou, Q., Cukierman-Yaffe, T., Gangji, A., Mills, E. J., Walter, S. D., Cook, D. J., Schunemann, H. J., … Guyatt, G. H.. (2012). Potential impact on estimated treatment effects of information lost to follow-up in randomised controlled trials (LOST-IT): systematic review. *BMJ*, 344(may18 1), e2809–e2809. https://doi.org/10.1136/bmj.e2809

Baer, R. A. (2003). Mindfulness training as a clinical intervention: A conceptual and empirical review. *Clinical Psychology: Science and Practice*, 10(2), 125–143. https://doi.org/10.1093/clipsy.bpg015

Baer, R.A. (2007). Mindfulness, assessment, and transdiagnostic processes. *Psychological Inquiry*, 18:4, 238-242, DOI: 10.1080/10478400701598306

Baer, R., Crane, C., Miller, E., & Kuyken, W. (2019). Doing no harm in mindfulness-based programs: Conceptual issues and empirical findings. *Clinical Psychology Review*, 71, 101–114. https://doi.org/10.1016/j.cpr.2019.01.001

Bechara, A., & Naqvi, N. (2004). Listening to your heart: interoceptive awareness as a gateway to feeling. *Nature Neuroscience*, 7(2), 102–103. https://doi.org/10.1038/nn0204-102

Bell, M. L., Fiero, M., Horton, N. J., & Hsu, C.-H.. (2014). Handling missing data in RCTs; a review of the top medical journals. *BMC Medical Research Methodology*, 14(1), 118. https://doi.org/10.1186/1471-2288-14-118

Belling, R., Mclaren, S., Paul, M., Ford, T., Kramer, T., Weaver, T., Hovish, K., Islam, Z., White, S., Singh, S.P., 2014. The effect of organisational resources and eligibility issues on transition from child and adolescent to adult mental health services. *Journal of Health Services Research & Policy* 19, 169–176. doi:10.1177/1355819614527439

Berlucchi, G., Aglioti, S.M., 2010. The body in the brain revisited. *Experimental Brain Research* 200, 25–35. doi:10.1007/s00221-009-1970-7

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., Segal, Z. V., Abbey, S., Speca, M., Velting, D., & Devins, G. (2004). Mindfulness: A proposed operational definition. *Clinical Psychology: Science and Practice*, 11(3), 230–241. https://doi.org/10.1093/clipsy.bph077

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. (2009). *Introduction to meta-analysis*. Chichester, U.K: John Wiley & Sons

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2010). A basic introduction to fixed-effect and random-effects models for meta-analysis. *Research Synthesis Methods*, 1(2), 97–111. https://doi.org/10.1002/jrsm.12

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2013). *Comprehensive Meta-Analysis*. In (Version 3.3.070) [Computer Software]. Biostat. https://www.metaanalysis.com/

Bornemann, B., Herbert, B. M., Mehling, W. E., & Singer, T. (2015). Differential changes in self-reported aspects of interoceptive awareness through 3 months of contemplative training. *Frontiers in Psychology*, 5, 1504. https://doi.org/10.3389/fpsyg.2014.01504

Bornemann, B., & Singer, T. (2017). Taking time to feel our body: Steady increases in heartbeat perception accuracy and decreases in alexithymia over 9 months of contemplative mental training. *Psychophysiology*, 54(3), 469–482. https://doi.org/10.1111/psyp.12790

Bower, P., & Gilbody, S. (2005). Managing common mental health disorders in primary care: conceptual models and evidence base. *BMJ* (Clinical research ed.), 330(7495), 839–842. https://doi.org/10.1136/bmj.330.7495.839

Bramer, W.M., Rethlefsen, M.L., Kleijnen, J. et al. Optimal database combinations for literature searches in systematic reviews: a prospective exploratory study. *Syst Rev* 6, 245 (2017). https://doi.org/10.1186/s13643-017-0644-y

Brener, J., & Ring, C. (2016). Towards a psychophysics of interoceptive processes: the measurement of heartbeat detection. Philosophical transactions of the Royal Society of London. Series B, *Biological Sciences*, 371(1708), 20160015. https://doi.org/10.1098/rstb.2016.0015

Brewer, R., Murphy, J., & Bird, G. (2021). Atypical interoception as a common risk factor for psychopathology: A review. *Neuroscience and Biobehavioral Reviews*, S0149-7634(21)00345-6. Advance online publication. https://doi.org/10.1016/j.neubiorev.2021.07.036

Brigham, G.S., Feaster, D.J., Wakim, P.G., Dempsey, C.L. (2009). Choosing a control group in effectiveness trials of behavioral drug abuse treatments. *Journal of Substance Abuse Treatment* 37, 388–397. doi:10.1016/j.jsat.2009.05.004

Britton W. B. (2019). Can mindfulness be too much of a good thing? The value of a middle way. *Current Opinion in Psychology*, 28, 159–165. https://doi.org/10.1016/j.copsyc.2018.12.011

Burke A. (2012). Comparing individual preferences for four meditation techniques: Zen, Vipassana (Mindfulness), Qigong, and Mantra. *Explore* (New York, N.Y.), 8(4), 237–242. https://doi.org/10.1016/j.explore.2012.04.003

Calì, G., Ambrosini, E., Picconi, L., Mehling, W. E., & Committeri, G. (2015). Investigating the relationship between interoceptive accuracy, interoceptive awareness, and emotional susceptibility. *Frontiers in Psychology*, 6, 1202. https://doi.org/10.3389/fpsyg.2015.01202

Cameron, O.G. (2001). Interoception: The inside story — A model for psychosomatic processes, *Psychosomatic Medicine*, 63(5), 697-710.

Carlson, L. E., Tamagawa, R., Stephen, J., Doll, R., Faris, P., Dirkse, D., & Speca, M. (2014). Tailoring mind-body therapies to individual needs: patients' program preference and psychological traits as moderators of the effects of mindfulness-based cancer recovery and supportive-expressive therapy in distressed breast cancer survivors. *Journal of the National Cancer Institute,* 50, 308–314. https://doi.org/10.1093/jncimonographs/lgu034

Carmody, J., & Baer, R. A. (2008). Relationships between mindfulness practice and levels of mindfulness, medical and psychological symptoms and well-being in a mindfulness-based stress reduction program. *Journal of Behavioral Medicine*, 31(1), 23–33. https://doi.org/10.1007/s10865-007-9130-7

Carmody, J., & Baer, R. A. (2009). How long does a mindfulness-based stress reduction program need to be? A review of class contact hours and effect sizes for psychological distress. *Journal of Clinical Psychology*, 65(6), 627–638. https://doi.org/10.1002/jclp.20555

Carmody, J., Baer, R. A., L B Lykins, E., & Olendzki, N. (2009). An empirical study of the mechanisms of mindfulness in a mindfulness-based stress reduction program. *Journal of Clinical Psychology*, 65(6), 613–626. https://doi.org/10.1002/jclp.20579

Caspi, A., Houts, R. M., Belsky, D. W., Goldman-Mellor, S. J., Harrington, H., Israel, S., Meier, M. H., Ramrakha, S., Shalev, I., Poulton, R., & Moffitt, T. E. (2014). The p factor. *Clinical Psychological Science*, 2(2), 119–137. https://doi.org/10.1177/2167702613497473

Cavanagh, K., Strauss, C., Forder, L., & Jones, F. (2014). Can mindfulness and acceptance be learnt by self-help?: a systematic review and meta-analysis of mindfulness and acceptance-based self-help interventions. *Clinical psychology review*, 34(2), 118–129. https://doi.org/10.1016/j.cpr.2014.01.001

Cayoun, B. A., & Shires, A. G. (2020). Co-emergence reinforcement and its relevance to interoceptive desensitization in mindfulness and therapies aiming at transdiagnostic efficacy. *Frontiers in Psychology*, 11, 545945. https://doi.org/10.3389/fpsyg.2020.545945

Chiesa, A., & Malinowski, P. (2011). Mindfulness-based approaches: are they all the same?. *Journal of Clinical Psychology*, 67(4), 404–424. https://doi.org/10.1002/jclp.20776

Cloitre, M., Courtois, C.A., Charuvastra, A., Carapezza, R., Stolbach, B.C. and Green, B.L. (2011), Treatment of complex PTSD: Results of the ISTSS expert clinician survey on best practices. *J. Traum. Stress*, 24: 615-627. https://doi.org/10.1002/jts.20697

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Cohen, J., (1992). Quantitative methods in psychology: A power primer. *Psychological Bulletin*, 112(1), 155-159.

Craig, A. How do you feel? Interoception: the sense of the physiological condition of the body. *Nat Rev Neurosci* 3, 655–666 (2002). https://doi.org/10.1038/nrn894

Crane, R. S., Kuyken, W., Hastings, R. P., Rothwell, N., & Williams, J. M. (2010). Training teachers to deliver mindfulness-based interventions: Learning from the UK experience. *Mindfulness*, 1(2), 74–86. https://doi.org/10.1007/s12671-010-0010-9

Crane, R. S., Brewer, J., Feldman, C., Kabat-Zinn, J., Santorelli, S., Williams, J. M., & Kuyken, W. (2017). What defines mindfulness-based programs? The warp and the weft. *Psychological Medicine*, 47(6), 990–999. https://doi.org/10.1017/S0033291716003317

Creswell, J. (2017). Mindfulness interventions. *Annual Review of Psychology*, 68, 491-516 .

Critchley, H. D., Wiens, S., Rotshtein, P., Ohman, A., & Dolan, R. J. (2004). Neural systems supporting interoceptive awareness. *Nature Neuroscience*, 7(2), 189–195. https://doi.org/10.1038/nn1176

Cuijpers, P., Berking, M., Andersson, G., Quigley, L., Kleiboer, A., & Dobson, K. S. (2013). A meta-analysis of cognitive-behavioural therapy for adult depression, alone and in comparison with other treatments. *Canadian Journal of Psychiatry*. Revue canadienne de psychiatrie, 58(7), 376–385. https://doi.org/10.1177/070674371305800702

de Jong, M., Lazar, S. W., Hug, K., Mehling, W. E., Hölzel, B. K., Sack, A. T., Peeters, F., Ashih, H., Mischoulon, D., & Gard, T. (2016). Effects of Mindfulness-Based Cognitive Therapy on Body Awareness in Patients with Chronic Pain and Comorbid Depression. *Frontiers in Psychology*, 7, 967. https://doi.org/10.3389/fpsyg.2016.00967

Dimidjian, S., & Linehan, M. (2003). Defining an Agenda for Future Research on the Clinical Application of Mindfulness Practice. *Clinical Psychology-science and Practice*, 10, 166-171.

Dimidjian, S., & Segal, Z. V. (2015). Prospects for a clinical science of mindfulness-based intervention. *The American Psychologist*, 70(7), 593–620. https://doi.org/10.1037/a0039589

Doll, R. (1998). Controlled trials: the 1948 watershed. *BMJ* 317, 1217–1220. doi:10.1136/bmj.317.7167.1217

Domschke, K., Stevens, S., Pfleiderer, B., Gerlach, A.L. (2010). Interoceptive sensitivity in anxiety and anxiety disorders: An overview and integration of neurobiological findings, *Clinical Psychology Review*. 30 (2010) 1–11.

Duncan, L. G., Cohn, M. A., Chao, M. T., Cook, J. G., Riccobono, J., & Bardacke, N. (2017). Benefits of preparing for childbirth with mindfulness training: a randomized controlled trial with active comparison. *BMC Pregnancy and Childbirth*, 17(1), 140. https://doi.org/10.1186/s12884-017-1319-3

Dunn, B. D., Galton, H. C., Morgan, R., Evans, D., Oliver, C., Meyer, M., Cusack, R., Lawrence, A. D., & Dalgleish, T. (2010). Listening to your heart: How interoception shapes emotion experience and intuitive decision making. *Psychological Science*, 21(12), 1835–1844. https://doi.org/10.1177/0956797610389191

Dunn, B. D., Stefanovitch, I., Evans, D., Oliver, C., Hawkins, A., & Dalgleish, T. (2010b). Can you feel the beat? Interoceptive awareness is an interactive function of anxiety- and depression-specific symptom dimensions. *Behaviour Research and Therapy*, 48(11), 1133–1138. https://doi.org/10.1016/j.brat.2010.07.006

Duquette P. (2017). Increasing Our Insular World View: Interoception and Psychopathology for Psychotherapists. *Frontiers in Neuroscience*, 11, 135. https://doi.org/10.3389/fnins.2017.00135

Duval, S., Tweedie, R., (2000). Trim and Fill: A Simple Funnel-Plot-Based Method of Testing and Adjusting for Publication Bias in Meta-Analysis. *Biometrics* 56, 455–463. doi:10.1111/j.0006-341x.2000.00455.x

Egger, M., Smith, G.D., Schneider, M., Minder, C., (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ,* 315, 629–634. doi:10.1136/bmj.315.7109.629

Ekici, Ç., Garip, G. & Van Gordon, W. (2020). The Lived Experiences of Experienced Vipassana Mahasi Meditators: an Interpretative Phenomenological Analysis. *Mindfulness* 11, 140–152. https://doi.org/10.1007/s12671-018-1063-4

Estrada, E., Ferrer, E., & Pardo, A. (2019). Statistics for Evaluating Pre-post Change: Relation Between Change in the Distribution Center and Change in the Individual Scores. *Frontiers in Psychology*, 9, 2696. https://doi.org/10.3389/fpsyg.2018.02696

Farb, N., Daubenmier, J., Price, C. J., Gard, T., Kerr, C., Dunn, B. D., Klein, A. C., Paulus, M. P., & Mehling, W. E. (2015). Interoception, contemplative practice, and health. *Frontiers in Psychology*, 6, 763. https://doi.org/10.3389/fpsyg.2015.00763

Ferentzi, E., Horváth, Á., & Köteles, F. (2019). Do body-related sensations make feel us better? Subjective well-being is associated only with the subjective aspect of interoception. *Psychophysiology*, 56(4), e13319. https://doi.org/10.1111/psyp.13319

Fischer, D., Messner, M., & Pollatos, O. (2017). Improvement of Interoceptive Processes after an 8-Week Body Scan Intervention. *Frontiers in Human Neuroscience*, 11, 452. https://doi.org/10.3389/fnhum.2017.00452

Fissler, M., Winnebeck, E., Schroeter, T., Gummersbach, M., Huntenburg, J. M., Gaertner, M., & Barnhofer, T. (2016). An investigation of the effects of brief mindfulness training on self-reported interoceptive awareness, the ability to decenter, and their role in the reduction of depressive symptoms. *Mindfulness*, 7(5), 1170–1181. https://doi.org/10.1007/s12671-016-0559-z

Fox, K. C., Zakarauskas, P., Dixon, M., Ellamil, M., Thompson, E., & Christoff, K. (2012). Meditation experience predicts introspective accuracy. *PloS one*, 7(9), e45370. https://doi.org/10.1371/journal.pone.0045370

Friedberg, J. P., Lipsitz, S. R., & Natarajan, S. (2010). Challenges and recommendations for blinding in behavioral interventions illustrated using a case study of a behavioral intervention to lower blood pressure. *Patient Education and Counseling*, 78(1), 5–11. https://doi.org/10.1016/j.pec.2009.04.009

Fu, R., Gartlehner, G., Grant, M., Shamliyan, T., Sedrakyan, A., Wilt, T. J., Griffith, L., Oremus, M., Raina, P., Ismaila, A., Santaguida, P., Lau, J., & Trikalinos, T. A. (2011). Conducting quantitative synthesis when comparing medical interventions: AHRQ and the Effective Health Care Program. *Journal of Clinical Epidemiology*, 64(11), 1187–1197. https://doi.org/10.1016/j.jclinepi.2010.08.010

Furman, D. J., Waugh, C. E., Bhattacharjee, K., Thompson, R. J., & Gotlib, I. H. (2013). Interoceptive awareness, positive affect, and decision making in major depressive disorder. *Journal of Affective Disorders*, 151(2), 780–785. https://doi.org/10.1016/j.jad.2013.06.044

Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (2015). Knowing your own heart: distinguishing interoceptive accuracy from interoceptive awareness. *Biological Psychology*, 104, 65–74. https://doi.org/10.1016/j.biopsycho.2014.11.004

Garfinkel, S. N., Tiley, C., O'Keeffe, S., Harrison, N. A., Seth, A. K., & Critchley, H. D. (2016). Discrepancies between dimensions of interoception in autism: Implications for emotion and anxiety. *Biological Psychology*, 114, 117–126. https://doi.org/10.1016/j.biopsycho.2015.12.003

Gawande, R., To, M. N., Pine, E., Griswold, T., Creedon, T. B., Brunel, A., Lozada, A., Loucks, E. B., & Schuman-Olivier, Z. (2018). Mindfulness Training Enhances Self-Regulation and Facilitates Health Behavior Change for Primary Care Patients: a Randomized Controlled Trial. *Journal of General Internal Medicine*, 34(2), 293–302. https://doi.org/10.1007/s11606-018-4739-5

Gibson J. (2019). Mindfulness, Interoception, and the Body: A Contemporary Perspective. *Frontiers in Psychology*, 10, 2012. https://doi.org/10.3389/fpsyg.2019.02012

Goldberg, S., Tucker, R.P., Greene, P.A., Simpson, T., Kearney, D., & Davidson, R. (2017). Is mindfulness research methodology improving over time? A systematic review. *PLoS ONE*, 12.

Goldberg, S., Tucker, R.P., Greene, P.A., Davidson, R., Wampold, B., Kearney, D., & Simpson, T. (2018). Mindfulness-based interventions for psychiatric disorders: A systematic review and meta-analysis. *Clinical Psychology Review*, 59, 52-60

Government of South Australia. (2016, July). *Transition for adolescents from paediatric health services to adult health services.* http://www.wch.sa.gov.au/services/adolescent/documents/transition_parent_july_2016.pdf

Grabauskaitė, A., Baranauskas, M., & Griškova-Bulanova, I. (2017). Interoception and gender: What aspects should we pay attention to?. *Consciousness and Cognition*, 48, 129–137. https://doi.org/10.1016/j.concog.2016.11.002

Grant, A. M., & Schwartz, B. (2011). Too Much of a Good Thing. *Perspectives on Psychological Science*, 6(1), 61–76. https://doi.org/10.1177/1745691610393523

Greeson J., Garland E. L., Black D. (2014). "Mindfulness: a transtherapeutic approach for transdiagnostic mental processes," in The Wiley-Blackwell Handbook of Mindfulness, 1st Edn, eds Ie A., Ngnoumen C. T., Langer E. J. (Chichester: Wiley;), 533–562.

Hayes, S. C., Wilson, K. G., Gifford, E. V., Follette, V. M., & Strosahl, K. (1996). Experimental avoidance and behavioral disorders: a functional dimensional approach to diagnosis and treatment. *Journal of consulting and Clinical Psychology*, 64(6), 1152–1168. https://doi.org/10.1037//0022-006x.64.6.1152

Hedman-Lagerlöf, M., Hedman-Lagerlöf, E., & Öst, L. (2018). The empirical support for mindfulness-based interventions for common psychiatric disorders: a systematic review and meta-analysis. *Psychological Medicine*, 48, 2116 - 2129.

Herbert, B. M., Herbert, C., & Pollatos, O. (2011). On the relationship between interoceptive awareness and alexithymia: is interoceptive awareness related to emotional awareness?. *Journal of Personality*, 79(5), 1149–1175. https://doi.org/10.1111/j.1467-6494.2011.00717.x

Hölzel, B. K., Ott, U., Hempel, H., Reibold, K., & Stark, R. (2006). How does mindfulness work? An interview study with experienced meditators. In 24th Symposium of the Section for Clinical Psychology and Psychotherapy of the German Society for Psychology, Würzburg, Germany

Hölzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011). How Does Mindfulness Meditation Work? Proposing Mechanisms of Action From a Conceptual and Neural Perspective. Perspectives on psychological science : *a journal of the Association for Psychological Science*, 6(6), 537–559. https://doi.org/10.1177/1745691611419671

Hölzel, B. K., Carmody, J., Vangel, M., Congleton, C., Yerramsetti, S. M., Gard, T., & Lazar, S. W. (2011_b). Mindfulness practice leads to increases in regional brain gray matter density. *Psychiatry Research*, 191(1), 36–43. https://doi.org/10.1016/j.pscychresns.2010.08.006

Higgins, J. P. T. (2003). Measuring inconsistency in meta-analyses. *BMJ*, 327(7414), 557–560. https://doi.org/10.1136/bmj.327.7414.557

Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA (editors). *Cochrane Handbook for Systematic Reviews of Interventions* version 6.2 (updated February 2021). Cochrane, 2021. Available from www.training.cochrane.org/handbook.

Jones, G. E. (1994). Perception of visceral sensations: A review of recent findings, methodologies, and future directions. In J. R. Jennings, P. K. Ackles, & M. G. H. Coles (Eds.), *Advances in Psychophysiology: A research Annual*, Vol. 5, pp. 55–191).

Katz, D., & Toner, B. (2013). A systematic review of gender differences in the effectiveness of mindfulness-based treatments for substance use disorders. *Mindfulness*, 4(4), 318–331. https://doi.org/10.1007/s12671-012-0132-3

Kabat-Zinn, J., & University of Massachusetts Medical Center/Worcester. (1990). *Full catastrophe living: Using the wisdom of your body and mind to face stress, pain, and illness.* New York, N.Y: Delacorte Press.

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology: Science and Practice*, 10(2), 144–156. https://doi.org/10.1093/clipsy.bpg016

Kearney, D. J., McDermott, K., Malte, C., Martinez, M., & Simpson, T. L. (2013). Effects of participation in a mindfulness program for veterans with posttraumatic stress disorder: a randomized controlled pilot study. *Journal of Clinical Psychology*, 69(1), 14–27. https://doi.org/10.1002/jclp.21911

Khalsa, S. S., Rudrauf, D., Damasio, A. R., Davidson, R. J., Lutz, A., & Tranel, D. (2008). Interoceptive awareness in experienced meditators. *Psychophysiology*, 45(4), 671–677. https://doi.org/10.1111/j.1469-8986.2008.00666.

Khalsa, S. S., Rudrauf, D., Sandesara, C., Olshansky, B., & Tranel, D. (2009). Bolus isoproterenol infusions provide a reliable method for assessing interoceptive awareness. *International Journal of Psychophysiology*, 72(1), 34–45. https://doi.org/10.1016/j.ijpsycho.2008.08.010

Khalsa, S.S., Rudrauf, D. and Tranel, D. (2009_b), Interoceptive awareness declines with age. *Psychophysiology*, 46: 1130-1136. https://doi.org/10.1111/j.1469-8986.2009.00859.x

Khalsa, S.S., Lapidus, R.C. (2016). Can Interoception Improve the Pragmatic Search for Biomarkers in Psychiatry? *Frontiers in Psychiatry* 7. doi:10.3389/fpsyt.2016.00121

Khalsa, S. S., Adolphs, R., Cameron, O. G., Critchley, H. D., Davenport, P. W., Feinstein, J. S., Feusner, J. D., Garfinkel, S. N., Lane, R. D., Mehling, W. E., Meuret, A. E., Nemeroff, C. B., Oppenheimer, S., Petzschner, F. H., Pollatos, O., Rhudy, J. L., Schramm, L. P., Simmons, W. K., Stein, M. B., Stephan, K. E., … Interoception Summit 2016 participants (2018). Interoception and Mental Health: A Roadmap. Biological psychiatry. *Cognitive Neuroscience and Neuroimaging*, 3(6), 501–513. https://doi.org/10.1016/j.bpsc.2017.12.004

Khalsa, S. S., Rudrauf, D., Hassanpour, M. S., Davidson, R. J., & Tranel, D. (2020). The practice of meditation is not associated with improved interoceptive awareness of the heartbeat. *Psychophysiology*, 57(2), e13479. https://doi.org/10.1111/psyp.13479

Khoury, B., Lecomte, T., Fortin, G., Masse, M., Therien, P., Bouchard, V., Chapleau, M. A., Paquin, K., & Hofmann, S. G. (2013). Mindfulness-based therapy: a comprehensive meta-analysis. *Clinical Psychology Review*, 33(6), 763–771. https://doi.org/10.1016/j.cpr.2013.05.005

Koch, A., & Pollatos, O. (2014). Interoceptive sensitivity, body weight and eating behavior in children: a prospective study. *Frontiers in Psychology*, 5, 1003. https://doi.org/10.3389/fpsyg.2014.01003

Kok, B.E., Singer, T. Phenomenological Fingerprints of Four Meditations: Differential State Changes in Affect, Mind-Wandering, Meta-Cognition, and Interoception Before and After Daily Practice Across 9 Months of Training. *Mindfulness* 8, 218–231 (2017). https://doi.org/10.1007/s12671-016-0594-9

Lakhan, S. E., & Schofield, K. L. (2013). Mindfulness-based therapies in the treatment of somatization disorders: a systematic review and meta-analysis. *PloS one*, 8(8), e71834. https://doi.org/10.1371/journal.pone.0071834

Landsman-Dijkstra, J. J., van Wijck, R., Groothoff, J. W., & Rispens, P. (2004). The short-term effects of a body awareness program: better self-management of health problems for individuals with chronic a-specific psychosomatic symptoms. *Patient Education and Counseling*, 55(2), 155–167. https://doi.org/10.1016/j.pec.2004.02.014

Langdon, S., Jones, F., Hutton, J. and Holttum, S. (2011). A grounded-theory study of mindfulness practice following mindfulness-based cognitive therapy. *Mindfulness*. 2 (4), 270-281, https://doi.org/10.1007/s12671-011-0070-5

Liberati, A., Altman, D.G., Tetzlaff, J., Mulrow, C., Gotzsche, P.C., Ioannidis, J.P.A., Clarke, M., Devereaux, P.J., Kleijnen, J., Moher, D., 2009. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ* 339, b2700–b2700.. doi:10.1136/bmj.b2700

Lindquist, R., Wyman, J.F., Talley, K.M.C., Findorff, M.J., Gross, C.R. (2007). Design of Control-Group Conditions in Clinical Trials of Behavioral Interventions. *Journal of Nursing Scholarship* 39, 214–221. doi:10.1111/j.1547-5069.2007.00171.x

Linehan, M. M. (1993). *Cognitive-behavioral treatment of borderline personality disorder*. Guilford Press

Lustyk, M. K., Chawla, N., Nolan, R. S., & Marlatt, G. A. (2009). Mindfulness meditation research: issues of participant screening, safety procedures, and researcher training. *Advances in Mind-body Medicine*, 24(1), 20–30.

Mallorquí-Bagué, N., Garfinkel, S.N., Engels, M., Eccles, J.A., Pailhez, G., Bulbena A., Critchley, H.D. (2014). Neuroimaging and psychophysiological investigation of the link between anxiety, enhanced affective reactivity and interoception in people with joint hypermobility, *Frontiers in Psychology*, 5 (1162).

Mascaro, J.S., Rilling, J.K., Negi, L.T., Raison, C.L. (2013). Pre-existing brain function predicts subsequent practice of mindfulness and compassion meditation, *NeuroImage*, 69, 35-42. https://doi.org/10.1016/j.neuroimage.2012.12.021.

Mathew, K. L., Whitford, H. S., Kenny, M. A., & Denson, L. A. (2010). The long-term effects of mindfulness-based cognitive therapy as a relapse prevention treatment for major depressive disorder. *Behavioural and Cognitive Psychotherapy*, 38(5), 561–576. https://doi.org/10.1017/S135246581000010X

Mehling, W. E., Gopisetty, V., Daubenmier, J., Price, C. J., Hecht, F. M., & Stewart, A. (2009). Body awareness: Construct and self-report measures. *Plos One*, 4(5), e5614. doi:10.1371/journal.pone.0005614

Mehling, W. E., Price, C., Daubenmier, J. J., Acree, M., Bartmess, E., & Stewart, A. (2012). The Multidimensional Assessment of Interoceptive Awareness (MAIA). *PloS one*, 7(11), e48230. https://doi.org/10.1371/journal.pone.0048230

Mehling, W.E., Daubenmier, J., Price, C.J., Acree, M., Bartmess, E., Stewart, A.L. (2013). Self-reported interoceptive awareness in primary care patients with past or current low back pain, *Journal of Pain Research* 6 (2013).

Mehling W. (2016). Differentiating attention styles and regulatory aspects of self-reported interoceptive sensibility. Philosophical transactions of the Royal Society of London. Series B, *Biological Sciences*, 371(1708), 20160013. https://doi.org/10.1098/rstb.2016.0013

Mehling, W. E., Chesney, M. A., Metzler, T. J., Goldstein, L. A., Maguen, S., Geronimo, C., Agcaoili, G., Barnes, D. E., Hlavin, J. A., & Neylan, T. C. (2018). A 12-week integrative exercise program improves self-reported mindfulness and interoceptive awareness in war veterans with posttraumatic stress symptoms. *Journal of Clinical Psychology*, 74(4), 554–565. https://doi.org/10.1002/jclp.22549

Melloni, M., Sedeño, L., Couto, B., Reynoso, M., Gelormini, C., Favaloro, R., Canales-Johnson, A., Sigman, M., Manes, F., & Ibanez, A. (2013). Preliminary evidence about the effects of meditation on interoceptive sensitivity and social cognition. *Behavioral and Brain Functions : BBF*, 9, 47. https://doi.org/10.1186/1744-9081-9-47

Merwin, R. M., Zucker, N. L., Lacy, J. L., & Elliott, C. A. (2010). Interoceptive awareness in eating disorders: Distinguishing lack of clarity from non-acceptance of internal experience. *Cognition and Emotion*, 24(5), 892–902. https://doi.org/10.1080/02699930902985845

Meyerholz, L., Irzinger, J., Witthöft, M., Gerlach, A. L., & Pohl, A. (2019). Contingent biofeedback outperforms other methods to enhance the accuracy of cardiac interoception: A comparison of short interventions. *Journal of Behavior Therapy and Experimental Psychiatry*, 63, 12–20. https://doi.org/10.1016/j.jbtep.2018.12.002

Mohr, D.C., Spring, B., Freedland, K.E., Beckner, V., Arean, P., Hollon, S.D., Ockene, J., Kaplan, R. (2009). The selection and design of control conditions for randomized controlled trials of psychological interventions. *Psychotherapy and Psychosomatics* 78, 275–284. doi:10.1159/000228248

Moncher, F.J., Prinz, R.J. (1991). Treatment fidelity in outcome studies. *Clinical Psychology Review* 11, 247–266. doi:10.1016/0272-7358(91)90103-2

Morone, N. E., Lynch, C. S., Greco, C. M., Tindle, H. A., & Weiner, D. K. (2008). "I felt like a new person." the effects of mindfulness meditation on older adults with chronic pain: qualitative narrative analysis of diary entries. *The Journal of Pain*, 9(9), 841–848. https://doi.org/10.1016/j.jpain.2008.04.003

Morone, N. E., Greco, C. M., Moore, C. G., Rollman, B. L., Lane, B., Morrow, L. A., Glynn, N. W., & Weiner, D. K. (2016). A Mind-Body Program for Older Adults with Chronic Low Back Pain: A Randomized Clinical Trial. *JAMA Internal Medicine*, 176(3), 329–337. https://doi.org/10.1001/jamainternmed.2015.8033

Munshi, K., Eisendrath, S., & Delucchi, K. (2013). Preliminary long-term follow-up of Mindfulness-based cognitive therapy-induced remission of depression. *Mindfulness*, 4(4), 354–361. https://doi.org/10.1007/s12671-012-0135-0

Munder, T., & Barth, J. (2018). Cochrane's risk of bias tool in the context of psychotherapy outcome research. *Psychotherapy research : journal of the Society for Psychotherapy Research*, 28(3), 347–355. https://doi.org/10.1080/10503307.2017.1411628

Murphy, J., Brewer, R., Catmur, C., & Bird, G. (2017). Interoception and psychopathology: A developmental neuroscience perspective. *Developmental Cognitive Neuroscience*, 23, 45–56. https://doi.org/10.1016/j.dcn.2016.12.006

Murphy, J., Catmur, C., & Bird, G. (2019). Classifying individual differences in interoception: Implications for the measurement of interoceptive awareness. *Psychonomic Bulletin & Review*, 26(5), 1467–1471. https://doi.org/10.3758/s13423-019-01632-7

Orwin, R. G. (1983). A fail-safe N for effect size in meta-analysis. *Journal of Educational Statistics*, 8(2), 157–159. https://doi.org/10.2307/1164923

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ (Clinical research ed.)*, 372, n71. https://doi.org/10.1136/bmj.n71

Parkin, L., Morgan, R., Rosselli, A., Howard., M, Sheppard, A., Evans, D., Hawkins, A., Martinelli, M., Golden, A., Dagleish, T., Dunn, B.D. (2013). Exploring the relationship between mindfulness and cardiac perception. *Mindfulness*. 5(3). 10.1007/s12671-012-0181-7.

Parsons, C. E., Crane, C., Parsons, L. J., Fjorback, L. O., & Kuyken, W. (2017). Home practice in Mindfulness-Based Cognitive Therapy and Mindfulness-Based Stress Reduction: A systematic review and meta-analysis of participants' mindfulness practice and its association with outcomes. *Behaviour Research and Therapy*, 95, 29–41. https://doi.org/10.1016/j.brat.2017.05.004

Paulus, M. P., & Stein, M. B. (2006). An insular view of anxiety. *Biological Psychiatry*, 60(4), 383–387. https://doi.org/10.1016/j.biopsych.2006.03.042

Paulus, D.L., & Vazire, S. (2007). The self-report method. In R.W. Robins, R.C. Fraley, & R.F. Krueger (Eds.), *Handbook of Research Methods in Personality Psychology* (pp.224-239). Guildford Press.

Paulus, M. P., Feinstein, J. S., & Khalsa, S. S. (2019). An active inference approach to interoceptive psychopathology. *Annual Review of Clinical Psychology*, 15, 97–122. https://doi.org/10.1146/annurev-clinpsy-050718-095617

Podsakoff, P. , MacKenzie, S. , Lee, J. , Podsakoff, N. & (2003). Common method biases in behavioral research. *Journal of Applied Psychology*, 88 (5), 879-903.

Pollatos, O., Traut-Mattausch, E., & Schandry, R. (2009). Differential effects of anxiety and depression on interoceptive accuracy. *Depression and Anxiety*, 26(2), 167–173. https://doi.org/10.1002/da.20504

Price, C. J., & Hooven, C. (2018). Interoceptive Awareness Skills for Emotion Regulation: Theory and Approach of Mindful Awareness in Body-Oriented Therapy (MABT). *Frontiers in Psychology*, 9, 798. https://doi.org/10.3389/fpsyg.2018.00798

Price, C. J., Thompson, E. A., Crowell, S. E., Pike, K., Cheng, S. C., Parent, S., & Hooven, C. (2019). Immediate effects of interoceptive awareness training through Mindful Awareness in Body-oriented Therapy (MABT) for women in substance use disorder treatment. *Substance Abuse*, 40(1), 102–115. https://doi.org/10.1080/08897077.2018.1488335

Price, C. J., Thompson, E. A., Crowell, S., & Pike, K. (2019b). Longitudinal effects of interoceptive awareness training through mindful awareness in body-oriented therapy (MABT) as an adjunct to women's substance use disorder treatment: A randomized controlled trial. *Drug and Alcohol Dependence*, 198, 140–149. https://doi.org/10.1016/j.drugalcdep.2019.02.012

Price, C. J., Merrill, J. O., McCarty, R. L., Pike, K. C., & Tsui, J. I. (2020). A pilot study of mindful body awareness training as an adjunct to office-based medication treatment of opioid use disorder. *Journal of Substance Abuse Treatment*, 108, 123–128. https://doi.org/10.1016/j.jsat.2019.05.013

Reibel, D. K., Greeson, J. M., Brainard, G. C., & Rosenzweig, S. (2001). Mindfulness-based stress reduction and health-related quality of life in a heterogeneous patient population. *General Hospital Psychiatry*, 23(4), 183–192. https://doi.org/10.1016/s0163-8343(01)00149-9

Riley B. (2014). Experiential avoidance mediates the association between thought suppression and mindfulness with problem gambling. *Journal of Gambling Studies*, 30(1), 163–171. https://doi.org/10.1007/s10899-012-9342-9

Rosenthal, R. (1991). *Meta-analytic procedures for social research* (Rev. ed.). Sage Publications, Inc. https://doi.org/10.4135/9781412984997

Rothstein, H. R., Sutton, A. J., & Borenstein, M. (2006). Publication bias in meta-analysis: Prevention, assessment and adjustments. *Publication bias in meta-analysis: Prevention, assessment and adjustments* (pp. 1-356) doi:10.1002/0470870168

Schaefer, M., Egloff, B., & Witthöft, M. (2012). Is interoceptive awareness really altered in somatoform disorders? Testing competing theories with two paradigms of heartbeat perception. *Journal of Abnormal Psychology*, 121(3), 719–724.

Schandry R. (1981). Heart beat perception and emotional experience. *Psychophysiology*, 18(4), 483–488. https://doi.org/10.1111/j.1469-8986.1981.tb02486.

Schulz, K. F., Chalmers, I., Hayes, R. J., & Altman, D. G. (1995). Empirical evidence of bias. Dimensions of methodological quality associated with estimates of treatment effects in controlled trials. *JAMA*, 273(5), 408–412. https://doi.org/10.1001/jama.273.5.408

Schulz, A., & Vögele, C. (2015). Interoception and stress. *Frontiers in Psychology*, 6, 993. https://doi.org/10.3389/fpsyg.2015.00993

Schuman-Olivier, Z., Trombka, M., Lovas, D. A., Brewer, J. A., Vago, D. R., Gawande, R., Dunne, J. P., Lazar, S. W., Loucks, E. B., & Fulwiler, C. (2020). Mindfulness and Behavior Change. *Harvard Review of Psychiatry*, 28(6), 371–394. https://doi.org/10.1097/HRP.0000000000000277

Schumer, M. C., Lindsay, E. K., & Creswell, J. D. (2018). Brief mindfulness training for negative affectivity: A systematic review and meta-analysis. *Journal of Consulting and Clinical Psychology*, 86(7), 569–583. https://doi.org/10.1037/ccp0000324

Seth A. K. (2013). Interoceptive inference, emotion, and the embodied self. *Trends in Cognitive Sciences*, 17(11), 565–573. https://doi.org/10.1016/j.tics.2013.09.007

Shapiro, S. L., Carlson, L. E., Astin, J. A., & Freedman, B. (2006). Mechanisms of mindfulness. *Journal of Clinical Psychology*, 62(3), 373–386. https://doi.org/10.1002/jclp.20237

Shapiro, S. L., Oman, D., Thoresen, C. E., Plante, T. G., & Flinders, T. (2008). Cultivating mindfulness: effects on well-being. *Journal of Clinical Psychology*, 64(7), 840–862. https://doi.org/10.1002/jclp.20491

Sharp, P. B., Sutton, B. P., Paul, E. J., Sherepa, N., Hillman, C. H., Cohen, N. J., Kramer, A. F., Prakash, R. S., Heller, W., Telzer, E. H., & Barbey, A. K. (2018). Mindfulness training induces structural connectome changes in insula networks. *Scientific Reports*, 8(1), 7929. https://doi.org/10.1038/s41598-018-26268

Signorini, G., Singh, S. P., Marsanic, V. B., Dieleman, G., Dodig-Ćurković, K., Franic, T., Gerritsen, S. E., Griffin, J., Maras, A., Mcnicholas, F., O'Hara, L., Purper-Ouakil, D., Paul, M., Russet, F., Santosh, P., Schulze, U., Street, C., Tremmery, S., Tuomainen, H., … De Girolamo, G. (2018). The interface between child/adolescent and adult mental health services: results from a European 28-country survey. *European Child & Adolescent Psychiatry*, 27(4), 501–511. https://doi.org/10.1007/s00787-018-1112-5

Singer, T., & Engert, V. (2019). It matters what you practice: differential training effects on subjective experience, behavior, brain and body in the ReSource Project. *Current Opinion in Psychology*, 28, 151–158. https://doi.org/10.1016/j.copsyc.2018.12.005

Singh, S.P., Paul, M., Ford, T., Kramer, T., Weaver, T., 2008. Transitions of Care from Child and Adolescent Mental Health Services to Adult Mental Health Services (TRACK Study): A study of protocols in Greater London. *BMC Health Services Research* 8, 135. doi:10.1186/1472-6963-8-135

Sterne, J., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H. Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., McAleenan, A., … Higgins, J. (2019). RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ (Clinical research ed.)*, 366, l4898. https://doi.org/10.1136/bmj.l4898

Sterne, J., Gavaghan, D., & Egger, M. (2000). Publication and related bias in meta-analysis: power of statistical tests and prevalence in the literature. *Journal of Clinical Epidemiology*, 53 11, 1119-29 .

Stone, A. A., Turkkan, J. S., Bachrach, C. A., Jobe, J. B., Kurtzman, H. S., & Cain, V. S. (Eds.). (2000). The science of self-report: Implications for research and practice. Lawrence Erlbaum Associates Publishers.

Strohmaier, S. The relationship between doses of mindfulness-based programs and depression, anxiety, stress, and mindfulness: a dose-response meta-regression of randomized controlled trials. *Mindfulness* 11, 1315–1335 (2020). https://doi.org/10.1007/s12671-020-01319-4

Sze, J. A., Gyurak, A., Yuan, J. W., & Levenson, R. W. (2010). Coherence between emotional experience and physiology: does body awareness training have an impact?. *Emotion* (Washington, D.C.), 10(6), 803–814. https://doi.org/10.1037/a0020146

Tang, Y. Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews, Neuroscience*, 16(4), 213–225. https://doi.org/10.1038/nrn3916

Tang, R., & Braver, T. S. (2020). Towards an individual differences perspective in mindfulness training research: Theoretical and empirical considerations. *Frontiers in Psychology*, 11, 818. https://doi.org/10.3389/fpsyg.2020.00818

Teasdale, J. D., Segal, Z. V., Williams, J. M. G., Ridgeway, V. A., Soulsby, J. M., & Lau, M. A. (2000). Prevention of relapse/recurrence in major depression by mindfulness-based cognitive therapy. *Journal of Consulting and Clinical Psychology*, 68(4), 615–623. https://doi.org/10.1037/0022-006X.68.4.615

Thomas, E. A., Mijangos, J. L., Hansen, P. A., White, S., Walker, D., Reimers, C., Beck, A. C., & Garland, E. L. (2019). Mindfulness-Oriented Recovery Enhancement Restructures Reward Processing and Promotes Interoceptive Awareness in Overweight Cancer Survivors: Mechanistic Results From a Stage 1 Randomized Controlled Trial. *Integrative Cancer Therapies*, 18, 1534735419855138. https://doi.org/10.1177/1534735419855138

Thompson, S. G., & Higgins, J. P. (2002). How should meta-regression analyses be undertaken and interpreted?. *Statistics in Medicine*, 21(11), 1559–1573. https://doi.org/10.1002/sim.1187

Treves, I. N., Tello, L. Y., Davidson, R. J., & Goldberg, S. B.. (2019). The relationship between mindfulness and objective measures of body awareness: A meta-analysis. *Scientific Reports*, 9(1). https://doi.org/10.1038/s41598-019-53978-6

Trevisan, D. A., Mehling, W. E., & McPartland, J. C. (2021). Adaptive and Maladaptive Bodily Awareness: Distinguishing Interoceptive Sensibility and Interoceptive Attention from Anxiety-Induced Somatization in Autism and Alexithymia. *Autism research : Official Journal of the International Society for Autism Research*, 14(2), 240–247. https://doi.org/10.1002/aur.2458

Viera, A., & Garrett, J. (2005). Understanding interobserver agreement: the kappa statistic. *Family Medicine*, 37 5, 360-3.

Weng, H. Y., Feldman, J. L., Leggio, L., Napadow, V., Park, J., & Price, C. J. (2021). Interventions and Manipulations of Interoception. *Trends in Neurosciences*, 44(1), 52–62. https://doi.org/10.1016/j.tins.2020.09.010

Williams, V., Ciarrochi, J., & Deane, F. P. (2010). On being mindful, emotionally aware, and more resilient: Longitudinal pilot study of police recruits. *Australian Psychologist*, 45(4), 274–282. https://doi.org/10.1080/00050060903573197

Appendix A

Table A1:

Search Terms with Boolean Operators for PsycINFO

Outcome: Interoception	Intervention: Mindfulness
Interoception.sh OR interoceptive.sh OR interocepti*.ti,ab OR Interoceptive interventions.tw OR physiological proces*.ti,ab OR somesthetic percepti*.ti,ab OR Sensorimotor.ti,ab OR viscerocept*.ti,ab OR Psychophysiol*.ti,ab OR Physiological state.ti,ab OR Internal state.ti,ab	Mindfulness.sh OR mindful.sh OR mindful*.ti,ab OR MABT.ti,ab OR MBCT.ti,ab OR MBSR.ti,ab OR meditation.ti,ab OR (acceptance adj2 commitment therap*).ti,ab OR Mind body.ti,ab OR Body oriented.ti,ab OR Somatic psychotherap*.ti,ab OR Body psychotherap*.ti,ab OR Contemplative practice*.ti,ab

Table A2:

Search Terms with Boolean Operators for Embase

Outcome: Interoception	Intervention: Mindfulness
‘Interoception’/exp OR ‘interoceptive awareness’/exp OR ‘interoceptive exposure’/exp OR ‘interoceptive accuracy’/exp OR ‘interoceptive sensitivity’/exp OR interocepti*:ti,ab OR ‘physiological proces*’:ti,ab OR ‘somesthetic percepti*’:ti,ab OR Sensorimotor:ti,ab OR viscerocept*:ti,ab OR Psychophysiol*:ti,ab OR ‘Physiological state’:ti,ab OR ‘Internal state’:ti,ab	‘Mindfulness’/exp OR ‘mindfulness meditiation’/exp mindful*:ti,ab OR MABT:ti,ab OR MBCT:ti,ab OR MBSR:ti,ab OR Meditation:ti,ab OR ‘acceptance and commitment therap*’:ti,ab OR ‘Mind body’:ti,ab OR ‘Body oriented’:ti,ab OR ‘Somatic psychotherap*’:ti,ab OR ‘Body psychotherap*’:ti,ab OR ‘contemplative practice*’:ti,ab

Table A3:

Search Terms with Boolean Operators for PubMed

Outcome: Interoception	Intervention: Mindfulness
Interoception[mh] OR interocepti*[tiab] OR physiological proces*[tiab] OR somesthetic percepti*[tiab] OR Sensorimotor*[tiab] OR viscerocept*[tiab] OR Psychophysiol*[tiab] OR Physiological state[tiab] OR Internal state[tiab]	Mindfulness[mh] OR Acceptance and commitment therapy[mh] OR Mind-body therapies[mh] mindful*[tiab] OR MABT[tiab] OR MBCT[tiab] OR MBSR[tiab] OR Meditation[tiab] OR acceptance and commitment therap*[tiab] OR Mind body[tiab] OR Body oriented[tiab] OR Somatic psychotherap*[tiab] OR Body psychotherap*[tiab] OR contemplative practice[tiab]

Table A4:

Search Terms with Boolean Operators for CINAHL

Outcome: Interoception	Intervention: Mindfulness
TI interocept* OR AB interocept* OR TI “body awar*” OR AB “body awar*” OR TI “physiological proces*” OR AB “physiological process*” OR TI “somesthetic percepti*” OR AB “somesthetic percepti*” OR TI viscerocept* OR AB viscerocept* OR TI Psychophysiol* OR AB Psychophysiol* OR TI “Physiological state” OR AB “Physiological state” OR TI “Internal state” OR AB “internal state”	MH Mindfulness+ OR TI mindfulness OR AB mindfulness OR MH “Acceptance and commitment therapy” OR TI “acceptance and commitment therap*” OR AB “acceptance and commitment therap*” OR TI “Mind-body therap*” OR AB “mind-body therap*” OR TI mindful* OR AB mindful* OR TI MABT OR AB MABT OR TI MBAT OR AB MBAT OR TI MBCT OR AB MBCT OR TI MBSR OR AB MBSR OR TI Meditation OR AB Meditation OR TI “Mind body” OR AB “mind body” OR TI “body cent*” OR AB “body cent*” OR TI “Body oriented” OR AB “body oriented” OR TI “Somatic psychotherap*” OR AB “somatic psychotherapy*” OR TI “Body psychotherap*” OR AB “body psychotherapy*” OR “TI contemplative practice” OR AB “contemplative practice”

Table A5:

Search Terms with Boolean Operators for Web of Science

Outcome: Interoception	Intervention: Mindfulness
TS=interocep* OR	TS=mindful* OR
interocepti* OR	mindful* OR
“physiological proces*” OR “somesthetic	MABT OR MBCT OR MBSR OR
percepti*” OR “somatic awareness” OR	meditation OR
“somatic perception” OR somato* OR	“acceptance and commitment therap*” OR
Sensorimotor OR	“Mind body” OR
viscerocept* OR	“Body oriented” OR
Psychophysiol* OR	“Somatic psychotherap*” OR
“Physiological state” OR	“Body psychotherap*” OR
“Internal state”	“Contemplative practice”

Appendix B

RoB 2 Scoring Criteria

Domain	Low Risk	Some Concerns	High Risk
1. Randomisation Process	▪ Randomisation sequence allocation adequately concealed (e.g., use of a random number generator). ▪ Intervention and control groups comparable (*p* > .05) at baseline on socio-demographics (age, gender, race), trait mindfulness, prior meditation experience etc.	▪ Insufficient information about concealment of allocation sequence and/or baseline imbalances (e.g., general statement of 'no baseline differences observed' provided in lieu of statistical results).	▪ Participants/investigators could have foreseen group assignment (e.g., assignment based on date of birth). ▪ Baseline imbalances suggest a problem with the randomisation process (i.e., statistically significant (p < .05) group differences on ≥1 sample parameters.
2. Deviations from intended interventions	▪ Participants/investigators unaware of intervention groups. ▪ Adherence to treatment protocol monitored with no major deviations reported. ▪ Intention-to-treat (ITT) analysis to estimate the effect of assignment to intervention.	▪ Participants/investigators may have been aware of group assignment. ▪ No information on whether there were deviations from intended intervention. ▪ Modified ITT analysis (e.g., excluded those lost to follow-up).	▪ No blinding. ▪ Deviations from intended interventions likely to have affected the outcome. ▪ 'Per-protocol' or 'as treated' analysis.
3. Missing outcome data	▪ No missing data. ▪ Similar proportion/similar reasons for missing data across groups, unrelated to the study (e.g., health, family issues).	▪ Insubstantial missingness (≤ 5%) or unclear information on proportion, and reasons for missingness, in compared groups.	▪ High degree of missing data or differential missing data (i.e., different proportion of/different reasons for missing data across groups).
4. Measurement of the outcome	▪ Standardised, validated measure of interoception. ▪ Unlikely that outcome assessment was influenced by participants' knowledge of intervention received.	▪ Standardised, validated measure of interoception ▪ No information provided to determine whether outcome assessment was influenced by knowledge of intervention received.	▪ Purposely designed (non-standardised) measure of interoception. ▪ Inconsistencies in group measurement of interoception within a study (e.g., at different time points, use of different measures/equipment etc)
5. Selection of the reported results	▪ A-priori data analysis plan (includes prior ethics approval). ▪ All data reported (e.g., single standardised measure applied; non-adjusted pre/post scores compared).	▪ Insufficient information to determine whether an a-priori data analysis plan was in place. ▪ Possibility that reported outcomes were purposely selected from multiple analyses of the data.	▪ No pre-specified data analysis plan. ▪ Reported outcome data purposely selected from multiple analyses (e.g., adjusted pre/post scores compared, measurement time points varied between groups).

Appendix C

RoB 2 Ratings Within Individual Studies

Lead author (year)	1. Randomisation process	2. Deviations from intended interventions	3. Missing outcome data	4. Measurement of outcomes	5. Selective reporting of results	6. Overall Bias
Aaron (2020)	+	!	+	+	+	!
deJong (2016)	+	!	!	!	+	!
Duncan (2017)	+	+	+	!	+	+
Fissler (2016)	+	+	+	+	+	+
Gawande (2018)	+	+	+	!	+	!
Mehling (2017)	+	+	!	!	+	!
Meyerholz (2018)	!	+	+	+	+	!
Parkin (2014a)	!	+	+	+	+	!
Parkin (2014b)	+	+	+	+	+	+
Price (2018)	+	+	+	!	+	!
Price (2019)	!	+	+	!	+	!
Thomas (2019)	+	+	+	!	+	+

Low risk of bias	+
Some concerns	!

Appendix D

Standardised Mean Group Differences (Hedges' *g*): Grouped by Construct and Sub-Scale

					95% CI					
Construct	**Sub-scale**	**Lead author (date)**	***g***	**SE**	**Lower**	**Upper**	***p***	**N**	**I^2**	**τ**
Awareness	Self Regulation	Thomas (2019)	1.703	0.323	1.069	2.337	.000	51		
		Mehling (2017)	1.513	0.376	0.777	2.249	.000	36		
		Price (2019)	1.299	0.160	0.985	1.613	.000	97		
		Fissler (2016)	1.291	0.253	0.794	1.788	.000	74		
		DeJong (2016)	0.671	0.392	-0.098	1.440	.087	26		
		Pooled g_w	**1.315**	**0.124**	**1.072**	**1.558**	**.000**	**284**	**9.790**	**0.091**
Awareness	Body Listening	Thomas (2019)	1.867	0.332	1.216	2.518	.000	51		
		Price (2019)	1.155	0.157	0.847	1.463	.000	97		
		Fissler (2016)	1.097	0.247	0.612	1.581	.000	74		
		Mehling (2017)	1.077	0.354	0.383	1.771	.002	36		
		Pooled g_w	**1.247**	**0.153**	**0.948**	**1.546**	**.000**	**258**	**31.507**	**0.173**
Awareness	Attention Regulation	Thomas (2019)	1.208	0.301	0.619	1.798	.000	51		
		Fissler (2016)	1.166	0.249	0.678	1.655	.000	74		
		Price (2019)	1.129	0.324	0.494	1.764	.000	97		
		Mehling (2017)	0.490	0.336	-0.168	1.148	.144	36		
		DeJong (2016)	0.084	0.381	-0.663	0.831	.825	26		
		Pooled g_w	**0.862**	**0.208**	**0.455**	**1.269**	**.000**	**284**	**54.329**	**0.341**
Awareness	Trusting	Thomas (2019)	1.088	0.296	0.507	1.668	.000	51		
		Price (2019)	0.833	0.151	0.537	1.129	.000	97		
		Fissler (2016)	0.733	0.238	0.267	1.199	.002	74		
		Mehling (2017)	0.219	0.332	-0.430	0.869	.508	36		
		Pooled g_w	**0.764**	**0.138**	**0.493**	**1.034**	**.000**	**258**	**26.829**	**0.145**
Awareness	Emotional Awareness	Price (2019)	0.901	0.152	0.603	1.199	.000	97		
		Thomas (2019)	0.799	0.287	0.236	1.361	.005	51		
		Mehling (2017)	0.767	0.343	0.095	1.439	.025	36		
		DeJong (2016)	0.511	0.388	-0.248	1.271	.187	26		
		Fissler (2016)	0.313	0.232	-0.141	0.766	.177	74		
		Pooled g_w	**0.701**	**0.124**	**0.458**	**0.943**	**.000**	**284**	**18.338**	**0.121**
Awareness	Noticing	Thomas (2019)	1.308	0.305	0.711	1.906	.000	51		
		Price (2019)	0.855	0.156	0.549	1.161	.000	97		
		Fissler (2016)	0.364	0.232	-0.091	0.819	.117	74		
		Mehling (2017)	0.337	0.333	-0.315	0.990	.311	36		
		DeJong (2016)	0.129	0.381	-0.618	0.877	.734	26		
		Pooled g_w	**0.634**	**0.192**	**0.259**	**1.010**	**.001**	**284**	**61.860**	**0.329**
Awareness	Not Distracting	DeJong (2016)	0.816	0.397	0.037	1.595	.040	26		
		Fissler (2016)	0.242	0.231	-0.211	0.695	.295	74		
		Thomas (2019)	0.240	0.277	-0.303	0.782	.386	51		
		Price (2019)	0.198	0.146	-0.088	0.484	.175	97		
		Mehling (2017)	0.166	0.331	-0.483	0.815	.616	36		
		Pooled g_w	**0.251**	**0.103**	**0.049**	**0.453**	**.015**	**284**	**0.000**	**0.000**
Awareness	Not Worrying	Price (2019)	0.314	0.146	0.028	0.600	.032	97		
		Mehling (2017)	0.187	0.331	-0.462	0.836	.573	36		
		Fissler (2016)	0.088	0.230	-0.363	0.540	.701	74		
		Thomas (2019)	0.007	0.276	-0.533	0.548	.978	51		
		Pooled g_w	**0.207**	**0.107**	**-0.002**	**0.416**	**.052**	**258**	**0.000**	**0.000**
Coherence		Parkin (2014a)	0.436	0.314	-0.179	1.051	.164	40		
		Parkin (2014b)	0.244	0.220	-0.187	0.675	.267	40		
		Pooled g_w	**0.307**	**0.180**	**-0.046**	**0.660**	**.088**	**80**	**0.000**	**0.000**
Sensibility		Parkin (2014a)	0.496	0.315	-0.121	1.113	.115	40		
		Aaron (2020)	0.414	0.241	-0.058	0.885	.086	69		
		Parkin (2014b)	0.078	0.219	-0.351	0.507	.722	40		
		Pooled g_w	**0.286**	**0.144**	**0.003**	**0.568**	**.047**	**149**	**0.000**	**0.000**
Accuracy		Parkin (2014a)	0.501	0.315	-0.116	1.119	.111	40		
		Parkin (2014b)	0.128	0.219	-0.301	0.557	.559	40		
		Aaron (2020)	0.000	0.238	-0.467	0.467	1.000	69		
		Meyerholz (2019)	0.000	0.281	-0.551	0.551	1.000	49		
		Pooled g_w	**0.126**	**0.128**	**-0.124**	**0.377**	**.324**	**198**	**0.000**	**0.000**

Note: *g* = effect size (Hedges' g); SE = standard error; 95%CI = 95% confidence interval; *p* = significance value for g/gw; N = total sample size; I^2 = proportion of between-studies variance; τ = tau or estimated standard deviation of underlying effects across studies