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EVALUATING THE ROLE OF INTEROCEPTIVE AWARENESS IN INSOMNIA AND ACROSS THE SLEEP HEALTH SPECTRUM

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University.

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Abstract

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at Virginia Commonwealth University.

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Interoceptive awareness, characterized by a non-judgmental and trusting attitude towards body sensations, is an understudied construct that is implicated in sleep and health outcomes. Interoceptive awareness is cultivated via contemplative and mindfulness-based practices. Given that it may be utilized to reduce pre-sleep arousal, which is a key mechanism in insomnia, interoceptive awareness is posited to be a protective factor for sleep health. A cross-sectional study was conducted among undergraduate university students (N = 420) in the Mid-Atlantic region of the United States to assess the association between interoceptive awareness and sleep outcomes. Participants received a survey link and completed a 45-minute online questionnaire via REDCap. Measures included the Multidimensional Assessment of Interoceptive Awareness-2 (MAIA-2), Pittsburgh Sleep Quality Index, Pre-sleep Arousal Scale, RU-SATED, Insomnia Severity Index, and the Mindful Attention Awareness Scale (MAAS). Data were analyzed using hierarchical linear and logistic regressions. Interoceptive awareness predicted pre-sleep arousal, sleep health, sleep quality, and insomnia. The ‘not-distracting’ factor, in particular, emerged as the strongest interoceptive predictor. When adjusting for covariates such as mood, not-distracting significantly predicted pre-sleep arousal (b^* = -0.13, p < .001) and sleep duration (b^* = 0.14, p = .01). These findings indicate that not engaging in maladaptive distraction from pain and discomfort was associated with lower levels of disruptive heightened cognitive and physiological states before sleep and longer total sleep times. Interoceptive awareness explained global sleep (MAIA general: $b^* = -0.12$, $p = .016$; not-distracting: $b^* = -0.14$, $p = .008$) and sleep health (MAIA general: $b^* = 0.12$, $p = .02$) above and beyond mindfulness except when controlling for mood. Findings suggest that specific training in interoceptive capacities could be a valuable complement to interventions for sleep health and insomnia.

Literature Review

Interoceptive awareness is an understudied construct that describes the cognitions around somatic experience. Specifically, interoceptive awareness is a positive relationship to internal body signals via emotional awareness, regulation, listening and trusting (Mehling, 2016). Interoceptive awareness can improve wellbeing through the cultivation of presence and agency and is often reduced in individuals with health conditions such as depression, PTSD, and chronic pain (Colgan et al., 2022; Farb et al., 2015; Fissler et al., 2016; Khalsa et al., 2018). This awareness can be inherent or developed through contemplative and somatic practices (Cali et al., 2015; Farb et al., 2015; Hanley et al., 2017; Holzel et al., 2011). Because interoceptive awareness characterizes thoughts relating to the physical body, it is especially pertinent to sleep processes, which require mental and physical relaxation. In the pre-sleep and nocturnal periods, the interaction of physiological and cognitive arousal can enhance wakefulness, and in the daytime, these factors may enhance perceived sleep deficits and thereby increase functional impairment. Consequently, arousal is a key mechanism through which poor sleep outcomes, including longer sleep latency, more disturbance, shorter duration, and poorer quality, are perpetuated (Jansson-Frojmark et al., 2012; Tang & Harvey, 2004). Mindfulness, which frequently involves training in interoceptive awareness, is considered a protective factor for sleep health (Ding et al., 2020), and brief mindfulness-based interventions are used to reduce insomnia and improve sleep outcomes by targeting disruptive arousal (Ong et al., 2012; Shallcross et al., 2019). However, existing mindfulness interventions involve broader awareness training that does not specifically focus on body signals relevant to sleep. Due to the prominence of the body in sleep and related daytime processes, there is potentially a unique role for interoceptive awareness as a protective factor for healthy sleep. This project broadly sought to explore the association between interoceptive awareness and sleep, given the potential of interoceptive awareness to promote adaptive physiological and cognitive processes necessary for healthy sleep.

Interoceptive Awareness

Interoceptive awareness refers to a healthy cognitive conception of body sensation that involves non-judgmental and trusting attention (Price & Hooven, 2018; Tsakiris & Critchley, 2016). This awareness includes noticing uncomfortable internal signals (e.g., tense muscles) when they arise but not letting this become preoccupation; at the same time, it involves finding solace in the body when external stressors create destabilization (e.g., focusing on the breath to reduce stress when taking an exam; Mehling et al., 2018). Compared to proprioception, which is sensing the body's position in physical surroundings (i.e., *external* environment), interoception involves perception of *internal* body sensations. Interoceptive awareness is conceptualized as consisting of eight individual components which sheds light on the complex constellation of how people experience and interpret their inner worlds (Mehling, 2016; Table 1).

Table 1

Multidimensional Assessment of Interoceptive Awareness (MAIA-2) Subscales

MAIA-2 Subscale	Definition

Noticing	Awareness of uncomfortable, comfortable and neutral body sensations
Not-distracting	Tendency not to ignore or distract oneself from sensations of pain or discomfort
Not-worrying	Tendency not to worry or experience emotional distress with sensations of pain or discomfort
Attention regulation	Ability to sustain and control attention to 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	The experience of one's own body as safe and trustworthy

Interoceptive awareness is not just a trait but rather a capacity that can be trained (Ferentzi et al., 2021; Mehling et al., 2018). It has been described as a "perceptual attentive presence within the body," and accordingly requires some level of conscious effort or practice, often using a mindfulness lens (Colgan et al., 2021, p.4). In fact, the MAIA-2 scale was developed to target the specific attentional elements that are enhanced via mind-body modalities (Mehling, 2016). Cultivation of interoceptive capability is believed to heighten sensitivity, non-reactivity, regulation, insight, presence, agency, and positive experiences (Farb et al., 2015).

The complex interplay between sensation, emotions, and cognitions which results in interoceptive awareness has a long history in the field of psychology. The James-Lange Theory proposed that physiological arousal gives rise to emotion, contrary to the previous understanding that the inverse was true (James, 1890). Schachter and Singer (1962) built upon this theory by suggesting that it is the interaction of cognition and arousal that produces emotion. In recent decades, psychological research has delved further into interoception and how it differs from other processes of sensation.

Interoceptive awareness is a term derived from the broader construct of interoception but should be distinguished from the latter in a number of ways. Both interoception and interoceptive awareness may be experienced in the face of painful or non-painful stimuli and can occur in states of high or low arousal; however, interoceptive awareness is positively valenced whereas interoception may be positively *or* negatively valenced (Khalsa et al., 2017). Interoceptive awareness is the conscious recognition and response to body signals, as compared with interoception, which usually occurs below the level of consciousness, with the exception of homeostatic disruption (e.g., stress, illness) or pain (Khalsa et al., 2017; Mehling et al., 2018). Whereas interoception encompasses detection of sensations, beliefs about the body, and the metacognitive domains of insight, attention, and attributions related to these beliefs (Khalsa et al., 2017; Suksalip and Garfinkel, 2022), interoceptive awareness is defined more narrowly as the healthy attention to these body signals.

In addition to differing from the broader construct of interoception, interoceptive awareness relates to a range of terminology referenced in the literature. Interoceptive sensibility and adaptive body awareness, for example, have been used to describe a construct analogous to interoceptive awareness (Colgan et al., 2021; Farb et al., 2015; Mehling et al., 2018). However, interoceptive awareness has lacked a consistent definition (Vig et al., 2022); thus, its description in this proposal should be distinguished from other identically named constructs. Some researchers have used interoceptive awareness as an umbrella term for interoceptive processes (Khalsa et al., 2017). It has also been operationalized as the ability to accurately report one's heart rate and the correspondence between interoceptive accuracy (objective measures of reporting) and sensibility (subjective confidence ratings; Duschek et al., 2017; Farb et al., 2015; Murphy et al., 2019). In contrast, the construct of interoceptive awareness included in the proposed study is *subjectively* measured via self-report and focuses on *attention* to, rather than *accuracy* of, interoceptive signals. Interoceptive awareness also should be distinguished from maladaptive awareness, which has been termed somatic amplification in the literature, referring to negatively valenced attention that is associated with anxiety and catastrophizing (Colgan et al., 2022). In other words, with maladaptive awareness one may have high awareness of interoceptive signals but interpret them in a way that increases, rather than reduces, overall levels of arousal. Conversely, interoceptive awareness is characterized by a calm and trusting attitude towards physiological stimuli (Mehling et al., 2018).

Interoceptive awareness has been examined as a consequence and correlate of stress and mental and physical well-being. When faced with stress, long-term changes in interoceptive awareness can occur in response to higher allostatic loads. For example, upregulation, leading to increased sensitivity and hypervigilance to interoceptive signals, or downregulation, blocking the cognition and metacognition surrounding bodily sensation, may present as a result of stressful or traumatic experiences (Price & Hooven, 2018). In the short-term, experience of these disruptive events may either lower interoception (e.g., numbing perception or reaction to body signals) or heighten interoception (e.g., hypervigilance to even non-harmful sensations). In the long term, these changes in interoceptive awareness make it challenging to accurately interpret cues and regulate the associated emotions.

Because stressful events both reduce interoceptive abilities and impact the functioning of various organ systems in the body, leading to illness and disease, it is perhaps not surprising that interoceptive dysfunction co-occurs with a wide range of health conditions. We see poor interoception (including but not limited to interoceptive awareness) in individuals diagnosed with many psychological disorders, including panic disorder, somatic symptom disorder, PTSD, and depression (Khalsa et al., 2018). Furthermore, mental health disorders may be split into two categories: implicitly related to the body (e.g., schizophrenia, depression) and explicitly related to the body (e.g., eating disorders, somatoform disorders; Herbert & Pollatos, 2012). Individuals with a depression diagnosis exhibit significant deficits in interoceptive awareness compared with controls (Fissler et al., 2016). As measured using the Multidimensional Assessment for Interoceptive Awareness (MAIA and MAIA-2), higher interoceptive awareness is linked to lower pain unpleasantness and higher levels of pain tolerance and inhibition as well as higher parasympathetic nervous system activity (Colgan et al., 2021); conversely, individuals with chronic pain and chronic illness have been found to demonstrate lower levels of interoceptive accuracy compared to healthy controls (Di Lernia et al., 2016; Locatelli et al., 2023). Thus, the literature suggests that interoceptive awareness has notable implications for health and wellbeing.

Interoceptive Awareness and Mindfulness

Interoceptive awareness and mindfulness are closely linked conceptually (Cali et al., 2015; Farb et al., 2015; Hanley et al., 2017; Holzel et al., 2011). Mindfulness is a broad term used to describe both a practice of Eastern religious and spiritual origin and a disposition of attunement to one’s surroundings and awareness of internal and external processes (Hanley et al., 2017; Mehling et al., 2011). Mindfulness is also characterized by the ability to recognize and name these internal and external processes which reduces reactivity and judgment towards the self and others (Ong & Moore, 2020). Because it can lead to alterations of one's inner experience, including lowering reactivity to stimuli and enhancing overall sense of wellbeing, mindfulness is now integrated into therapies designed to treat a range of health conditions (Garland et al., 2016).

Mindfulness interventions, which are commonly used to address poor sleep, can serve to strengthen interoceptive awareness. A brief mindfulness training for individuals with clinical depression showed improved interoceptive awareness as an outcome (Fissler et al., 2016). Another 8-week mindfulness intervention for anxiety and depression led to significantly increased body trusting, one of the facets of interoceptive awareness (Datko et al., 2022). Additionally, statistically significant changes in self-regulation, attention regulation, and body listening (three of the eight interoceptive awareness subscales) have been demonstrated among individuals engaging in three months of contemplative practice (Bornemann et al., 2015). Finally, participants in a mindfulness-based cognitive therapy intervention reported significant changes in most facets of body awareness (operationalized using MAIA-2), and the subscales attention regulation, self-regulation, body listening, and trusting partially mediated the relationship between the treatment and outcomes (Perez-Pena et al., 2022). The link between mindfulness and interoception can also be seen in brain function. Mindfulness and interoceptive activity converge in the prefrontal cortex, anterior cingulate cortex, and anterior insular cortex (Casals-Gutierrez & Abbey, 2020). The close relationship between these two variables, conceptually and anatomically, is one of a number of factors suggesting that interoceptive awareness and mindfulness are related constructs.

Although both interoceptive awareness and mindfulness are characterized by moving away from evaluative thought in favor of present-moment processing (Cali et al., 2015), they also have distinct elements. Mindfulness meditation trains many components of interoceptive awareness, including attention regulation, body awareness, and emotional awareness (Holzel et al., 2011). However, whereas mindfulness practices involve modulation of internal and external sources that may capture the attention of the mind, interoceptive awareness is specifically interested in the mind's relationship to bodily signals (Hanley et al., 2017; Holzel et al., 2011; Ong & Moore, 2020). When operationalized using the Five Facet Mindfulness Questionnaire (FFMQ), which consists of non-reacting, observing, describing, acting with awareness, and allowing, the two constructs demonstrated a shared variance of approximately 70% (Hanley et al., 2017). Constructs that differ between mindfulness and interoceptive awareness include Not-distracting (MAIA-2) and Describing (FFMQ; Hanley et al., 2017). Not-distracting is promoted more in interoceptive awareness, whereas mindfulness orients towards being present with unwanted thoughts or sensations until they become less potent. Differences in Describing (FFMQ) could be due to interoceptive awareness placing less emphasis on explaining what is occurring than a measure of mindfulness might.

Sleep Outcomes

Sleep Health

Interoceptive awareness, as it is characterized by healthy attention to the physical body, is highly relevant to sleep processes, which can be hampered by maladaptive awareness of the bodily sensations. Sleep can be conceptualized as existing along a continuum from healthy sleep to disturbed sleep to disordered sleep. "Sleep health" is an emerging term in sleep literature, which has historically focused on sleep deficiency. "Sleep health" lends itself towards the promotion of positive habits and recognizes that sleep affects all individuals, not only those with poor sleep outcomes (Buysse, 2014). Good sleepers have energy to allocate to other life elements such as work, relationships, and stress management (Hamilton et al., 2007). Healthy sleep is positively associated with personal growth and development, engagement with one's environment, positive relationships, and a sense of purpose in life (Hamilton et al., 2007). Examining interoceptive awareness in relation to sleep health could have benefits for the broader population, beyond just those experiencing poor sleep.

Sleep health is conceptualized as existing along a continuum and is composed of six key elements: a) regularity, or consistency of wake and sleep times; b) satisfaction, or subjective assessment of sleep; c) alertness, referring to the ability to maintain a wakeful state throughout the day; d) timing, meaning the hours of the day in which sleep occurs; e) efficiency, or how rapidly one can fall asleep or return to sleep when awakened; and f) duration, meaning total amount of sleep achieved on a nightly basis (Buysse, 2014). These six dimensions of sleep impact health, disease, and function via the more proximal outcomes of genetic, epigenetic, molecular, and cellular processes in addition to systems-level processes such as sympathetic nervous system activation (Buysse, 2014). Although sleep health is understudied, there is some research that points to protective factors for healthy sleep across the lifespan. Sleep health is affected by a range of biopsychosocial factors, including employment, housing, socioeconomic status, physical and mental health conditions, sleep disorders, behaviors, and beliefs (Grandner, 2017; Gohari et al., 2022). Consistent sleep schedules, physical activity, social support, and trait mindfulness are all associated with healthy sleep outcomes (Ding et al., 2020; Gillis et al., 2021; Newton et al., 2020; Troxel et al., 2010). Interoceptive awareness is posited as a protective factor for sleep health that has not formerly been identified given its potential as an arousal-reducing strategy and its close relationship with mindfulness.

Sleep Disturbance

In contrast with healthy sleep, sleep disturbance, which includes both sub-clinical disturbances and extends to Sleep-Wake disorders, consists of difficulty initiating or maintaining sleep, excessive sleep, and unusual sleep states (e.g., partial awakening, sleepwalking). Sleep disturbance is among the most frequent issues presenting to a healthcare provider (Jaurequi et al., 2022) and is common in the population, with 66% not meeting recommendations for duration and between 8 and 18% of people reporting dissatisfaction with their sleep (Jansson-Fröjmark et al., 2012; Shallcross et al., 2019). At the population level, women experience higher rates of sleep disturbance than men (Grandner, 2017). Whereas sleep duration tends to decline with age, younger adults are more likely to report dissatisfaction with their sleep (Grandner, 2017). In terms of racial differences, Black Americans report fewer sleep disturbances but show poorer objective outcomes (e.g., duration, efficiency) as compared to white individuals; racism and discrimination are associated with these race-based sleep disparities (Ahn et al., 2021; Grander et al., 2016). Socioeconomic adversity also impacts sleep health starting in infancy and is perpetuated via structural factors such as access to housing and employment (El-Sheikh et al., 2022). Sleep disturbance is also associated with chronic health conditions (e.g. cancer, diabetes, Alzheimer's disease), mental health conditions (e.g., depression, anxiety), and mortality via accidents or suicide (Shallcross et al., 2019).

Insomnia

Insomnia, one of the most commonly occurring sleep-wake disorders with 6-10% of the population meeting clinical criteria (APA, 2013), is one manifestation of sleep disturbance that is particularly relevant for interoceptive processes given its underlying cognitive and physiological mechanisms. Formerly, insomnia was considered to be a heterogeneous category that included many different etiologies, including substance use, mental health disorders, or other sleep-wake conditions such as sleep apnea (Spielman, 1986). The fifth Diagnostic and Statistical Manual of Mental Health Disorders (DSM-5) separates out some of these contributors to the condition and establishes insomnia as a primary or comorbid disorder. Clinically significant Insomnia Disorder (ID) is characterized by sleep dissatisfaction at least 3 nights per week and occurring for a minimum of 3 months that is not better explained by substance use or another disorder. Sleep dissatisfaction must occur in spite of access to "adequate opportunity" for sleep, meaning that it should not be the result of external conditions such as noise pollution, child care needs, or work shift schedules (APA, 2013, p.362). Individuals who are diagnosed with insomnia have difficulty falling asleep and/or remaining asleep, leading to long latency or wake periods and shortened total sleep durations (APA, 2013). Despite the existence of established diagnostic criteria, insomnia does not need to meet diagnostic criteria to constitute significant disruption. Many individuals experience "transient and situational" insomnia in which a precipitating event temporarily results in long sleep latency or wake after sleep onset (Spielman, 1986). Individuals experiencing insomnia symptoms for more than one but less than three months are specified as "episodic" (APA, 2013). Those with higher sleep reactivity, or susceptibility to experience sleep deficits as the result of stress, are more likely to experience both acute and chronic insomnia (Walker et al., 2022). Transient insomnia can also become chronic due to the presence of certain habits and conditions, such as spending excessive time in bed, irregular sleep patterns, frequent naps, and use of sedatives or alcohol (Spielman, 1986).

Sleep Processes

Pre-sleep and Nocturnal Arousal

The role of interoceptive awareness in sleep becomes evident when we look at the processes by which sleep is maintained or, conversely, disrupted. The transition to sleep and continuance through different stages of sleep is predicated on low levels of cognitive processing, affective load, and thought initiation, as well as limited effort to sleep (Wicklow & Espie, 2000). The alternative to these sleep-promoting states is pre-sleep and nocturnal arousal, which often leads to longer latency periods, shorter total sleep times, and contributes to the maintenance of insomnia (Jansson-Frojmark et al., 2012; Tang & Harvey, 2004). Arousal may be cognitive, resulting in mental activation via processes like rumination or not being able to “shut off your thoughts” (PSAS; Nicassio et al., 1985). Arousal may also be experienced somatically or physiologically, leading to autonomic nervous system activation, with reactions such as increased heart rate or experiencing “a jittery, nervous feeling in your body” (PSAS; Nicassio et al., 1985). Often, there is interplay between the two, with one type of arousal enhancing the other type of arousal (Palagini et al., 2016). For example, an individual might notice that their heart is racing, followed by a mental preoccupation with their heart rate, with thoughts such as, “I’m never going to be able to sleep in this state” and behaviors such as tracking one’s pulse or monitoring heart rate on a wearable device.

The role of pre-sleep and nocturnal arousal in the maintenance of insomnia has been established. Numerous studies demonstrate that nighttime cognitive arousal is higher in individuals with insomnia than in good sleepers (Lemyre et al., 2020). Cognitive arousal such as worrying and monitoring are positively associated with sleep onset latency and negatively associated with sleep quality and total sleep time (Jansson-Fröjmark et al., 2012; Tang & Harvey, 2004). Although most research has focused on cognitive arousal, physiological arousal is also linked to higher sleep latency and lower total sleep time and is observed at higher rates in individuals with insomnia compared with good sleepers (Baglioni et al., 2010; Palagini et al., 2016; Tang & Harvey, 2004). Together, these two types of arousal that frequently co-occur in the pre-sleep period appear to negatively impact multiple sleep outcomes.

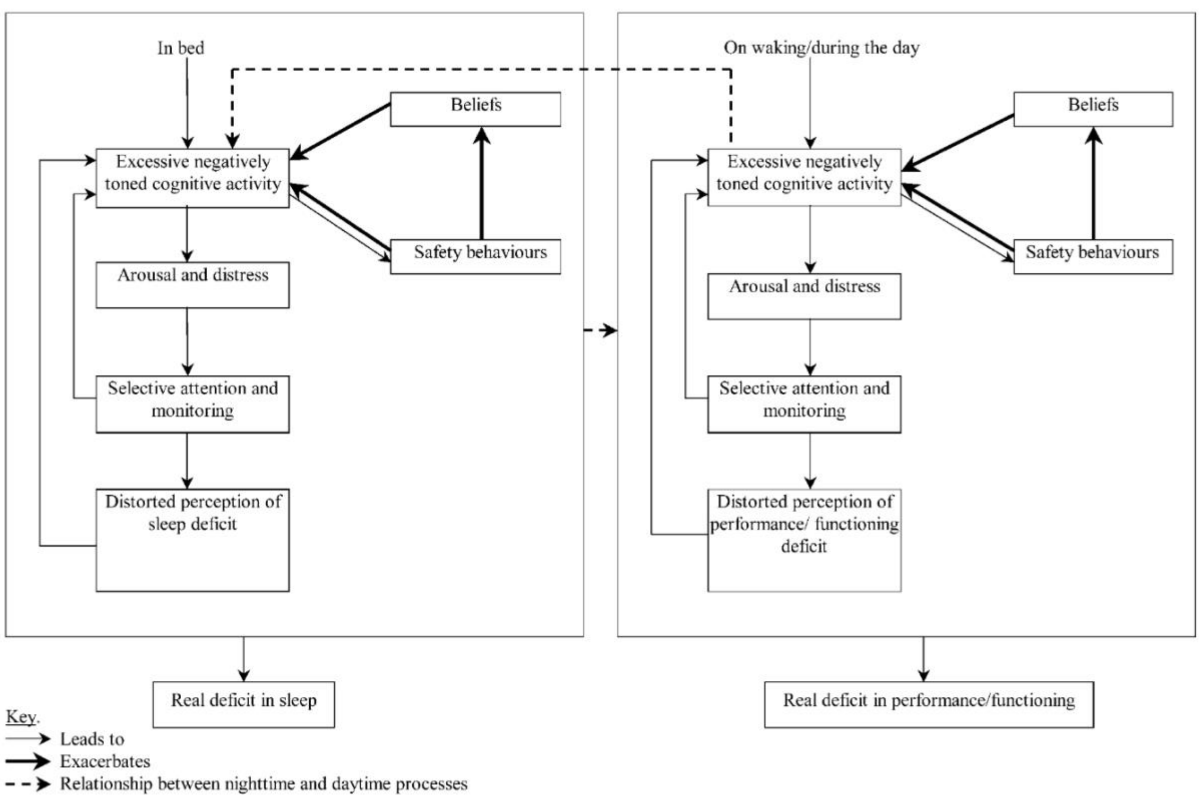
Cognitive Models of Insomnia

Interoceptive awareness is a potentially relevant predictor of sleep in general, and insomnia more specifically, given its potential role in the cognitive and physiological mechanisms underlying sleep. Two conceptual models illustrate the role of arousal in insomnia. Harvey (2002) describes how cognitive and physiological arousal contribute to one another, both before sleep and in the daytime, resulting in the continuance of insomnia over a prolonged period of time. Ong et al. (2012) focus on the ways in which disruptive pre-sleep and nocturnal thoughts can become heightened by the way one relates to them, reducing the likelihood of falling asleep. Both models can be used to illustrate how interoceptive awareness has the potential to improve sleep processes for individuals with insomnia as well as to promote better sleep health.

According to Harvey's cognitive model of insomnia (Figure 1), the interplay of cognitive and physiological arousal leads to poor sleep outcomes (Harvey, 2002). Before sleep, individuals with insomnia often experience highly negatively toned cognitions, leading to autonomic nervous system arousal. Arousal promotes monitoring of both the *external environment*, such as checking a clock or watch to estimate the time spent awake before sleep or to calculate expected sleep time, and *internal sensations* (i.e., interoception), including signs of wakefulness (e.g. pounding heart, tight muscles) or indicators of falling asleep (e.g. slow heart rate, relaxed muscles). Because of the physiological response to negative cognitions preceding sleep, it is more likely that these individuals will notice concerning body signals, further contributing to arousal, and ultimately leading to real sleep deficits. Upon waking and during the day, an individual may monitor their body for signals of sleep deficits and potentially engage in safety behaviors to compensate for perceived deficits (e.g., call in sick to work or stay in bed longer; Harvey, 2002). These safety behaviors, in turn, can perpetuate sleep disturbances by adopting poor sleep hygiene (e.g., irregular sleep times, staying in bed when awake). Harvey's model illustrates the ways in which interpretation of interoceptive signals contributes to the pathways that heighten arousal, increase sleep latency and wake time, and decrease sleep efficiency. Although the model focuses on the mechanisms underlying insomnia, cognitive and physiological processes occur across the sleep health spectrum and are likely to influence healthy sleep as well as acute and subclinical insomnia symptoms.

Figure 1

Cognitive Model of Insomnia



Note: From "A cognitive model of insomnia," by A.G. Harvey, 2002, *Behavior Research and Therapy,* 40(8), p.874 (10.1016/S0005-7967(01)00061-4).

Simplifying Harvey's (2002) Cognitive Model of Insomnia to demonstrate how mindfulness concepts may ameliorate maladaptive sleep processes, Ong et al. (2012) conceptualizes pre-sleep cognitive arousal as consisting of two parts: primary and secondary arousal. This two-part model relates to the Buddhist concept of "the two arrows of pain" in which a physical sensation produces emotion that then heightens the overall physical and emotional pain (Nicolardi et al., 2022). In Ong et al.'s (2012) conception, *primary arousal* includes sleep-interfering thoughts that relate directly to beliefs about sleep. This might include, "I need eight hours of sleep to perform well at work tomorrow." *Secondary arousal* involves the emotional response and credibility attributed to those thoughts, such as a preoccupation with one's sleep habits (Ong et al., 2012). For example, the strength of the belief that eight hours of sleep is required for adequate performance influences the amount of arousal that it creates. This second, metacognitive level is influenced by mental qualities such as absorption, rigidity, bias, and attachment and is proposed as the target of mindfulness-based interventions (Ong & Moore, 2020). Specifically, Ong suggests that creating distance between the experience of sleep and the corresponding emotions via metacognitive awareness (i.e., focus on the present with a non-judging stance), shifting (i.e., re-orienting from the desire to change the situation to acceptance), and new stance (i.e., adapting equanimity, balance, flexibility, and commitment to values in one's approach to sleep) can reduce secondary arousal and thereby reduce primary arousal as well (Ong et al., 2012). For example, one might be able to shift inflexible metacognitions such as "I need eight hours of sleep to perform well at work tomorrow" by engaging their "beginner's mind" and recognizing that each day is different. The goal of this exercise would be to understand that effects of poor sleep are not guaranteed, which in turn serves to reduce secondary arousal and minimize sleep disruption. This model illustrates ways in which the use of a mindfulness frame, which is utilized in interoceptive awareness, can be used to improve sleep outcomes by targeting the dual levels of arousal.

Current Treatments for Insomnia

Given that a sizable portion of the population experiences insomnia or subclinical levels of disturbance, a number of treatment pathways have been developed to improve sleep outcomes. Although poor sleep is often addressed pharmacologically, both as prescribed by a medical professional and via self-medication (Garland et al., 2016), non-pharmacological approaches are considered the first line of treatment and the gold standard approach (Zhang et al., 2022). Psychotherapy for sleep outcomes generally addresses sleep behaviors or cognitive processes with the goal of reducing unwanted arousal and wake time. Cognitive-behavioral therapy for insomnia (CBT-I), which consists of cognitive reframing (e.g., altering rigid beliefs about sleep) and behavioral shifts (e.g., stimulus control, sleep restriction) is considered the front line treatment approach for most adults (Qaseem et al., 2016). However, behavioral and cognitive interventions have not led to significant improvements in the non-clinical population and a large minority do not respond to CBT-I or have difficulty maintaining the behavioral elements; thus, the use of mindfulness-based interventions (MBIs) as alternative treatments have increased dramatically over the past decade (Garland et al., 2016; Murawski et al., 2018; Ong et al., 2012).

The MBIs that are most widely tested are one of two short-term treatment courses (4- to 8-week): mindfulness-based stress reduction (MBSR), developed by Jon Kabat-Zinn to treat a wide range of health conditions, and mindfulness-based therapy for insomnia (MBT-I), which synthesizes mindfulness training with techniques used in CBT-I, replacing the cognitive element with mindfulness education. Other MBIs used to treat insomnia include mindfulness-based cognitive therapy (MBCT) and mindfulness meditation training (Gong et al., 2016; Shallcross et al., 2019). MBIs, which attempt to target metacognitive processes, have also been found to indirectly impact cognition, making it similarly effective as CBT-I at altering thought processes (Lee et al., 2018). A description of each of these intervention methods, strength of evidence, and the strategies that they employ to address arousal can be found in Table 2.

Table 2

Therapeutic Modalities for Insomnia

Treatment Type	Acronym	Sleep Specific?	Evidence Base	Method of addressing arousal
Cognitive Behavioral Therapy for Insomnia	CBT-I	Y	Strong	Relaxation techniques, stress-management, addressing worries about sleep
Mindfulness-Based Stress Reduction	MBSR	N	Strong	Body scans, gentle yoga, seated meditation
Mindfulness-Based Therapy for Insomnia	MBT-I	Y	Moderate	Seated and movement meditation, discussions on applications
Mindfulness-Based Cognitive Therapy	MBCT	N	Limited	Seated meditation, breathing techniques
Mindfulness Meditation Training	n/a	N	Limited	Seated meditation

MBIs are posited to improve sleep by increasing metacognitive awareness, characterized by a non-judging and present state, and then engaging in metacognitive shifts by observing thoughts and sensations and allowing them to be as is (Ong et al., 2012). Others hypothesize that becoming aware of disproportionate attention to certain thoughts, disengaging from rumination, and improving emotion regulation are the means by which mindfulness interventions improve sleep (Garland et al., 2016). However, it is not clear that MBIs *consistently* (i.e., to the same extent across different treatment modalities) and *explicitly* (e.g., by addressing the beliefs and cognitions about the body and how these relate to sleep) teach interoceptive awareness in the way that it is conceptualized in the original Eastern practices (Farb et al., 2015).

Despite these hypothesized pathways, much remains unknown about the mechanisms by which MBIs impact sleep health (Shallcross et al., 2019; Ong & Moore, 2020). Mindfulness tools are rarely delivered in isolation and are often accompanied by strategies from other theoretical approaches (e.g., behavioral; Ong & Moore, 2020), making it difficult to discern their unique mechanisms of action. Interoceptive awareness may be one mechanism explaining the effectiveness of MBIs for insomnia. Non-reactivity and non-judging, both shared concepts between mindfulness and interoceptive awareness, have been found to mediate the relationship between attachment anxiety and sleep disturbance among adults (Jaurequi et al., 2022). Self-regulation, also a facet of interoceptive awareness, was found to mediate the relationship between mindfulness and sleep in an undergraduate sample (Howell et al., 2010). Since MBIs are gaining empirical support for effectiveness in the treatment of insomnia but it is not clear exactly how they operate, interoceptive awareness is proposed as a means by which they may be understood. Furthermore, there may be a role for interoceptive awareness in enhancing and tailoring MBI therapies to directly address the daytime and nocturnal arousal that perpetuates insomnia.

Interoceptive Awareness and Sleep

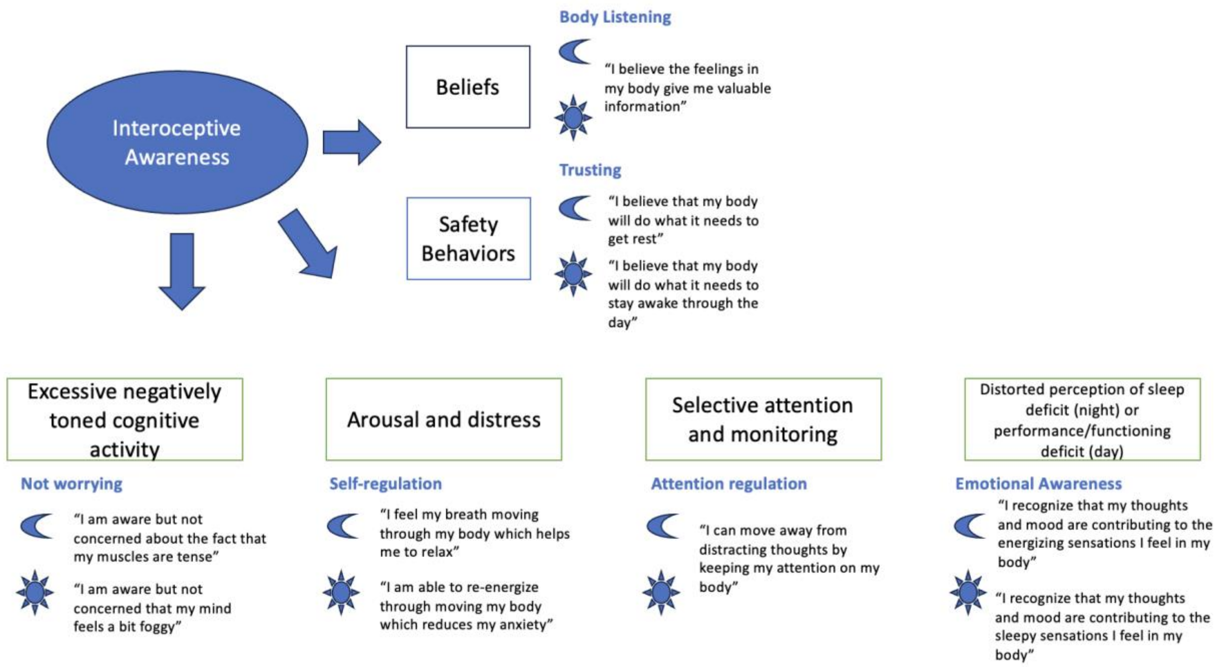
Although the literature relating mindfulness, sleep, and interoceptive awareness suggests that the three constructs are closely linked, there is a very small body of research examining the direct association between interoceptive awareness and sleep. In fact, to date, no studies have assessed interoceptive awareness as an independent predictor of sleep. However, the role of both physiological and cognitive arousal in sleep processes points to the importance of examining the role of interoceptive awareness – the healthy attunement to physiological signals –in good sleep and sleep disturbance. Individuals with insomnia demonstrate increased confidence in detection of interoceptive signals but they are less likely to identify positive and pleasant sensations (Wei & Van Someren, 2020). Thus, the high levels of interoceptive awareness that they experience are better understood as somatic amplification, which is essentially the opposite of an adaptive interoceptive awareness. Interestingly, pre-sleep images reported with insomnia were more likely to be associated with physical sensation than pre-sleep images in good sleepers (Harvey, 2000). The somatic nature of these images in the pre-sleep period suggests that high levels of cognitive arousal may be related to body signals; thus, interoceptive awareness might be a valuable tool in reducing pre-sleep arousal deriving from bodily sensations, both in poor sleepers and individuals with an insomnia diagnosis. Interoceptive awareness has also been linked to parasympathetic activation such as reductions in blood pressure, without which many individuals experience insomnia and other sleep disturbances (Colgan et al., 2022; Redline et al., 2019; Wei et al., 2016). Affect may also amplify the relationship between sleep and interoceptive awareness. For example, in individuals with strong interoceptive abilities, negative affect was a significant predictor of poor sleep, whereas in individuals with lower interceptive abilities, alexithymia was a significant predictor of poor sleep (Huang et al., 2022). In the present study, an attempt is made to reduce this effect by controlling for mood. Lastly, the reciprocal association between sleep and interoceptive awareness has been investigated with better global sleep (measured using the PSQI) significantly predicting higher interoceptive awareness, although the effect size was small (Arora et al., 2021). Additionally, poor sleep was associated with lower levels of interoceptive sensibility and metacognitive interoceptive awareness (Ewing et al., 2017). More research is needed to assess directionality, as it is plausible that this association is bidirectional and reciprocal, with better interoceptive awareness facilitating more restful sleep, leading one to be more attuned to internal body signals and better able to regulate emotions that might arise in reaction to them.

Conceptual Framework - Interoceptive Awareness and Insomnia

Despite the small body of literature tying interoceptive awareness empirically to sleep, there are strong conceptual foundations linking interoceptive awareness to the maintenance of insomnia (Harvey, 2002) and to primary and secondary arousal (Ong et al., 2012). As such, there is potentially a unique role for interoceptive awareness in reducing the pre-sleep, nocturnal arousal, and daytime arousal experienced with insomnia. Figure 2 demonstrates how interoceptive awareness can address all of the components in Harvey's model that lead to perceived and real sleep deficits. The blue text under each box represents a component of interoceptive awareness as measured by the MAIA-2 that is posited to reduce insomnia-perpetuating thought patterns and behaviors. For example, arousal and distress can be addressed using self-regulation, which involves finding solace in the body when external and internal events create heightened emotions and reactivity. The quotes in Figure 2 provide examples of how interoceptive skills might disrupt the ruminative thought processes that occur during the day and at night, respectively, and contribute to the real and perceived deficits associated with insomnia.

Figure 2

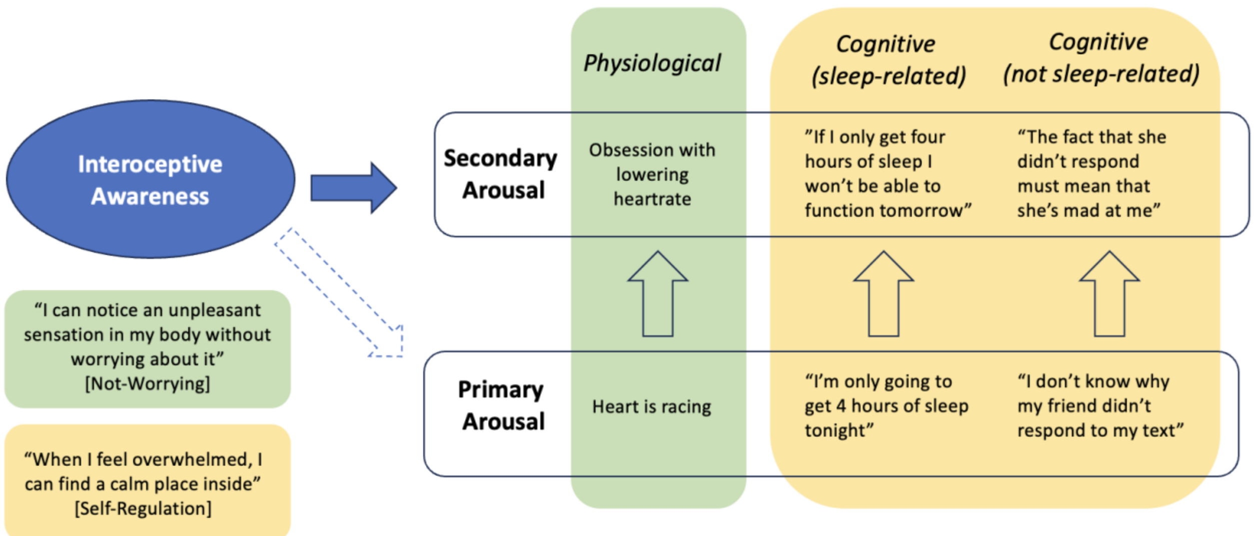
Interoceptive Awareness Applied to Harvey's Cognitive Model of Insomnia (Harvey, 2002)



Existing sleep interventions have centered on dysfunctional beliefs about *sleep* and their role in creating rigidity and preventing relaxation. However, since one's relationship with physical sensation is implicated in the process of falling and staying asleep and insomnia often occurs with comorbid mental and physical health conditions that affect perception of the body, it is proposed that the nature of beliefs about the *body* be considered as salient factors for sleep maintenance. Figure 3 demonstrates how interoceptive awareness can be applied to Ong et al.'s model of arousal. It shows three categories of arousal that might occur before sleep, including the initial thought content (primary arousal) and attachment or rigidity surrounding the thought (secondary arousal). Quotes from the MAIA-2 scale represent arousal-reducing strategies and are color-coded to match the corresponding cognition. For example, self-regulation can take the form of "finding a calm place inside" and shifting attention to the physical body to reduce cognitive arousal. Conversely, noticing but not fixating on physical discomfort reduces preoccupation with the physical body and facilitates increased relaxation.

Figure 3

Interoceptive Awareness applied to Ong et al.'s (2012) Metacognitive Model of Insomnia



Both models demonstrate the ways in which interoceptive awareness is relevant to sleep processes. Existing sleep interventions have primarily focused on cognitive elements, seeking to reframe thoughts through CBT or foster acceptance of thoughts through MBTs. In the effort to highlight the role of thoughts, physiological processes have not been as highly explored as maintainers of sleep disturbance beyond the use of relaxation techniques (e.g., in CBT-I and MBTs). Interoceptive awareness bridges the link between physiological awareness and cognition in a way that could potentially reduce nocturnal arousal and perceived daytime impacts. Mindfulness-based interventions, which address interoceptive awareness to varying degrees, are known to be effective for sleep but the mechanisms are not fully understood (Ong & Moore, 2020; Shallcross et al., 2019). Additionally, although mindfulness and interoceptive awareness are closely linked, it is only through intensive practice that interoceptive abilities in particular are significantly increased. For brief interventions, it may be useful to target interoceptive awareness for enhanced effect. Given the prominent role of physiology in sleep onset and maintenance, as well as the interplay of cognitive and physiological arousal in the pre-sleep and nocturnal periods, it may be valuable to explicitly address interoceptive awareness in mindfulness-based interventions for insomnia. This approach could include psychoeducation about the differences between somatic amplification and interoceptive awareness and attention to cognitions and meta-cognitions relating to the body in addition to the cognitions and meta-cognitions pertaining to sleep. A wider range of mind-body techniques (e.g., taichi, Feldenkrais), beyond the yoga and meditation modalities typically taught via MBIs, could be introduced to facilitate more specific practice and skill-building in interoceptive awareness. Training in interoceptive capacities, with emphasis on body listening and trusting, has the potential to improve outcomes across the sleep health spectrum. First, for disordered sleep, interoceptive awareness could be used to improve the design of secondary prevention interventions for insomnia to slow or prevent the transition from acute to chronic manifestations. Second, there is a role for interoceptive awareness in public health initiatives that address the population as a whole. Specifically, understanding the role of interoceptive awareness in sleep health could lead to identification of a potentially protective factor that can be incorporated into psychoeducation and used to enhance sleep for heightened wellness.

Specific Aims and Hypotheses

The overall objective of the proposed study was to evaluate the associations between interoceptive awareness and sleep. The goal was to isolate a potential protective factor for sleep that may contribute to improvements of mindfulness-based therapies for insomnia and enhance psychoeducation across the sleep health spectrum. This overall objective was achieved via the following specific aims:

Aim 1. The first aim of the study was to establish the association between pre-sleep/nocturnal arousal and interoceptive awareness. Arousal may be cognitive or physiological in nature and has been demonstrated to play a significant role in sleep onset and maintenance (Baglioni et al., 2010; Lemyre et al., 2020; Palagini et al., 2016; Tang & Harvey, 2004). Cognitive and physiological arousal typically co-occur and enhance overall arousal (Harvey, 2002; Palagini et al., 2016- Trait). Interoceptive awareness showed potential for addressing the mechanisms that perpetuate arousal in order to improve sleep health (Bornemann et al., 2015; Datko et al., 2022; Fissler et al., 2016; Perez-Pena et al., 2022). Based on the connections from existing literature, I predicted that, when controlling for selected covariates (gender, race, SES, mood):

a) Interoceptive awareness factors (general factor, not-worrying, not-distracting) will be negatively associated with pre-sleep/nocturnal arousal (cognitive)
b) Interoceptive awareness factors (general factor, not-worrying, not-distracting) will be negatively associated with pre-sleep/nocturnal arousal (physiological)
c) Interoceptive awareness factors (general factor, not-worrying, not-distracting) will be negatively associated with pre-sleep/nocturnal arousal (total)

Aim 2. The second aim of the study was to evaluate the associations between interoceptive awareness and self-reported sleep health, sleep quality (including specific sleep outcomes) and insomnia status and to test discrete differences between good and poor sleepers. Sleep latency and efficiency (available sleep variables) are both influenced by cognitive and physiological processes that are trained by interoceptive awareness (Jansson-Frojmark et al., 2012; Tang &

Harvey, 2004). I predicted that, when controlling for selected covariates (gender, race, SES, mood):

a) Interoceptive awareness (general factor, not-worrying, not-distracting) will be negatively associated with PSQI sleep latency
b) Interoceptive awareness (general factor, not-worrying, not-distracting) will be negatively associated with PSQI sleep duration
c) Interoceptive awareness (general factor, not-worrying, not-distracting) will be positively associated with PSQI sleep efficiency
d) Interoceptive awareness (general factor, not-worrying, not-distracting) will be positively associated with sleep health (RU-SATED)
e) Interoceptive awareness (general factor, not-worrying, not-distracting) will be significantly higher in good sleepers (PSQI score < 5) as compared with poor sleepers (PSQI score ≥ 5)
f) Interoceptive awareness (general factor, not-worrying, not-distracting) will be significantly higher in individuals not showing insomnia symptomatology (ISI < 14) as compared with individuals reporting insomnia symptomatology (ISI ≥ 14)

Aim 3. The third aim of the study was to examine whether interoceptive awareness is a unique predictor of sleep health, PSQI global sleep quality, and insomnia status outcomes above and beyond trait mindfulness. Mindfulness and interoceptive awareness are closely related constructs, but interoceptive awareness captures distinct elements of the perceptual relationship to the body that are particularly relevant to sleep processes. Specifically, interoceptive awareness centers attunement to internal body sensation whereas mindfulness extends to all inputs, within and beyond the body (Hanley et al., 2017; Holzel et al., 2011; Ong & Moore, 2020).

Furthermore, as trait mindfulness and interoceptive awareness each have been demonstrated to have unique components using the FFMQ (Hanley et al., 2017), using the MAAS added additional support for their unique and shared variance using an alternative measure of mindfulness. I predicted that, when controlling for mindfulness and select covariates (gender, race, SES, mood):

a) Interoceptive awareness (general factor, not-worrying, not-distracting subscales) will be a unique predictor of global sleep quality (PSQI)

b) Interoceptive awareness (general factor, not-worrying, not-distracting subscales) will be a unique predictor of sleep health (RU SATED)

c) Interoceptive awareness (general factor, not-worrying, not-distracting subscales) will be a unique predictor of insomnia severity (ISI)

Approach

Participants

The Promoting Undergraduate Sleep Health study was conducted among students at a large public university in the Mid-Atlantic United States. Study participants were required to be age 18 or older and able to complete study materials written in English. At the point of data analysis, 130 records were removed because they did not meet the validity checks, and 29 records were cut due to implausible data or outliers. Because there was no participant screening prior to participation, we also removed a number of incomplete or partially completed records. The resulting sample consisted of 420 participants.

Descriptive statistics are included in full in Table 3. Participants had a mean age of 19.07 years (*SD* = 2.11). The majority of participants identified as female (72.4%) and middle class (65.6%). Although white participants were the largest group (33.2%), the sample was racially diverse with 20.7% Black/African American, 19% multiracial, 16.1% Asian American/Pacific Islander, and 10.4% Hispanic/Latinx participants. Overall the sample was moderate in the not-distracting and not-worrying factors of interoceptive awareness and moderate to high in the general factor. Pre-sleep cognitive and total arousal were in the moderate range and somatic arousal fell below the middle of the scale range. On average, participants reported sleeping 7.05 hours a night (*SD* = 1.34) and taking 34.64 minutes to fall asleep (*SD* = 31.27), with an average sleep efficiency of 83.71% (*SD* = 13.11). The average participant had moderate sleep health and was a poor sleeper (per the PSQI) but fell close to the cut-off point for good and poor sleepers. The average insomnia severity was subthreshold and 5.7% of the sample reported an insomnia diagnosis. Mood outcomes were normally distributed, with mean anxiety and depression scores falling below the middle of the range. Respondents were moderate to high in dispositional mindfulness, although only 18.5% reported engaging in a mindfulness practice. The majority of the sample reported consuming caffeine (82.9%), and less than one fifth of the sample reported marijuana use (17.1%).

Table 3

Sample Descriptive Statistics

Variable	
Age, years *M*(*SD*)	19.07 (2.11)
Gender Identity *N*(%)	
Female	305 (72.4)
Male	96 (22.8)
Gender minority	19 (4.5)
Race/Ethnicity *N*(%)	
White	144 (33.2)
Black/African American	90 (20.7)
Asian American/Pacific Islander	70 (16.1)
Hispanic/Latinx	45 (10.4)
Multiracial	80 (19.0)

Socioeconomic Status *N*(%)	
Poor or low income	26 (6.2)
Working class	91 (21.6)
Middle class	276 (65.6)
Rich or upper class	27 (6.4)
Caffeine Use *N*(%)	343 (82.9)
Alcohol Use *N*(%)	101 (24.0)
Marijuana Use *N*(%)	72 (17.1)
Interoceptive Awareness *M*(*SD*)	
Not worrying	2.37 (0.79)
Not distracting	2.02 (0.98)
General factor	17.96 (4.60)
Mindfulness *M*(*SD*)	3.40 (0.77)
Mindfulness Practice *N*(%)	78 (18.5)
Pre-Sleep Arousal *M*(*SD*)	
Cognitive	23.31 (7.64)
Somatic	15.53 (6.53)
Total	38.76 (12.67)
PSQI *M*(*SD*)	(178.38, 87.87)
Latency (mins)	34.64 (31.27)
Duration (mins)	7.05 (1.34)
Efficiency (%)	83.71 (13.11)
Global Score	6.32 (3.11)
PSQI Good Sleepers *N*(%)	128 (30.5)
Sleep Health *M*(*SD*)	7.35 (2.27)
Insomnia Severity *M*(*SD*)	9.48 (5.35)
Insomnia Diagnosis *N*(%)	24 (5.7)
Depression *M*(*SD*)	9.87 (6.21)
Anxiety *M*(*SD*)	9.35 (5.57)

Procedure

Data was collected at a large public, urban university in the mid-Atlantic United States during Fall 2023. A description of the study, entitled Promoting Undergraduate Sleep Health (PUSH), was posted on an online portal through which students are able to view and participate in research studies for course credit. Individuals who were currently or previously enrolled in a psychology course at the institution had the opportunity to participate. Psychology professors at the university were also notified about the study via email and were asked to share information with their students with the option to provide extra credit at their discretion. No monetary compensation was provided and students had the option to engage in alternative activities for research or extra credit. Participants completed online questionnaires via REDCap that included demographic questions, sleep questionnaires, and a range of psychosocial measures. The current study used a subset of these measures. Validation questions were included to increase reliability of the data. The measures took approximately forty-five minutes to complete.

Measures

Demographic Factors. The baseline questionnaire asked participants to report current age, gender identity, racial identity, and socioeconomic status. Options available for describing gender identity included male, female, non-binary/third gender, transgender, agender, and genderfluid, with options to self-describe or not disclose. Multiple boxes could be selected for racial or ethnic identity, which included Asian, Black/African-American, white, Hispanic/Latinx, Native American, and Pacific Islander, with an option not to disclose. Answer choices for socioeconomic status included poor or low-income, working class, middle class, and rich or upper-class.

Mood. Mood was operationally defined as anxiety and depression using two scales: the Generalized Anxiety Disorder-7 (GAD-7; Spitzer et al., 2006) and the Patient Health Questionnaire (PHQ-9; Spitzer et al., 2000). The GAD-7 is composed of 7 items in which participants are asked to report how bothersome the stated problem has been in the last two weeks. Likert style responses range from 0 (*not at all*) to 3 (*nearly every day*). Sample items include “Not being able to stop or control worrying” and “Trouble relaxing.” Total scores range from 0 (*no anxiety*) to 21 (*severe anxiety*). The scale is validated among college students (Byrd-Bredbenner et al., 2020) and has good internal consistency in the present sample ($\alpha = .90$). The

PHQ-9 consists of 9 items in which participants are asked to report how bothersome the stated problem has been in the last two weeks. Likert style responses range from 0 (*not at all*) to 3 (*nearly every day*). Sample items include "Feeling down, depressed, or hopeless" and "Poor appetite or overeating." Total scores range from 0 (*no depression*) to 27 (*severe depression*). The scale has been validated among a diverse body of college students in the United States (Keum et al., 2018) and demonstrates good internal consistency in the present sample (α =.89).

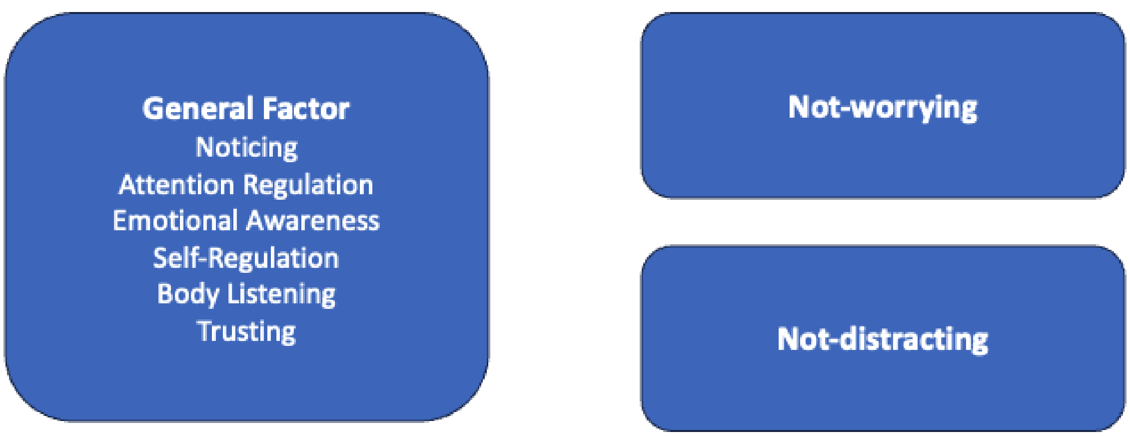
Pre-Sleep Arousal. The Pre-Sleep Arousal Scale (PSAS) is a validated self-report measure for assessing an individual's state prior to sleep onset. It consists of 16 items with answer choices ranging from 1 (*not at all)* to 5 (*extremely*). Half of the items refer to cognitive arousal, such as "Can't shut off your thoughts," and the other half refer to somatic or physiological arousal, including "A tight, tense feeling in your muscles ." Total scores can range from 16 to 80. The cognitive and physiological subscales, as well as the total score, were utilized in Aim 1. The scale is validated (Jansson-Frojmark & Norell-Clarke, 2012) with high internal consistency in the present sample (α = .82).

Interoceptive Awareness. The Multidimensional Assessment of Interoceptive Awareness Version 2 (MAIA-2) was used to assess interoceptive awareness. It consists of 37 items with answer choices ranging from 0 (*never*) to 5 (*always*). Higher subscale scores indicate more interoceptive awareness. It contains eight subscales: Noticing, Not-distracting, Not-worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting. The subscales, which are described in Table 1 on pages 4-5, consist of between three and seven questions each. The subscales are intended to be considered separately rather than to be used to derive a total score; however, a General MAIA Factor consisting of six of the eight subscales (Noticing, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening and

Trusting) has been validated (Ferentzi et al., 2021). Furthermore, two of the subscales, Not-worrying and Not-distracting, also show distinct and valid construct validity (Ferentzi et al., 2021; Gaggero et al., 2022). I used the General MAIA factor in my analysis in addition to the other two subscales - Not-worrying and Not-distracting. Scores for the General factor range from 0 (no interoceptive awareness) to 30 (highest level of interoceptive awareness). Scores for not-worrying and not-distracting range between 0 (no interoceptive awareness) to 5 (highest level of interoceptive awareness). Within the present sample Not-distracting (α = 0.89) and the General factor (α = 0.83) had good internal consistency and Not-worrying (α = 0.65) had moderate internal consistency.

Figure 4

MAIA-2 Factors



Subjective Sleep Quality. The Pittsburgh Sleep Quality Index (PSQI) assesses self-reported sleep quality over the previous one-month interval. Responses are made on a 4-point Likert scale with the exception of a few write-in answers. The PSQI includes 19 items and produces seven subscales, including sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. The seven component scores are used to calculate a global score ranging from 0 to 21 and a score of less than five indicates good sleep while greater than five indicates poor sleep. The scale has been validated in a college sample, with high internal consistency ($\alpha = 0.87$; Dietch et al., 2016). For the current study, three of the component scores (sleep duration, sleep onset latency, and sleep efficiency), the global score, and good versus poor sleeper classification were analyzed as sleep outcomes. Sleep duration (TST) is defined as total time in bed minus time spent awake. Sleep onset latency (SOL) is defined as the amount of delay between the attempt to initiate sleep and actual sleep onset and is calculated based on responses to two items. Sleep efficiency (SE) refers to the amount of sleep relative to the time in bed and is calculated based on the responses to three items.

Sleep Health. The RegUlarity, Satisfaction, Alertness, Timing, Efficiency, and Duration (RU SATED) scale is a validated scale used to measure the six dimensions of sleep health (Buysse, 2014). Regularity refers to consistency of wake and sleep times, satisfaction represents the subjective assessment of sleep, alertness is the ability to maintain a wakeful state throughout the day, timing means the hours of the day in which sleep occurs, efficiency represents how rapidly one can fall asleep or return to sleep when awakened, and duration means total amount of sleep achieved on a nightly basis. The scale contains six items that participants are asked to rank on a Likert scale ranging from 0 (*rarely*) to 2 (*usually/always*). Sample items include, “Do you stay awake all day without dosing?” and “Do you sleep between 7 and 8 hours per night?” Total scores range from 0 to 12, with higher scores indicating better sleep health. The scale is validated in a sample of adults and although it has lower internal consistency in the present sample ($\alpha = .48$) it is considered to be an appropriate measure of sleep health (Ravyts et al., 2021).

Insomnia Severity. The Insomnia Severity Index (ISI) is used to measure insomnia symptoms, ranging from no clinically significant insomnia to clinical insomnia (severe). The scale contains seven items with Likert-style responses ranging from 0 to 4. Anchors in the response choices vary, with "none" to "very," "very satisfied" to "very satisfied," and "not at all" to "very much." Sample items include, "How satisfied/dissatisfied are you with your current sleep pattern?" and "How noticeable to others do you think your sleeping problem is in terms of impairing the quality of your life?" Scores are summed to produce a total score between 0 and 28. Scores of 7 or less indicate no clinically significant insomnia, scores between 8 and 14 represent subthreshold insomnia; and scores between 15 to 21 and 22 to 28 represent clinical insomnia, of moderate and severe severity, respectively. For Aim 2, the cut point of 14 was used to divide participants into two groups, those with and without clinically significant insomnia. The scale is validated in community and clinical populations (Cerri et al., 2023) with good internal consistency in the present sample ($\alpha = 0.83$).

Dispositional Mindfulness. The Mindful Attention Awareness Scale (MAAS) is used to assess dispositional mindfulness. The scale contains 15 items which participants are asked to rate on a scale ranging from 1 (*almost always*) to 6 *(almost never*). Total scores are calculated by taking the average of the 15 item responses, with higher scores (closer to 5) representing greater levels of dispositional mindfulness. Sample items include "I find it difficult to stay focused on what's happening in the present," and "I do jobs or tasks automatically, without being aware of what I'm doing." The scale is validated among university students (Brown & Ryan, 2003) and has good internal consistency in the present sample ($\alpha = .87$).

Results

A power analysis conducted using G*power software (Faul et al., 2007) showed that a sample of 209 participants provided 80% power to detect a small to medium effect size of $f^2 \geq$ .075, with a type-I error rate of α = .05, and using eight predictors. The final sample consisted of 420 participants, exceeding the expected size and indicating that the study was adequately powered. All analyses were completed using SPSS version 28. Prior to analyses, normality tests were applied to assess for normal distribution of data via tests of skewness and kurtosis (critical values +/- 2; Ghasemi & Zahedias, 2012). Additionally, data assumptions were reviewed to ensure that assumptions of independence, normality, multicollinearity, and homoscedasticity are met. Univariate and multivariate outliers, as well as implausible item responses (e.g. average of 18 hours of sleep per night) were eliminated or winsorized.

Table 4

Pearson Correlation Coefficients among Predictor and Outcome Variables

	Gen	ND	NW	PSAS-C	PSAS-S	PSAS	ISI	PSQI Global	RU-SATED	Latency	Duration	Efficiency	MAAS
Gen	-	-	-	-	-	-	-	-	-	-	-	-	-
ND	.03	-	-	-	-	-	-	-	-	-	-	-	-
NW	-0.03	-0.01	-	-	-	-	-	-	-	-	-	-	-
PSAS-C	-0.09	-0.33**	-0.18**	-	-	-	-	-	-	-	-	-	-
PSAS-S	-0.09	-0.21**	-0.09	0.58**	-	-	-	-	-	-	-	-	-
PSAS	-0.10	-0.31**	-0.15**	0.91**	0.87**	-	-	-	-	-	-	-	-
ISI	-0.12	0.21**	-0.08	0.59**	0.48**	0.61**	-	-	-	-	-	-	-
PSQI Global	-0.18**	-0.21**	-0.04	0.56**	0.38**	0.54**	0.67**	-	-	-	-	-	-
RU-SATED	0.147	0.19**	-0.05	-0.35**	-0.28**	-0.36*	-0.56**	-0.55**	-	-	-	-	-
Latency	-0.09	0.05	-0.01	0.29**	0.18**	0.27**	0.35**	0.41**	-0.19**	-	-	-	-
Duration	-0.04	0.19**	-0.01	-0.27**	0.18**	-0.26**	-0.36**	-0.57**	0.49**	-0.16**	-	-	-
Efficiency	-0.08	0.04	-0.04	-0.08	-0.08	-0.10	-0.19**	-0.55**	0.24**	-0.12*	0.48**	-	-
MAAS	0.10	0.34**	0.13*	-0.44*	-0.43	-0.49**	-0.34**	-0.24**	-0.55**	-0.12*	0.08	-0.10*	-
Male	0.02	0.09	0.22**	-0.17**	-0.17**	-0.19**	-0.12*	-0.13**	0.10*	-0.11*	0.02	0.15**	0.09
Female	0.01	-0.01	-0.24**	0.11*	0.11*	0.12*	0.06	0.06	-0.09	0.09	0.02	-0.11*	-0.07
GMin	-0.07	-0.17**	0.10	0.97*	0.11*	0.12*	0.11*	0.13**	-0.01	0.03	-0.06	-0.07	-0.05

MR	-0.06	-0.03	-0.01	0.11*	0.08	0.10*	0.10	0.11*	-0.08	0.05	-0.06	-0.03	-0.04

Note. Gen = MAIA general factor; ND = MAIA Not-distracting factor; NW = MAIA Not-worrying factor; PSAS-C = pre-sleep arousal, cognitive; PSAS-S = pre-sleep arousal, somatic; ISI = insomnia severity; MAAS = trait mindfulness; MR = Multiracial; GMin = gender minority.

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

Gender identity, racial identity, SES, and mood (i.e., anxiety and depression) were selected as potential covariates for all regression analyses given their significant associations with sleep outcomes. Bivariate correlations were run between all demographic and outcome variables to determine which would be entered into the models (see Table 4). For the purposes of the analyses, racial/ethnic and gender demographic groups comprising less than 10% of the total sample were grouped together. Additionally, individuals checking more than one box for race/ethnicity were coded into a new multiracial category. All demographic variables were dummy coded to ensure that analysis results were easily interpretable. Given the known associations between demographic and mood variables and sleep outcomes, and the fact that interoceptive awareness is a relatively novel predictor of sleep, interoceptive awareness was entered as the first step in all models to better understand its unique association with sleep. Mood and demographic predictors were then entered into the models in step 2 and 3, respectively. To assess Aim 1, three hierarchical regressions were conducted to predict pre-sleep arousal (cognitive, physiological, and overall arousal) with interoceptive awareness (three subscales). For Aim 2, three multivariate regressions were used to predict sleep outcomes (sleep duration, sleep latency, sleep efficiency, and sleep health) from interoceptive awareness and two hierarchical logistic regressions were conducted predicting PSQI and ISI scores from interoceptive awareness. Lastly, hierarchical linear regression analyses were used to test Aim 3 with mindfulness entered in step 1, interoceptive awareness entered in step 2, mood was entered in step 3, and demographic variables were entered in step 4. Given the potential collinearity between the interoceptive awareness and mindfulness variables, I planned to employ residualization (Garcia et al., 2019) if the variables were highly collinear (e.g., VIF > 10). However, VIFs were all less than 10, indicating that there was not an issue with multicollinearity.

Table 5

Hierarchical Regression Results for Pre-Sleep Arousal (Cognitive and Somatic)

	PSAS Cognitive				PSAS Somatic			
Variable	*B*	95% CI for *B*	SE *B*	ß	*B*	95% CI for *B*	SE *B*	ß
Step 1								
Gen	-0.13	[-0.29, 0.03]	0.82	-0.08	-0.13	[-0.28, 0.02]	0.07	-0.09
ND	-2.72***	[-3.48, -1.97]	0.38	-0.35***	-1.54***	[-2.21, -0.86]	0.34	-0.23***
NW	-1.48**	[-2.41, -0.56]	0.47	-0.15**	-0.58	[-1.40, 0.25]	0.42	-0.07
	$R^2 = 0.15^{***}$, $\Delta R^2 = 0.15^{***}$				$R^2 = 0.66^{***}$, $\Delta R^2 = 0.66^{***}$			
Step 2								
Gen	0.05	[-0.07, 0.17]	0.06	0.03	0.01	[-0.11, 0.13]	0.06	0.01
ND	-1.17***	[-1.73, -0.61]	0.29	-0.15***	-0.38	[-0.95, 0.19]	0.29	-0.06
NW	-0.72	[-1.42, 0.04]	0.35	-0.08	-0.09	[-0.79, -0.61]	0.36	-0.01
Anx	0.38***	[0.24, 0.52]	0.07	0.29***	0.25***	[0.11, 0.39]	0.07	0.22***
Dep	0.56***	[0.43, 0.68]	0.07	0.46***	0.45***	[0.32, 0.58]	0.07	0.43***
	$R^2 = 0.76^{***}$, $\Delta R^2 = 0.42^{***}$				$R^2 = 0.39^{***}$, $\Delta R^2 = 0.33^{***}$			
Step 3								
Gen	0.05	[-0.07, 0.17]	0.06	0.03	0.13	[-0.11, 0.13]	0.06	0.01
ND	-1.13***	[-1.70, -0.56]	0.29	-0.14***	-0.36	[-0.94, 0.21]	0.29	-0.05
NW	-0.75	[-1.45, -0.05]	0.36	-0.08	-0.06	[-0.77, 0.66]]	0.36	-0.01
Anx	0.39***	[0.25, 0.53]	0.07	0.29***	0.25**	[0.10, 0.39]	0.07	0.21**
Dep	0.54***	[0.42, 0.67]	0.07	0.45***	0.45***	[0.32, 0.58]	0.07	0.43***
MR	0.75	[-0.54, 2.04]	0.66	0.04	0.12	[-1.21, 1.44]	0.67	0.01
Male	-0.94	[-5.10, 3.23]	2.12	-0.05	-1.69	[-11.92, 8.54]	5.29	-0.11
Fem	-0.99	[-5.05, 3.08]	2.07	-0.06	-1.24	[-11.39, 8.92]	5.16	-0.08
GMin	0.71	[-4.47, 5.89]	2.63	0.02	-0.65	[-11.17, 9.87]	5.35	-0.02
	$R^2 = 0.76$, $\Delta R^2 = 0.00$				$R^2 = 0.40$, $\Delta R^2 = 0.00$			

Note. CI = confidence interval; Gen = MAIA general factor; ND = MAIA Not-distracting factor; NW = MAIA Not-worrying factor; Anx = anxiety; Dep = depression; MR = Multiracial; Fem = female; GMin = gender minority.

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

Table 6

Hierarchical Regression Results for Pre-Sleep Arousal (Total)

Variable	B	95% CI for B		SE B	ß	R^2	ΔR^2
		LL	UL				
Step 1						0.13^{***}	0.13^{***}
Gen	-0.26	-0.53	0.01	0.14	-0.10		
ND	-4.24^{***}	-5.50	-2.99	0.64	-0.33^{***}		
NW	-2.02^{*}	-3.55	-0.48	0.78	-0.13^{*}		
Step 2						0.61^{***}	0.48^{***}
General	0.06	-0.12	0.25	0.09	0.02		
ND	-1.51^{***}	-2.38	-0.64	0.44	-0.12^{***}		
NW	-0.74	-1.81	0.33	0.54	-0.05		
Anx	0.63^{***}	0.42	0.85	0.11	0.29^{***}		
Dep	1.01^{***}	0.81	1.21	0.10	0.51^{***}		
Step 3						0.62^{***}	0.00
Gen	0.07	-0.11	0.25	0.09	0.03		
ND	-1.45^{**}	-2.34	-0.57	0.45	-0.11^{**}		
NW	-0.74	-1.84	0.36	0.56	-0.05		
Anx	0.63^{***}	0.41	0.86	0.11	0.29^{***}		
Dep	1.00^{***}	0.80	1.20	0.10	0.50^{***}		
MR	0.85	-1.18	2.87	1.03	0.03		
Male	-2.23	-17.80	13.35	7.92	-0.07		
Fem	-1.90	-17.36	13.55	7.86	-0.07		
GMin	0.19	-15.83	16.20	8.14	0.00		

Note. CI = confidence interval; LL = lower limit; UL = upper limit; Gen = MAIA general factor; ND = MAIA Not-distracting factor; NW = MAIA Not-worrying factor; Anx = anxiety; Dep = depression; MR = Multiracial; Fem = female; GMin = gender minority.

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

Associations between Interoceptive Awareness and Pre-Sleep/Nocturnal Arousal

Hierarchical linear regressions were run to examine the association between interoceptive awareness and pre-sleep cognitive, somatic, and total arousal. For the first regression, in the first block, interoceptive awareness was a significant predictor of cognitive arousal, $F(3, 358) = 20.87$, $p < .001$, $R^2 = 0.15$. Within the block, not-distracting, $b^* = -0.35$, $p < .001$, and not-worrying, $b^* = -0.15$, $p = .002$, were significant predictors. In the second block, adding mood, significantly improved the model, $\Delta R^2 = 0.42$, p < .001 and the overall model was significant, $F(5, 356) = 94.34$, $p < .001$, $R^2 = 0.57$. Within this block, not-distracting, $b^* = -0.15$, $p < .001$, not-worrying, b^* = -0.08, p = .039, anxiety, b^* = 0.29, $p < .001$, and depression, b^* = 0.46 and $p < .001$, were significant predictors. In the third block, adding gender and race did not significantly improve the model.

For pre-sleep somatic arousal, interoceptive awareness was a significant predictor of arousal when entered in the first block, $F(3, 358) = 8.44$, $p < .001$, $R^2 = 0.07$. Within the block, only not-distracting, b^* = -0.23, $p < .001$, was a significant predictor. In the second block, adding mood, significantly improved the model, $\Delta R^2 = 0.33$, $p < .001$, and the overall model was significant, $F(5, 356) = 46.31$, $p < .001$, $R^2 = 0.39$. Within this block, only depression, b^* = 0.43, $p < .001$, and anxiety, b^* = 0.22, $p < .001$, remained statistically significant. In the third block, adding gender and race, did not significantly improve the model.

Interoceptive awareness was also a significant predictor of total pre-sleep arousal when entered in the first block, $F(3, 356) = 18.23$, $p < .001$, $R^2 = 0.13$. Within the block, not-distracting, b^* = -0.33, $p < .001$, and not-worrying, b^* = -0.13, p = .01, were significant predictors. In the second block, adding mood, significantly improved the model, $\Delta R^2 = 0.47$, $p < .001$, and the overall model was significant, $F(5, 354) = 113.97$, $p < .001$, $R^2 = 0.62$. Within this block, not-distracting (b^* = -0.12, $p < .001$), depression (b^* = 0.51, p < .001), and anxiety (b^* = 0.29, $p < .001$) were statistically significant. In the third block, adding gender and race, did not significantly improve the model.

Table 7

Hierarchical Regression Results for Sleep Latency and Duration

	Sleep Latency				Sleep Duration			
Variable	*B*	95% CI for *B*	SE *B*	ß	*B*	95% CI for *B*	SE *B*	ß
Step 1								
Gen	-0.39	[-1.08, 0.30]	0.35	-0.06	0.01	[-0.02, 0.04]	0.02	0.02
ND	1.19	[-2.02, 4.41]	1.64	0.04	0.27^{***}	[0.13, 0.41]	0.07	0.20^{***}
NW	0.85	[-3.09, 4.78]	2.00	0.02	-0.06	[-0.23, 0.11]	0.09	-0.04
	$R^2 = 0.01$, $\Delta R^2 = 0.01$				$R^2 = 0.04^{**}$, $\Delta R^2 = 0.04^{**}$			

Step 2								
Gen	-0.13	[-0.82, 0.57]	0.35	-0.02	-0.00	[-0.03, 0.03]	0.02	-0.01
ND	3.07	[-0.23, 6.37]	1.68	0.10	0.20^{**}	[0.06, 0.35]	0.07	0.15^{**}
NW	1.35	[-2.69, 5.39]	2.06	0.04	-0.08	[-0.26, 0.10]	0.09	-0.05
Anx	0.20	[-0.62, 1.03]	0.42	0.04	-0.01	[-0.05, 0.03]	0.02	-0.04
Dep	0.92^{*}	[0.17, 1.67]	0.38	0.19^{*}	-0.03	[-0.07, 0.00]	0.02	-0.15
	$R^2= 0.05^{*}$, $\Delta R^2= 0.04^{***}$				$R^2= 0.07^{***}$, $\Delta R^2= 0.03^{**}$			
Step 3								
Gen	-0.11	[-0.80, 0.58]	0.35	-0.02	-0.00	[-0.03, 0.03]	0.02	-0.01
ND	3.20	[-0.12, 6.53]	1.69	0.10	0.19^{*}	[0.05, 0.34]	0.07	0.14^{*}
NW	1.77	[-2.34, 5.88]	2.09	0.05	-0.05	[-0.23, 0.13]	0.09	-0.03
Anx	0.12	[-0.71, 0.96]	0.42	0.02	-0.01	[-0.05, 0.02]	0.02	-0.05
Dep	0.92^{*}	[0.17, 1.67]	0.38	0.19^{*}	-0.03	[-0.06, 0.00]	0.02	-0.15
Male	-9.19	[-25.77, 7.39]	8.43	-0.13	0.26	[-0.46, 0.98]	0.37	0.08
Fem	-3.62	[-19.24, 11.99]	7.94	-0.05	0.45	[-0.23, 1.13]	0.35	0.15
	$R^2= 0.05$, $\Delta R^2= 0.01$				$R^2= 0.08^{***}$, $\Delta R^2= 0.01$			

Note. CI = confidence interval; Gen = MAIA general factor; ND = MAIA Not-distracting factor; NW = MAIA Not-worrying factor; Anx = anxiety; Dep = depression; Fem = female.
*p<.05. **p<.01. ***p<.001.

Table 8

Hierarchical Regression Results for Sleep Efficiency and Sleep Health

	Sleep Efficiency				Sleep Health			
Variable	*B*	95% CI for *B*	SE *B*	ß	*B*	95% CI for *B*	SE *B*	ß
Step 1								
Gen	0.22	[-0.08, 0.52]	0.15	0.08	0.07^{**}	[0.02, 0.12]	0.03	0.14^{**}
ND	0.38	[-1.00, 1.76]	0.70	0.03	0.43^{***}	[0.19, 0.67]	0.12	0.18^{***}
NW	-0.33	[-2.03, 1.36]	0.86	-0.02	-0.12	[-0.41, 0.17]	0.15	-0.04
	$R^2= 0.01$, $\Delta R^2= 0.01$				$R^2= 0.06^{***}$, $\Delta R^2= 0.06^{***}$			
Step 2								
Gen	0.19	[-0.12, 0.49]	0.16	0.07	0.04	[-0.01, 0.08]	0.03	0.07
ND	0.25	[-1.19, 1.69]	0.73	0.02	0.17	[-0.06, 0.40]	0.12	0.07
NW	-0.22	[-2.00, 1.55]	0.90	-0.01	-0.16	[-0.45, 0.12]	0.14	-0.06
Anx	0.09	[-0.27, 0.45]	0.18	0.04	-0.01^{***}	[-0.07, 0.05]	0.03	-0.03^{***}
Dep	-0.16	[-0.49, 0.17]	0.17	-0.08	-0.14^{***}	[-0.19, -0.08]	0.03	-0.37^{***}
	$R^2= 0.01$, $\Delta R^2= 0.00$				$R^2= 0.20^{***}$, $\Delta R^2= 0.14^{***}$			
Step 3								
Gen	0.17	[-0.13, 0.48]	0.15	0.06	0.04	[-0.01, 0.09]	0.03	0.07
ND	0.16	[-1.28, 1.61]	0.73	0.01	0.19	[-0.05, 0.42]	0.12	0.08
NW	-0.57	[-2.36, 1.22]	0.91	-0.04	-0.18	[-0.47, 0.11]	0.15	-0.06
Anx	0.16	[-0.21, 0.52]	0.18	0.07	-0.01	[-0.07, 0.05]	0.03	-0.03
Dep	-0.16	[-0.49, 0.17]	0.17	-0.08	-0.14^{***}	[-0.19, -0.09]	0.03	-0.37^{***}
Male	6.66	[-0.55, 13.87]	3.67	0.22	-0.47	[-1.63, 0.69]	0.59	-0.09
Fem	2.22	[-4.57, 9.01]	3.45	0.08	-0.50	[-1.58, 0.60]	0.56	-0.10
	$R^2= 0.03$, $\Delta R^2= 0.02^{*}$				$R^2= 0.20^{***}$, $\Delta R^2= 0.00$			

Note. CI = confidence interval; Gen = MAIA general factor; ND = MAIA Not-distracting factor; NW = MAIA Not-worrying factor; Anx = anxiety; Dep = depression; Fem = female.

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

Associations between Interoceptive Awareness and Sleep Outcomes

Sleep Latency

Hierarchical linear regressions were run to examine the associations between interoceptive awareness and PSQI sleep outcomes. In the first block predicting sleep latency, interoceptive awareness, was not a significant predictor. In the second block, entering mood significantly improved the model, $\Delta R^2 = 0.04$, $p < .001$ and the overall model was significant, F(5,357) = 3.56, $p = .004$, $R^2 = 0.05$. Within the second block, only depression was significant, $b^* = 0.19$, $p = .017$. In the third block, entering gender was significant, F(7,355) = 2.90, p =. 006, $R^2 = 0.05$. However, it did not significantly improve the model.

Sleep Duration

A hierarchical linear regression was run to examine the association between interoceptive awareness and sleep duration. In the first block, entering interoceptive awareness was significant, F(3,359) = 5.30, $p = .001$, $R^2 = 0.04$. Within the block, only not-distracting was significant, $b^* = 0.20$, p <. 001. In the second block, entering mood significantly improved the model, $\Delta R^2 = 0.07$, p=.003. The overall model was significant, F(5,357) = 5.59, p <. 001, $R^2 = 0.03$. Within this block, only not-distracting remained significant, b* = 0.14, $p = .01$. In the third block, entering gender was significant, F(7,355) = 4.39, p <. 001, $R^2 = 0.08$. However, it did not significantly improve the model.

Sleep Efficiency

A hierarchical linear regression was run to examine the association between interoceptive awareness and sleep efficiency. In the first block, entering interoceptive awareness was not significant. In the second block, entering mood was also not significant. In the third block, adding gender significantly improved the model, **Δ***R*^{2} = 0.02, *p* = .022. However, the overall block was not significant.

Sleep Health

A hierarchical linear regression was run to examine the association between interoceptive awareness and sleep health. In the first block, entering interoceptive awareness was significant, F(3,357) = 7.47, p<.001, R^2 = 0.06. Within the block, not-distracting, *b** = 0.18, p <. 001, and the general factor, *b** = 0.14, *p* = .006, were significant. In the second block, entering mood, significantly improved the model, **Δ***R*^{2} = 0.14, *p* < .001. The overall model was significant, F(5,355) = 17.51, *p* <.001, R^2 = 0.20. Within this block, only depression remained significant, *b** = -0.37, *p* < .001. The addition of the third block did not significantly improve the model.

Table 9

Hierarchical Regression Results for PSQI Good/Poor Sleep and Insomnia

	PSQI Good/Poor Sleep				Insomnia			
Variable	*B*	SE *B*	OR	95% CI OR	*B*	SE *B*	OR	95% CI OR
Step 1								
Gen	-0.05	0.03	0.95	[0.90, 1.00]	-0.02	0.03	0.98	[0.93, 1.04]
ND	-0.35**	0.12	0.71	[0.56, 0.90]	-0.49***	0.14	0.61	[0.47, 0.81]
NW	0.01	0.15	1.01	[0.75, 1.36]	-0.05	0.16	0.95	[0.70, 1.30]
	Nagelkerke R^2= 0.05				*Nagelkerke R^2= 0.06*			
Step 2								
Gen	-0.02	0.03	0.98	[0.93, 1.04]	0.04	0.04	1.04	[0.97, 1.11]
ND	-0.14	0.14	0.87	[0.67, 1.13]	-0.16	0.17	0.85	[0.62, 1.18]
NW	0.09	0.17	1.09	[0.78, 1.53]	0.08	0.19	1.09	[0.75, 1.58]
Anx	0.02	0.04	1.02	[0.96, 1.10]	0.08*	0.04	1.08	[1.01, 1.16]
Dep	0.15***	0.04	1.16	[1.09, 1.25]	0.18***	0.04	1.19	[1.11, 1.28]
	Nagelkerke R^2=0.23				*Nagelkerke R^2= 0.37*			
Step 3								
Gen	-0.02	0.03	0.98	[0.93, 1.04]	0.03	0.04	1.03	[0.96, 1.11]
ND	-0.13	0.14	0.88	[0.67, 1.14]	-0.15	0.17	0.86	[0.62, 1.20]
NW	0.04	0.18	1.04	[0.73, 1.47]	0.01	0.20	1.01	[0.69, 1.49]
Anx	0.03	0.04	1.03	[0.96, 1.11]	0.10*	0.04	1.10	[1.02, 1.19]
Dep	0.15***	0.04	1.16	[1.08, 1.24]	0.17***	0.04	1.19	[1.10, 1.27]

Male	0.31	0.32	1.37	[0.73, 2.55]	0.92	0.38	2.50	[1.18, 5.31]
GMin	1.13	1.08	3.09	[0.37, 25.85]	0.54	0.68	1.72	[0.46, 6.48]
MR	0.24	0.34	1.26	[0.65, 2.45]	0.20	0.36	1.22	[0.61, 2.47]
		Nagelkerke R^2= 0.23				*Nagelkerke R^2= 0.39*		

Note. CI = confidence interval; OR = odds ratio; Gen = MAIA general factor; ND = MAIA Not-distracting factor; NW = MAIA Not-worrying factor; Anx = anxiety; Dep = depression; MR = Multiracial; Fem = female; GMin = gender minority.

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

Insomnia Severity

A hierarchical logistic regression was run to examine the differences in interoceptive awareness between individuals with and without clinically significant insomnia. In the first block, entering interoceptive awareness, was significant, Wald's $\chi^2(3) = 13.94$, $p = .003$. Within the block, not-distracting was significant, OR = 0.61 (95% CI: 0.47-0.81), $p <. 001$. This indicated that for every 0.1 point increase in not-distracting, participants had about 61% likelihood of having clinically significant insomnia as compared with no insomnia or subthreshold level insomnia. In the second block, entering mood was significant, Wald's $\chi^2(5)=94.36$, $p < .001$. Within the block, anxiety, OR = 1.08 (95% CI: 1.01-1.16), $p = .033$, and depression, OR= 1.19 (95% CI: 1.11-1.28), $p <.001$, were significant. This indicated that for every 0.1 point increase in anxiety, an individual was 8% more likely to have clinically significant insomnia; additionally, for every 0.1 point increase in depression, an individual was 19% more likely to have clinically significant insomnia. In the third block, entering gender and race/ethnicity did not significantly improve the model.

Global Sleep - Good and Poor Sleeper Classification

A hierarchical logistic regression was run to examine the differences in interoceptive awareness between good and poor sleepers. In the first block, entering interoceptive awareness was significant, Wald's $\chi^2(3)=12.23$, $p = .007$. Within the block, not-distracting was significant, OR=0.71 (95% CI: 0.56-0.90), p = .005. This indicated that for every 0.1 point increase in not-distracting, participants had about 71% likelihood of having being a poor sleeper as compared with being a good sleeper. In the second block, entering mood, was significant, Wald's $\chi^2(2)$ = 62.39, p < .001. Within the block, only depression remained significant, OR = 1.16 (95% CI: 1.09-1.25), p <.001. This indicated that for every 0.1 point increase in depression, an individual was 16% more likely to be a poor sleeper. In the third block, entering gender and race/ethnicity did not significantly improve the model.

Table 10

Hierarchical Regression Results for Global Sleep, Sleep Health, and Mindfulness

	Global Sleep				Sleep Health			
Variable	*B*	95% CI for *B*	SE *B*	ß	*B*	95% CI for *B*	SE *B*	ß
Step 1								
MAAS	-1.09^{***}	[-1.49, -0.69]	0.21	-0.27^{***}	0.68^{***}	[0.37, 0.99]	0.16	0.23^{***}
	$R^2 = 0.07^{***}$, $\Delta R^2 = 0.07^{***}$				$R^2 = 0.05^{***}$, $\Delta R^2 = 0.05^{***}$			
Step 2								
MAAS	-0.87^{***}	[-1.30, -0.45]	0.22	-0.22^{***}	0.57^{***}	[0.24, 0.90]	0.17	0.19^{***}
Gen	-0.08^{*}	[-0.15, -0.02]	0.03	-0.12^{*}	0.06^{*}	[0.01, 0.11]	0.03	0.12^{*}
ND	-0.45^{**}	[-0.78, -0.11]	0.17	-0.14^{**}	0.25	[-0.00, 0.51]	0.13	0.11
NW	0.06	[-0.33, 0.45]	0.20	0.02	-0.20	[-0.50, 0.09]	0.15	-0.07
	$R^2 = 0.11^{***}$, $\Delta R^2 = 0.03^{**}$				$R^2 = 0.08^{***}$, $\Delta R^2 = 0.03^{**}$			
Step 3								
MAAS	0.08	[-0.35, 0.50]	0.22	0.02	0.03	[-0.31, 0.38]	0.18	0.01
Gen	-0.03	[-0.10, 0.03]	0.03	-0.05	0.03	[-0.02, 0.08]	0.03	0.07
ND	-0.26	[-0.56, 0.04]	0.15	-0.08	0.14	[-0.10, 0.39]	0.12	0.06
NW	0.00	[-0.36, 0.36]	0.18	0.00	-0.17	[-0.46, 0.12]	0.15	-0.06
Anx	0.02^{***}	[-0.06, 0.09]	0.04	0.03^{***}	-0.01	[-0.07, 0.05]	0.03	-0.02
Dep	0.24^{***}	[0.18, 0.31]	0.04	0.50^{***}	-0.14^{***}	[-0.20, -0.09]	0.03	-0.38^{***}
	$R^2 = 0.30^{***}$, $\Delta R^2 = 0.20^{***}$				$R^2 = 0.19^{***}$, $\Delta R^2 = 0.11^{***}$			
Step 4								
MAAS	0.06	[-0.36, 0.49]	0.22	0.02	0.04	[-0.31, 0.38]	0.18	0.01
Gen	-0.03	[-0.09, 0.03]	0.03	-0.05	0.03	[-0.02, 0.08]	0.03	0.07
ND	-0.23	[-0.53, 0.07]	0.15	-0.07	0.16	[-0.09, 0.40]	0.12	0.07
NW	-0.00	[-0.37, 0.36]	0.19	-0.00	-0.18	[-0.48, 0. 12]	0.15	-0.06
Anx	0.02	[-0.06, 0.09]	0.04	0.03	-0.01	[-0.07, 0.05]	0.03	-0.02
Dep	0.24^{***}	[0.17, 0.31]	0.04	0.48^{***}	-0.14^{***}	[-0.20, -0.08]	0.03	-0.38^{***}
Male	-0.11	[-0.78, 0.57]	0.34	-0.02	0.02	[-0.53, 0.57]	0.28	0.00
GMin	1.07	[-0.39, 2.53]	0.74	0.07	0.40	[-0.79, 1.59]	0.60	0.03
MR	0.41	[-0.25, 1.08]	0.34	0.06	-0.14	[-0.69, 0.40]	0.28	-0.03
	$R^2 = 0.31^{***}$, $\Delta R^2 = 0.01$				$R^2 = 0.20^{***}$, $\Delta R^2 = 0.00$			

Note. CI = confidence interval; Gen = MAIA general factor; ND = MAIA Not-distracting factor; NW = MAIA Not-worrying factor; Anx = anxiety; Dep = depression; MR = Multiracial; Fem = female; GMin = gender minority.

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

Table 11

Regression Results for Insomnia Severity and Mindfulness

Variable	*B*	95% CI for *B*		SE *B*	ß	R^2	ΔR^2
		LL	UL				
Step 1						0.14^{***}	0.14^{***}
MAAS	-2.59	-3.28	-1.90	1.23	-0.37		
Step 2						0.39^{***}	0.02
MAAS	-2.29^{***}	-3.03	-1.55	0.38	-0.33^{***}		
Gen	-0.05	-0.17	0.07	0.06	-0.05		
ND	-0.65^{*}	-1.23	-0.08	0.29	-0.12^{*}		
NW	-0.08	-0.75	0.59	0.34	-0.01		
Step 3						0.42^{***}	0.27^{***}
MAAS	-0.27	-0.96	0.43	0.35	-0.04		
Gen	0.02	-0.08	0.12	0.05	0.02		
ND	-0.27	-0.75	0.21	0.25	-0.05		
NW	-0.04	-0.62	0.54	0.30	-0.01		
Anx	0.15^{*}	0.03	0.27	0.06	0.16^{*}		
Dep	0.42^{***}	0.31	0.53	0.06	0.49^{***}		
Step 4						0.42^{***}	0.00
MAAS	-0.27	-0.96	0.43	0.35	-0.04		
Gen	0.02	-0.08	0.12	0.05	0.02		
ND	-0.24	-0.73	0.25	0.25	-0.04		
NW	-0.08	-0.68	0.51	0.30	-0.01		
Anx	0.16^{*}	0.04	0.28	0.06	0.17^{*}		
Dep	0.41^{***}	0.30	0.53	0.06	0.48^{***}		
Male	0.31	-0.79	1.41	0.56	0.02		
GMin	1.07	-1.29	3.43	1.20	0.04		
MR	0.39	-0.71	1.48	0.56	0.03		

Note. CI = confidence interval; LL = lower limit; UL = upper limit; Gen = MAIA general factor; ND = MAIA Not-distracting factor; NW = MAIA Not-worrying factor; Anx = anxiety; Dep = depression; MR = Multiracial; Fem = female; GMin = gender minority.

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

Comparing the Predictive Power of Interoceptive Awareness and Mindfulness

Global Sleep

A hierarchical linear regression was run to determine to what extent interoceptive awareness predicted global sleep above and beyond mindfulness. In the first block, entering mindfulness was significant, F(1,349) = 28.05, p < .001, R^2 = 0.07. Within the block, mindfulness was a significant predictor, *b** = -0.27, *p* < .001. In the second block, entering interoceptive awareness, significantly improved the model, ΔR^2 = 0.03, *p* = .004. The overall model was significant, F(4,346) = 86.52, *p* < .001, R^2 = 0.11. Within the block, mindfulness, *b** = -0.22, *p* < .001, not-distracting, *b** = -0.14, *p* = .008, and the MAIA general factor, *b** = -0.12, *p* = .016 were significant. In the third block, entering mood, significantly improved the model, ΔR^2 = 0.19. The overall model was significant, F(6,344) = 24.51, *p* < .001, R^2 = 0.30. Within the block, only depression remained significant, *b** = 0.50, *p* < .001. In the fourth block, entering gender and race did not significantly improve the model.

Sleep Health

A hierarchical linear regression was run to determine how much interoceptive awareness predicted sleep health above and beyond mindfulness. In the first block, entering mindfulness was significant, F(1,347) = 18.65, *p* < .001, R^2 = .05. Within the block, mindfulness was a significant predictor, *b** = 0.23, *p* < .001. In the second block, entering interoceptive awareness significantly improved the model, ΔR^2 = 0.03, *p* = .007. The overall model was significant, F(4,344) = 7.83, *p* = .007, R^2 = 0.08. Within the block, mindfulness, *b** = 0.19, *p* < .001, and the MAIA general factor, *b** = 0.12, *p* = .02, were significant. In the third block, entering mood, significantly improved the model, ΔR^2 = 0.11, *p* <. 001. The overall model was significant, F(6,342) = 13.67, *p* < .001, R^2 = 0.19. Within the block, only depression remained significant, *b** = -0.38, *p* < .001. In the fourth block, entering gender and race did not significantly improve the model.

Insomnia Severity

A hierarchical linear regression was run to determine how much interoceptive awareness predicted insomnia severity above and beyond mindfulness. In the first block, entering mindfulness was significant, F(1,341) = 53.88, $p < .001$, $R^2 = 0.14$. Within the block, mindfulness was a significant predictor, $b^* = -0.37$, $p < .001$. In the second block, entering interoceptive awareness did not significantly improve the model. In the third block, entering mood, significantly improved the model, $\Delta R^2 = 0.27$, $p < .001$. The overall model was significant, F(6,336) = 40.03, $p < .001$, $R^2 = 0.42$. Within the block, only depression, $b^* = 0.48$, $p < .001$, and anxiety, $b^* = 0.17$, $p = .011$, were significant. In the fourth block, entering gender and race did not significantly improve the model.

Discussion

The objective of the present study was to establish the association between interoceptive awareness and sleep health across the spectrum, including insomnia. The study consisted of three central aims: 1) to explore the association between interoceptive awareness and pre-sleep arousal, 2) to explore the association between interoceptive awareness and self-reported sleep outcomes, and 3) to examine interoceptive awareness as a unique predictor of sleep outcomes as compared with mindfulness. Interoceptive awareness, in particular the not-distracting subscale, was linked to several pre-sleep and sleep outcomes. Furthermore, interoceptive awareness predicted global sleep and sleep health above and beyond mindfulness. Mood emerged as the strongest predictor of sleep outcomes, nullifying some of these associations.

Overall, the present study demonstrated differences in predictive power among the three facets of interoceptive awareness. Previously, the measure of interoception in the current study, the Multidimensional Assessment of Interoceptive Awareness - 2 (MAIA-2), was designed to be split into eight subscales/factors without the calculation of a total interoceptive awareness score. However, recent research yielded three distinct factors: not-distracting, not-worrying, and the general factor (Ferentzi et al., 2021). Not distracting, characterized by not ignoring or tuning out uncomfortable body sensation, emerged as the most significant factor in the current study. Individuals who are higher in interoception as characterized by not-distracting, are less likely to 'power through' discomfort or occupy or distract themselves with something else so they don't have to feel a sensation. The not-distracting subscale assesses for the absence of these distraction tendencies (e.g., noticing that one's heart is pounding but not attending to it). The tendency to disengage from internal body sensation is on the opposite end of the spectrum from body awareness as captured by the eight collective MAIA-2 subscales.

In terms of specific findings, the interoceptive characteristic of not-distracting was linked to lower pre-sleep arousal and longer sleep duration. First, the rationale for examining associations between pre-sleep arousal and interoceptive awareness is that pre-sleep arousal can be a barrier to good sleep health. As hypothesized, I found that interoceptive awareness significantly predicted pre-sleep arousal (cognitive, somatic, and total). Although all three factors were negatively associated with arousal, only not-distracting retained significance for both cognitive pre-sleep arousal and total pre-sleep arousal when considering demographic and mood factors. In other words, people who reported a lower likelihood of distracting themselves from unpleasant sensation also had lower self-reported levels of cognitive and overall wakefulness before sleep. This was the first study to examine interoceptive awareness in relation to pre-sleep arousal. A few studies have demonstrated that distraction is an ineffective strategy for improving sleep outcomes among good sleepers and individuals with insomnia (Lemyre et al., 2020). It is possible that mentally conjuring a distraction from something that is pulling one's attention, even if this occurs at the subconscious level, actually increases cognitive activity rather than reducing it in a way that prepares the mind and body for sleep. Given that pre-sleep and nocturnal arousal are established mechanisms by which insomnia is maintained (Harvey, 2002), the negative association between pre-sleep arousal and interoceptive awareness may show its potential to counteract nighttime arousal.

It is interesting that there was a smaller association with somatic awareness, given that interoceptive awareness seemingly pertains equally to the experience of physiological and cognitive disturbance. It is possible that it was more difficult to detect a somatic effect due to the lower levels of somatic arousal in this sample (falling below the midpoint of the range). The lower levels of physiological arousal in our sample in spite of moderate cognitive arousal reflects findings that somatic and cognitive arousal do not always co-occur and the alignment of the two types may be moderated by anxiety (i.e. individuals higher in anxiety may be more likely to present with both, whereas they are less likely to be simultaneously present in lower-anxiety individuals; Tang & Harvey, 2004). Additionally, it may be that somatic arousal is more difficult to detect via self-report when accompanied by cognitive arousal, since the former typically occurs more at the subconscious level (Nicassio et al., 1985).

Given the potential for interoceptive awareness to promote sleep health in addition to being a factor in disordered sleep, another goal of the study was to examine the relation between interoceptive awareness and self-reported sleep outcomes, with the expectation that we might see differences in body awareness across the sleep spectrum. In the present study, higher interoceptive awareness (specifically the characteristic of ‘not-distracting’) was associated with sleeping longer. This is a novel finding, since the association between these two constructs has not been previously examined. However, these findings are consistent with prior research showing a strong association between MAIA not-distracting and PSQI global sleep, which includes total sleep time (Arora et al., 2021). Average duration of sleep in the present study was seven hours, corresponding with the lower end of the National Sleep Foundation's recommendations for nightly total sleep time (Hirshkowitz et al., 2015). It is possible that the lower nighttime arousal associated with not-distracting also decreases latency and wake after sleep onset, with the result being longer total sleep times. The inverse effect is also possible, with more sleep leading to greater capacity for body attunement via an increased sense of wakefulness.

There were no notable links between sleep latency and efficiency with interoceptive awareness. It is surprising that interoceptive awareness did not predict latency as measured by the PSQI, given that arousal before sleep prolongs the initiation of sleep, thereby increasing latency (Jansson-Frojmark et al, 2012; Tang & Harvey, 2004). It may be that some of the arousal reported on the PSAS manifested as wake after sleep onset (WASO), which would then detract from total sleep time (duration) without impacting latency. The non-significant findings relating to sleep efficiency could also be attributed to measurement error. Because efficiency is a composite measure using average sleep and wake, time in bed, as well as total sleep duration, any inaccurate reporting for the other measures would have been inflated in the calculation. In future studies, it will be valuable to explore the association between interoceptive awareness and objective measures of latency and efficiency or daily subjective measures such as sleep diaries to detect a possible effect not observed in the current study.

Although interoceptive awareness was not linked to latency and efficiency, it demonstrated an association with the broader construct of sleep health. Individuals reporting a higher level of overall interoceptive awareness (per the general factor) as well as not-distracting reported better sleep health. Interoceptive awareness explained 6% of the variance in sleep health, constituting a small positive effect. Sleep health includes the constructs of regularity, satisfaction and alertness in addition to perceived efficiency and duration (Buysse, 2014). Within the sample, average sleep health fell just above the middle of the range, indicating moderate to good sleep. In addition to understanding the association between interoceptive awareness and sleep health across the spectrum, this study sought to assess the ways in which this construct may differentiate two discrete groups of sleepers. The odds of being a good sleeper or not having an insomnia diagnosis were higher among individuals who scored higher on the not-distracting facet of interoceptive awareness. However, both effects disappeared when anxiety and depression were entered into the model, suggesting that these broader sleep outcomes may be better explained by mood variables.

In fact, mood covariates emerged as significant predictors of all sleep outcomes. This pattern of findings is perhaps unsurprising, given that sleep disturbance is included in the diagnostic criteria for both Generalized Anxiety Disorder and Major Depressive Disorder in the DSM-5 (APA, 2013). In the current study, depression was a significant predictor across the board. Specifically, depression was positively associated with all three categories of pre-sleep arousal, sleep latency, and insomnia severity and negatively associated with sleep health. These results are consistent with existing findings of a bidirectional relationship between depression and sleep outcomes, with some evidence that sleep disturbance often temporally precedes the onset of depression (Boland et al., 2020). Average mood measures for participants in our sample fell in the lower end of the range, indicating that our sample represented a healthy sample rather than a clinical population.

In addition to depression being independently associated with sleep outcomes, it may also interact with interoceptive awareness. Previous findings demonstrate a negative association between depression and interoceptive awareness, meaning that greater levels of depressive symptoms co-occur with less noticing and trusting of body sensation and regulation of the corresponding emotion (Desdentado et al., 2022; Dunne et al., 2021; Eggert & Stauber, 2021; Solano Lopez & Moore, 2019). Less interoception may occur because depressive symptoms dull one's attention to internal body signals in favor of ruminative thought processes; alternatively, poor interoception may enhance depressive symptoms by dulling one's experience of sensation and contributing to anhedonia and low energy. It appears that when depression was added into various models in the study, it explains some of the variance previously explained by interoceptive awareness. Although beyond the aims of the current analyses, it is possible that depression and interoceptive awareness may work in concert in relation to sleep. For example, higher levels of depression may reduce attunement to internal body signals, reducing the ability to recognize and accept unpleasant sensation; instead, arousal may be enhanced, increasing latency and reducing total sleep time. Further testing of this interaction is needed to draw additional conclusions.

Anxiety also emerged as a significant predictor of pre-sleep arousal and insomnia severity, with higher anxiety predicting more nighttime arousal and greater severity of insomnia symptoms. This finding is not particularly surprising, given that trait anxiety leads to ruminative processes that contribute to arousal before and during sleep, and pre-sleep and nocturnal arousal are mechanisms of insomnia (Harvey, 2002). However, anxiety did not explain some of the variance previously explained by interoceptive awareness in the way that depression did. It is possible that there is some effect of "canceling out" between anxiety and interoceptive awareness. For example, although a person high in health anxiety may score high in noticing and not-distracting, they may simultaneously have difficulty balancing their awareness and believing the body will find its own equilibrium, thus scoring lower on attention regulation and trusting. Therefore, a potential interaction between the two constructs may be neutralized.

The lack of significant association between insomnia severity and interoceptive awareness when controlling for mood contradicts our prediction that interoceptive awareness would be especially relevant to the processes that create and maintain insomnia. The small effect size and nonsignificance with the addition of covariates could be attributed to the low levels of clinically significant insomnia in our sample. Although about 70% of the sample consisted of poor sleepers based on the PSQI cut point, only one quarter of the sample had clinically significant insomnia symptoms and 5.7% reported an insomnia diagnosis. Notably, some behaviorally-induced insufficient sleep syndrome (BIISS), characterized by self-imposed sleep limitations and daytime sleepiness, is experienced by 1 in 10 college students and may explain the discrepancy between those demonstrating insomnia symptoms and those with a diagnosed sleep disorder (Williams et al., 2020). Consequently, insomnia symptoms in this sample could be representative of behaviorally-induced sleep limitations that may not be as related to interoceptive processes. Another possibility is that trait interoceptive awareness acts as a protective factor only to a certain point of insomnia severity, at which point other factors supersede the effects of baseline awareness of body sensation. Less than one fifth of the sample reported engaging in an intentional contemplative or mindfulness practice. It may be that specific training and practice of interoceptive skills could override the complex cognitive processes that contribute to and maintain insomnia (i.e. negatively toned cognitive activity, arousal and distress, selective attention and monitoring, and resulting distorted perceptions of sleep).

Beyond the association of interoception and our sleep measures, the final aim of this project was to compare interoceptive awareness to the more widely researched construct of mindfulness. Consistent with our hypothesis, interoceptive awareness appeared to be a unique predictor of global sleep and sleep health above and beyond mindfulness. Together, mindfulness and interoceptive awareness predicted 11% of the variance in global sleep and 8% of the variance in sleep health. Depression symptoms, however, rendered these associations non-significant once mood was entered into the models. Consequently, there is a need to better understand the unique and overlapping roles for depression, interoceptive awareness, and mindfulness as barriers to and potential promoters of sleep health. Nonetheless, given that interoceptive awareness is often blended conceptually with mindfulness (Colgan et al., 2013; Mehling et al., 2018), its establishment as a construct with unique variance and predictive power is important because it allows us to understand the ways in which mindfulness-based interventions for sleep may exclude elements with potential to improve sleep health and reduce insomnia symptoms. For example, interoceptive awareness emphasizes body listening and trusting in a way that is not fully captured by some mindfulness training. Body listening may promote more attunement to signals of drowsiness and thus result in greater sensitivity to one's sleep needs. Body trusting may increase the likelihood of one's responsiveness to interoceptive signals (e.g. sleepiness) and decrease reactivity to disruptive sensation (e.g. pain), leading to more restful sleep with minimal interruptions. In the analyses entering mindfulness and interoceptive awareness, the interoceptive awareness general and non-distracting factors both emerged as predictors. The dual significance of these two factors indicates that seven out of the eight interoceptive awareness subscales and two of the three factors had notable associations with overall subjectively reported sleep and perceived sleep outcomes that could be differentiated from the effects of mindfulness.

Interoceptive awareness did not uniquely predict insomnia severity above and beyond mindfulness, mirroring the nonsignificant association between interoceptive awareness and insomnia severity in Aim 2 when accounting for mood. This finding suggests that interoceptive awareness consists of unique elements linked to sleep health and global sleep, but when it comes to insomnia severity, mindfulness absorbs these facets. It is important to note that our mindfulness measure (the Mindful Attention Awareness Scale) captures attentional capacities as they pertain to the outer world (with the exception of two items), whereas interoceptive tendencies (as measured by the MAIA-2) focus on one's inner experience. Thus, another hypothesis is that greater sleep disturbance in the form of insomnia compromises one's mindful awareness (i.e. their ability to attend to tasks and activities) due to its impact on cognitive function; at the same time, disturbed sleep causes focus to move inward but in a way that is lacking a trusting and nonjudgmental quality, increasing some facets of interoceptive awareness but lowering others and resulting in an insignificant association. Lastly, as discussed above, the non-significant effect of interoceptive awareness on insomnia may be explained by the low level of insomnia severity in the sample. More research is needed to explore the association between insomnia and mindfulness as compared with interoceptive awareness.

Demographic covariates did not emerge as significant predictors of sleep outcomes above and beyond interoceptive awareness and mood, suggesting that in this sample, interoceptive awareness and/or mood were stronger predictors of pre-sleep arousal and sleep outcomes than demographic factors. Additionally, there are several other explanations for the lack of demographic effects. Previous research indicates that gender minorities experience poorer sleep outcomes as a result of marginalization and discrimination (Butler et al., 2020; Slopen et al., 2016), and women report greater levels of sleep disturbance than men (Grandner, 2017). The majority of the sample was female-identifying, with male participants and gender minorities comprising 22.8% and 4.5% of the sample, respectively, so we might have expected to see female gender emerge as a predictor. Our findings may be explained by the fact that anxiety and depression have a higher prevalence among female-identifying individuals (Kessler et al. 1994), which may have resulted in the masking of gender effects by mood variables. We also did not see significant differences in sleep outcomes based on race and ethnicity. This lack of findings may be due to the fact that racial and ethnic differences in sleep have been captured via objective measures but may be less apparent when using subjective data (Ahn et al., 2021). Finally, socioeconomic status and related discrimination has been found to be associated with poorer sleep outcomes, including efficiency (Fuller-Rowell, 2023). However, it is likely that night shifts and other irregular work hours play into these disparities; while college students of lower SES also often hold secondary jobs, their sleep and wake times may not be as divergent from that of other college students due to the general unpredictability of an undergraduate lifestyle. Other mechanisms tying lower socioeconomic status and discriminatory experiences to sleep (e.g., poorer sleep environment, heightened stress) could have been muffled in the current sample due to more universality across sleeping environments (e.g., living in dorms) and shared sources of stress among college students.

Strengths The present study has a number of strengths that differentiate it from the existing body of research. Unlike much of the research conducted at universities in the United States, this study drew from a relatively diverse sample of students in terms of race/ethnicity and socioeconomic status. While white students remained the largest group within the sample, a sizable portion also identified as Black/African-American, Latinx, Asian-American or Pacific Islander, and multiracial. Consequently, this sample has the implication of being more generalizable to the United States population, which is similarly racially and ethnically diverse. Additionally, socioeconomic status was normally distributed, with less than two-thirds of the sample identifying as middle class and about one-fifth as working class.

In addition to the diverse composition of the sample, the study was unprecedented in its use of measures. Although the MAIA-2 has been used extensively in research, the three factors identified by Ferentzi et al. (2021) have not previously been applied. The present study was unique in its ability to highlight the predictive power of the not-distracting factor as compared to the general and not-worrying factors. Other research has used the eight subscales, but I chose to use the factors based on prior validation research.

Beyond this, the current study provided new understanding of associations between interoceptive awareness and sleep health constructs. Specifically, I examined interoceptive awareness as a predictor of pre-sleep arousal, sleep health, and insomnia, which have not previously been explored. Existing research demonstrates that mindfulness, which shares some elements with interoceptive awareness, may serve as a protective factor against insomnia. However, to date, no steps have been taken to explicitly test the association between interoceptive awareness and insomnia, and only a small body of research has explored the association between global sleep health and interoceptive awareness. Thus, this study provides a novel contribution to the literature on this topic.

Finally, it has been established that interoceptive awareness can be enhanced via mindfulness training and that there is shared variance between the two closely linked constructs. No studies have formerly assessed the unique predictive power of interoceptive awareness as compared with mindfulness. Since mindfulness-based interventions for insomnia and sleep health are on the rise, it is important to understand what specific areas of these constructs lend themselves to the improvement of sleep outcomes.

Limitations While highlighting the strengths of the current study, it is equally important to comment on its limitations. First, this study relied solely on self-report measures rather than incorporating objective assessment of interoception and sleep. Other studies have utilized heart rate detection tasks to study interoceptive sensitivity (Duschek et al., 2017; Murphy et al., 2019). In the present study, the researcher was specifically interested in the subjective measure of interoceptive awareness given its incorporation of cognitive processes and a mindfulness lens. There are a number of established objective sleep measures, including actigraphy or polysomnography, and daily diary assessments. These tools were not used in the present study due to limited time and resources. This is a limitation in that college age participants may have struggled with determining their average wake and sleep times and durations for the retrospective sleep measures due to the variability in their schedules. Participants were also asked to report these times using military time and provided with instructions on how to calculate this; however, the participants' unfamiliarity with this time format may have created confusion and contributed to inaccurate reporting.

Besides limitations related to its use of subjective measures, there were also limitations to the study procedure. The current study was conducted online rather than in person, leaving room for possible measurement error. The researcher compensated for this weakness by checking for duplicate records and including attention checks to ensure quality of the results. Participants were also provided with a study email address to which they were able to direct questions. Still, it is possible that the accuracy of the results was compromised by the lack of oversight while participants were completing the assessment.

Some other drawbacks in the design was the utilization of an undergraduate student sample, with participants ranging in age from 18 to 38 (age outliers are due to some non-traditional students), and the absence of substance use and trauma as covariates. College students are known to have unique sleep habits, including irregular sleep patterns and more resilient sleep compared with the adult population (Williams et al., 2020). This characteristic of our sample limits the generalizability of our results to other adult samples in the United States. Beyond this, we did not test the effects of substances on reported sleep outcomes, in spite of the high prevalence of caffeine use in our sample. College students are more likely to misuse substances due to relative novelty and higher risk-taking behavior. Although non-caffeine substance use was relatively low in our sample (17% reported marijuana use and 24% reported alcohol consumption), it is likely that it was significantly underreported. The present study also did not assess for trauma history or PTSD diagnosis, which may moderate the relationship between interoceptive awareness and sleep and demonstrate a more complex picture than the mood variables alone. Future studies should control for substance use and trauma history in order to explore these potential interactions.

A final limitation is in the cross-sectional nature of the study, which prevented us from assessing causality. There is reason to believe that the relationship between interoceptive awareness and sleep may be bidirectional (Arora et al., 2021). For example, individuals who get the recommended amount of sleep with shorter latency and longer total sleep times may be better equipped to respond to internal body sensations in a healthy and non-reactive manner. Without conducting an intervention with pre- and post-test measures, it is not possible to assess the impact of interoceptive awareness training on sleep outcomes.

Implications and Future Directions Despite the limitations of its sample, design, and methods, the present study provides a novel examination of the role of interoceptive awareness in sleep processes. Previous research has demonstrated the role of nighttime arousal in insomnia as well as the protective nature of mindfulness training for sleep, but few have made the connection between internal body awareness with sleep outcomes. The findings of the current study suggest that further exploration of interoceptive awareness in both healthy and clinical populations is warranted.

Given the findings of significant associations between interoceptive awareness and multiple sleep outcomes, it would be valuable to establish causality and directionality. Future research could test an interoceptive awareness intervention and its effect on sleep outcomes. The use of objective and daily sleep measures to triangulate self-reported data could also bolster the study. The use of other sleep measures may particularly help to identify findings with relation to specific sleep outcomes (e.g. latency, efficiency) which emerged as non-significant in the current study. Conducting a study in a population in a clinical population of individuals with insomnia may provide further insight into the association between sleep health and insomnia processes.

Conclusion

The current study provided evidence of an association between the not-distracting factor of interoceptive awareness and sleep outcomes, specifically pre-sleep arousal and sleep duration, and unique variance of interoceptive awareness above and beyond mindfulness for global sleep and sleep health. These findings contribute to a small but growing body of literature on interoceptive awareness and provide novel links between interoceptive awareness and sleep outcomes. Future research may explore the moderating role of interoceptive awareness in the association between mood and sleep outcomes. Additionally, it may be valuable to assess similar associations with the incorporation of objective sleep measures and using a sample of individuals with clinically significant insomnia.

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