

Can't You Feel Your Heartbeat Fast?:

Mindfulness as a mediator between interoception and anxiety

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Abstract

Interoception is the perception of physical and emotional sensations within the body, such as hunger, respiration, and pain. Interoception is conceptualized in different components, including interoceptive accuracy (IAc), operationalized in this study as the objective ability to detect heartbeats within the body, and interoceptive sensibility (IS), measured by self-reports of subjective interoception. There is conflicting literature on whether or not interoception is helpful or hurtful in emotion regulation. In an undergraduate, nonclinical sample, we hypothesized that: (1) IAc will not significantly correlate with IS; (2) mindfulness will mediate the effect of IS on anxiety such that IS will predict higher anxiety at low levels of mindfulness while IS will predict low anxiety at high levels of mindfulness; (3) mindfulness will mediate the effect of IAc on anxiety such that better IAc will predict higher anxiety at low levels of mindfulness while better IAc will predict low anxiety at high levels of mindfulness. As hypothesized, accuracy on the heartbeat perception task (IAc) was not significantly correlated with IS ($p = .52$). In contrast to hypotheses 2 and 3, multiple linear regression models did not show interoception mediating the relationship between mindfulness and anxiety. Further studies should be conducted in clinical populations to investigate the relationships between interoception, mindfulness, and anxiety.

Introduction

Like Zumba, P90X, and juice cleanses of the past, yoga and meditation are the new health fads taking over gyms, homes and social media. Could these popular practices have unintended consequences? On and off the mat, mind-body practices aimed at bringing awareness to the sensations within the body are becoming increasingly popular. These practices, often in the form of meditation, allow people to be in tune with their thoughts and feelings, with the ultimate goal of reducing stress, achieving mental clarity, and increasing overall well-being. Mindfulness-based therapy is often used to treat depression and anxiety and has been found to be moderately effective in the overall population and extremely effective among those who have anxiety and mood disorders (Hoffman et al., 2010). Even among non-clinical samples, mindfulness-based cognitive therapy helped participants deal with their anxiety and depressive feelings (Kaviani et al., 2011). Even so, therapies that increase bodily awareness can potentially be maladaptive by increasing self-focused attention, which has been associated with negative emotion in clinical and non-clinical samples (Harvey et al., 2004; Mor & Winquist, 2002). Without the accepting, nonjudging, and nonreactive qualities of mindfulness, heightened awareness of bodily sensations may result in emotion dysregulation.

Emotion Regulation

Effective emotion regulation involves an adaptive, appropriate emotional response to internal and external signals (Blair & Raver, 2012). In the situation that a challenging sensation elicits a behavioral or physiological response, one must appropriately interpret the sensations in order to influence the emotional response (Price & Hooven, 2018). On the other end of the spectrum, emotion dysregulation involves an emotional response that is inappropriate or out of

proportion, causing intense emotion that is problematic to well-being. Dysregulated emotion can be characteristic of anxiety, depression, and PTSD (Price & Hooven, 2018). Studies have found that the detection and interpretation of these internal signals, whether emotional or physical, involve interoception, suggesting that interoception is central to emotion experience and regulation (Terasawa et al., 2012).

Interoceptive Awareness and Emotion Regulation

Interoception is the perception of physical and emotional sensations within the body, such as hunger, respiration, and pain (Vaitl, 1996). Though most of these perceptions remain unconscious, interoceptive awareness refers to the sensations that become conscious and accessible (Cameron, 2001). Interoceptive awareness is operationalized and conceptualized in different components, including interoceptive accuracy and interoceptive sensibility.

Interoceptive accuracy refers to the objective ability to detect signals within the body, such as heartbeats (Garfinkel et al., 2015). On the other hand, interoceptive sensibility refers to the subjective experience of interoceptive signals, gathered by self-reports that include statements such as “When I am tense I notice where the tension is located in my body” (Mehling et al, 2012).

The literature on the correlation between interoceptive awareness and emotion regulation is conflicting, often differing based on the measure used for interoceptive awareness or the disorder tested. In some studies, lack of interoceptive accuracy is linked to emotion disorders such as depression (Furman et al., 2013). Fustos and colleagues (2012) found that interoceptive awareness facilitates cognitive reappraisal, a technique effective in combating anxiety (Hoffman et al, 2009). Low interoceptive awareness is also often associated with various eating disorders. Lack of interoceptive awareness is a strong predictor for eating disorders in adolescent girls

(Leon et al., 1993) and correlated with increased negative self-objectification (Ainley & Tsakris, 2013). In situations where lack of interoceptive awareness is correlated with harmful behavior, it is possible that the signals coming from the body are fuzzy and inaccurate.

Though previous studies have shown that poor interoceptive awareness is linked with certain emotional disorders, some studies show that higher interoceptive awareness is correlated with emotion dysregulation that can present in the form of panic and anxiety disorder. In general, interoceptive awareness is positively associated with more intense processing of emotionally arousing stimuli (Herbert, Pollatos, & Schandry, 2007; Pollatos, Kirsch, & Schandry, 2005b). Emotion regulation depends on the proper emotional response to internal stimuli. Experiencing emotion at a greater intensity can negatively impact well-being and be related to panic attacks, anxiety attacks, and other negative mood experiences.

Data have shown that interoceptive awareness may be altered in anxiety disorders. For example, heightened awareness of bodily arousal combined with misattributions of the source of arousal could contribute to the maintenance of panic disorder and social phobia (Clark, 1986; Clark & Wells, 1995). Studies found that patients with panic disorder have also shown significantly more accurate heartbeat perception than the rest of the population (Ehlers & Breuer, 1992). This correlation held true in those with panic disorder with agoraphobia as well (Ehlers, Breuer, Dohn, & Fiegenbaum, 1995). Furthermore, in a longitudinal study in patients with panic disorder, infrequent panickers, and patients with simple phobias, heightened interoceptive accuracy was found to be predictive of poor treatment outcome and recurrence of panic attacks (Ehlers, 1995). Finally, van der Does, van Dyck, and Spinhoven (1997) found that patients with panic disorder had better interoceptive accuracy than patients with depression or healthy

subjects. There was an additional correlation between accurate heartrate perception and higher scores on negative affectivity.

Heightened interoceptive awareness has also been found to increase anxiety sensitivity, state anxiety and trait anxiety. Anxiety sensitivity refers to beliefs about the dangerousness of anxiety symptoms and the resulting fear of these symptoms. It has been found that non-clinical high- anxiety sensitivity subjects were better than low-anxiety sensitivity subjects at heartbeat perception (Sturges & Geotsch, 1996). State anxiety refers to the momentary unpleasant emotional arousal when faced with threatening stimuli. Good heartbeat perceivers were revealed to have higher state anxiety than bad heartbeat perceivers (Schandry, 1981; Ludwick-Rosenthal & Neufeld, 1985). Trait anxiety refers to the relatively stable individual proneness to anxiety symptoms. Most literature has found that increased interoceptive awareness does not correlate with trait anxiety, as it does with state anxiety and anxiety sensitivity. Some studies found no relationship between trait anxiety and interoceptive accuracy (Stephoe & Vogeles, 1992), while other studies found a negative relationship (DePascalis et al., 1984; Richards & Bertram, 2000). It is possible that a heightened awareness of bodily sensations temporarily increases anxiety, measured in higher state anxiety, but does not affect an individual's overall state anxiety. Interoceptive accuracy was found to mediate the relationship between emotional arousal and trait anxiety (Pollatos, et al., 2007). When shown unpleasant pictures, participants' trait anxiety was positively correlated with interoceptive awareness, as well as emotional arousal scores. To explain these varying correlations between interoceptive awareness and emotional regulation, we look to mindfulness as a potential mediator.

Mindfulness and Self-Focused Attention

Mindfulness is the practice of focusing on the present moment and accepting any thoughts and sensations that arise. Mindfulness meditation is an increasingly popular trend and mindfulness interventions have been found to be effective for combatting depression and anxiety (Hoffman et al., 2010). The relationship between mindfulness and emotion regulation is complex. Watkins and Teasdale (2004) found that mindful self-awareness can be adaptive and beneficial, while ruminative self-awareness is not. Simply increasing interoceptive awareness may not be enough to tackle issues of emotion regulation. Research has found that self-focused attention can indeed be maladaptive (Ingram, 1990). Self-focused attention has been associated with negative emotion in clinical and nonclinical samples (Mor & Winquist, 2002). Comprehensive mindfulness training can counteract the maladaptive aspect of increased interoceptive awareness by teaching participants to observe their internal stimuli with an accepting, nonjudging, and nonreactive stance. Mindfulness and interoceptive awareness interventions include close observation of internal sensations but should teach participants to acknowledge their sensations, even if unpleasant, in an appropriate way. It is possible that higher levels of mindfulness are required to benefit from heightened interoceptive awareness.

The Present Study

In order to better understand the mechanism and processes by which interoceptive awareness contributes to emotion regulation, the present study examined the relationship between interoceptive accuracy, interoceptive sensibility, mindfulness, and anxiety in undergraduates. Specifically, it was predicted that mindfulness will mediate the relationship between interoception and trait anxiety. The following hypotheses were tested: (1) the heartbeat perception task (IAC) will not significantly correlate with interoceptive sensibility; (2) mindfulness will mediate the effect of interoceptive sensibility on anxiety such that interoceptive

sensibility will predict higher anxiety at low levels of mindfulness while IS will predict low anxiety at high levels of mindfulness; (3) mindfulness will mediate the effect of IAc on anxiety such that IAc will predict higher anxiety at low levels of mindfulness while IAc will predict low anxiety at high levels of mindfulness.

Method

Study

The analysis in this manuscript are part of a larger parent study addressing the relationship among interoception, emotion regulation, and psychological outcomes.

Participants

A total of 94 participants were recruited from the Duke Undergraduate Subject Pool, which consists of students enrolled in introductory psychology courses. The sample was 65% female and 35% male. Participants were 56% Caucasian, 19% Asian, 16% African American, 6% Hispanic American, 1% American Indian, 2% other. Participants received course credit for participating in the 1-hour study visit.

Procedure

All procedures were approved by the Duke University Institutional Review Board. Participants were tested in the laboratory within the Cognitive Behavioral Research and Treatment Program at Duke University. After arriving at the lab, participants were first given a consent form detailing the minimal risks, confidentiality, and the option to leave the study at any point. After consenting, a copy of this consent form was given to the participant. The participant first completed a Qualtrics survey that included a number of self-report measures. Here we report

on interoceptive accuracy, interoceptive sensibility, mindfulness, and anxiety. The Qualtrics survey concluded with a demographics questionnaire. Finally, participants then completed a heartbeat perception task and time estimation, described in detail below. At the end of the study, participants were offered a debriefing sheet explaining the study in further detail.

Measures

Interoceptive accuracy (IAc). IAc was measured using a heartbeat perception task (HPT).

Participants were asked to sit in a soundproof room and try to feel their heartbeats without taking their pulse. Participants wrote down their counted heartbeats after three separate time intervals lasting 35 seconds, 25 seconds, and 45 seconds. These time intervals were chosen based on the Mental Tracking method (Schandry, 1981). The participants were not told how long each interval lasted. Instead, they heard a 100ms, 800Hz warning tone followed by a three second pause, and then a 50ms, 1000Hz tone indicating the start of the interval. After the designated amount of time, a 50ms, 1000Hz stop tone indicated to the participants the end of the time interval in which they stopped counting and reported a number. After the time estimation task mentioned below, participants did another trial of each of the three time intervals.

During this period, heart rate was recording using a BIOPAC MP150 unit and an ECG, connected to a PC running Acqknowledge 4.1 (BIOPAC, 1997). Midway through the study, the software was updated to Acqknowledge 5.0. ECG electrodes were placed on each participant's right wrist and left ankle.

Time Estimation Task. Individuals who are better at estimating lengths of time that have passed may be able to calculate the number of heartbeats that occurred using their known resting heart

rate, rather than reporting the number of heartbeats that they actually felt. To control for participants' time estimation accuracy when assessing their IAc, we included a time estimation task (Dunn et al., 2010). Participants were asked to estimate the number of seconds that passed during three time intervals, lasting 23 seconds, 56 seconds, and 40 seconds. The participants heard the same warning, start, and stop tones used in the HPT. Time estimation accuracy was calculated by subtracting the estimated number of seconds from the actual total number of seconds, dividing by the actual value ($1 - \frac{|\text{actual} - \text{estimated}|}{\text{actual}}$), averaged across the three trials. We also included a question asking participants whether they knew their resting heart rate.

Interoceptive sensibility (IS). IS is defined as an individual's subjective belief in their ability to detect interoceptive signals (Garfinkel, 2014). In the present study, IS was measured using the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012), which included eight subscales of different factors of interoceptive awareness: 1) Noticing (being aware of body sensations of discomfort, comfort and neutrality); 2) Not Distracting (being inclined to not distract or ignore painful or uncomfortable sensations); 3) Not Worrying (inclination to not worry or be emotionally distressed by painful or uncomfortable sensations); 4) Attention Regulation (paying attention to and controlling attention on body sensations); 5) Emotional Awareness (being aware of the connection between emotions and body sensations); 6) Self-Regulation (regulating distress through paying attention to body sensations); 7) Body Listening (purposefully listening for insight from the body), and 8) Trusting (experiencing trust with and safety in the body). The primary subscale of interest in this study was the Noticing subscale. Participants were asked to rate the extent to which they relate to each statement which directly correlated with a specific dimension of interoceptive awareness using a 6-point scale (0 = never,

5 = always). The average score for each factor was calculated by adding the score or reverse-score of each question and dividing by the number of questions. Higher scores indicate higher levels of interoceptive awareness. The MAIA subscales have an internal consistency of $\alpha = 0.66$ – 0.82 , and the Noticing subscale specifically has an internal consistency of $\alpha = .69$ (Mehling et al., 2012).

Mindfulness. Mindfulness was measured using the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al. 2006). The FFMQ is a 39-item, self-report measure that asks participants to rate items on a 5-point Likert-type scale (1 = never or very rarely true, 5 = very often or always true). The five facets measured are: Observing (the tendency to notice or attend to internal and external experiences), Describing (labeling internal experiences with words), Acting with awareness (the tendency to focus on one's activity in the moment), Nonjudging (a nonevaluative stance toward inner experiences), and Nonreactivity (the tendency to allow thoughts and feelings to come and go). The present study will omit the Observing facet score when calculating the total FFMQ score because Observing has only been found to correlate with overall mindfulness in populations of experienced mindfulness practitioners (Baer et al., 2008). Higher total FFMQ scores indicate higher trait mindfulness. The FFMQ has high internal consistency of $\alpha = 0.77$ – 0.93 (Williams et al., 2014).

Anxiety. Anxiety was measured using the Beck Anxiety Inventory (BAI; Beck et al., 1988), a self-report inventory of 21 items describing the somatic symptoms of anxiety (e.g., numbness or tingling, feeling of choking). Individuals are asked to assess the amount of distress caused by these symptoms over the previous 7 days on a 4-point Likert-type scale (0 = not at all to 3 =

severely.) The score ranges from 0 to 63, with higher scores indicating higher trait anxiety. Scores of 0 to 7 indicate minimal anxiety, 8 to 15 mild anxiety, 16 to 25 moderate anxiety, and 30 to 63 severe anxiety. The BAI has a high internal consistency of $\alpha = 0.92$ (Beck et al., 1988).

Potential Covariates Tested

Physical Activity. Physical activity was measured using the Physical Activity Global Physical Activity Questionnaire (GPAQ). The GPAQ is a 16-item measure that assesses moderate and vigorous physical activity in three settings: work, leisure, and transportation (e.g. getting to or from work via walking or biking) (Armstrong & Bull, 2006). Questions on the GPAQ ask how much time individuals spend engaging in moderate and/or vigorous activity across these three settings on a weekly basis. Participants' scores are reported in Metabolic Equivalent (METs). One MET is the ratio of a person's working metabolic rate relative to the resting metabolic rate. Guidelines for scoring the GPAQ can be found in the GPAQ Analysis Guide (Organization, 2012). The GPAQ has been shown to correlate with accelerometry-derived estimates of physical activity (although respondents tend to overestimate their daily activity) and has moderate test-retest reliability (Chu, Ng, Koh, & Muller-Riemenschneider, 2015).

Heart Rate. Participants' heart rate was calculated by taking their average heart rate from the ECG recording during the six time intervals of the HPT.

Heart Rate Knowledge. Participants were asked to rate Yes/No whether they knew their resting heartrate.

Body Mass Index (BMI) and Gender. Weight and height were measured via self-report.

Participants' BMI was calculated using the following formula $703 \times \text{weight (lbs)} / [\text{height (in)}]^2$.

Gender was assessed via self-report.

Analysis and Descriptive Statistics

Analyses were conducted using SPSS Version 24.0 (Cor, 2016).

Calculating Variables

Participants' performance in the HPT was calculated as a relative error score by taking the absolute difference between the actual number of recorded heartbeats and the number of estimated heartbeats. Next, consistent with standard practice (Cali et al., 2015), heartbeat perception accuracy was computed using the following formula :

$$\left\{ \frac{1}{6} \sum \left[1 - \left(\frac{|\text{EKG recorded heartbeats} - \text{participant counted heartbeats}|}{\text{EKG recorded heartbeats}} \right) \right] \right\}$$

IAC scores range from 0-1, with higher scores indicating better heartbeat perception.

Covariates

We evaluated BMI, gender, physical activity, heart rate, time estimation ability, and knowledge of resting heart rate as potential covariates for HPT performance by examining the bivariate correlation between each variable and HPT performance for significance. Variables that were significantly correlated with HPT performance were included in prediction models using HPT performance.

Assessing Validity of the HPT

Ehlers (1998) suggests evaluating the number of participants who show poor performance on the HPT, defined as accuracy rates of $<.3$ or less, as a means of evaluating validity. None of the participants in our sample performed below $.3$. We conducted two blocks of three trials of the HPT. A single paired t-test revealed there were no significant differences in participants' performance between the two blocks, and thus we took an average of performance on all six blocks to calculate a final HPT accuracy score.

Regressions

Four participants were excluded from analysis due to inaccurate self-report completion. All variables were mean centered before being entered into the regression analyses.

Results

Table 1 shows the means scores of all measures.

Table 1. Descriptives of Predictor and Outcome Variables

	Min	Max	Mean	SD
Heart Rate	48	109.67	71.79	12.58
IAC (HPT)	0.3	0.98	0.7	0.17
Time Estimation	0.38	0.99	0.76	0.12
Anxiety (BAI total)	0	36	10.95	7.391

IS (MAIA Noticing avg)	0.5	5	3.02	0.87
Mindfulness (FFMQ total-obs)	27	84	61.33	10.74
Confidence	1.33	8.83	4.04	1.85

Note: N = 94.

Hypothesis 1

It was hypothesized that the heartbeat perception task would not correlate significantly with the Noticing factor of the MAIA during the heartbeat perception task. The hypothesis was supported, $r = -.07$, $p = .52$. The heartbeat perception task is an operationalization of interoceptive accuracy, while Noticing is measuring interoceptive sensibility. A nonsignificant correlation between these two measures supports previous studies that have found that interoceptive accuracy and interoceptive sensibility are different traits and should be regarded separately. Therefore, the following analyses investigate both Noticing and heartbeat perception when operationalizing interoceptive awareness.

Hypothesis 2

It was hypothesized that mindfulness would moderate the effect of Noticing on anxiety such that Noticing would predict higher anxiety at low levels of mindfulness while Noticing would predict low anxiety at high levels of mindfulness.

Regression Diagnostics

All variables were examined for outliers. Outliers were defined as being greater than 2.5 standard deviations above or below the mean. Mean and standard deviation values can be found in **Table 1**. One participant had an outlier score on the BAI, one participant had an outlier time estimation score, and two participants had outlier average heart rates. Excluding these participants from the regressions did not change the significance of results, and so these

participants were included in the analyses reported here. Review of skewness and kurtosis for all variables suggested normality was a reasonable assumption (all values between -2 and 2).

Regression results

Table 2. Regression including Mindfulness, IS, and IS x Mindfulness interaction predicting Anxiety

	β	t	Sig.
(Constant)		15.76	<.001
Mindfulness (FFMQ total - obs)	-0.57**	-5.61	<.001
Interoceptive Sensibility (Noticing)	0.18	1.75	0.08
Interoceptive Sensibility x Mindfulness	-0.08	-0.91	0.37

Note: **. Prediction is significant at the 0.001 level.

Multiple linear regression was used to examine the effects of mindfulness and noticing on anxiety. The results are shown in **Table 2**. The overall model including Noticing, mindfulness and their interaction term Noticing x Mindfulness is significant, $F(3, 87) = 11.46, p < .001$, accounting for 25.9% of the variance in anxiety scores. The main effect of mindfulness was significant, $\beta = -.57, t = -5.61, p < .001$. There was a nonsignificant trend for a main effect of Noticing to predict anxiety, $\beta = .18, t = 1.75, p = .08$. Contrary to hypothesis 2, the interaction effect of Noticing x Mindfulness on anxiety was not significant, $\beta = -.08, t = -.91, p = .37$.

Hypothesis 3

It was hypothesized that mindfulness would moderate the effect of heartbeat perception on anxiety such that heartbeat perception would predict higher anxiety at low levels of mindfulness while heartbeat perception would predict low anxiety at high levels of mindfulness. This is identical to hypothesis 2, but replacing the interoceptive sensibility variable (Noticing) with interoceptive accuracy (heartbeat perception).

Covariate Analysis for Heartbeat Perception

BMI, gender, physical activity, heart rate, time estimation, and knowledge of resting heart rate were assessed as potential covariates with performance on the HPT. Independent samples t-tests revealed no significant differences in heartbeat perception based on gender, $t(91) = .499, p = .619$, or knowledge of resting heart rate, $t(92) = -.484, p = .629$. Correlations for the remaining continuous variables were used to select covariates for inclusion in regression analysis. One participant had an invalid physical activity score and thus was removed from this analysis. Outliers over 2.5 standard deviations above or below the mean were excluded from correlation analyses containing said variables.

Table 3 reports the correlations of heartbeat perception with each covariate. Average heart rate ($r = -.378, p < .001$) and time estimation ($r = .246, p = .017$) were significantly correlated with HPT performance, and thus included as covariates in subsequent regression analysis. Because BMI and physical activity were not included as covariates, participants with outlier scores on these scales were not excluded from the later regression analysis.

Table 3. HPT and Covariate Correlations

		HR	Time Estimation	HPT	METs	BMI
HR	Pearson Correlation	-				
	Sig. (2-tailed)	-				
	N	-				
Time Estimation	Pearson Correlation	-0.038	-			
	Sig. (2-tailed)	0.72	-			
	N	91	-			
HPT	Pearson Correlation	-.378**	.246*	-		
	Sig. (2-tailed)	0	0.017	-		
	N	92	93	-		
Physical Activity (METs)	Pearson Correlation	-.235*	-0.067	0.001	-	
	Sig. (2-tailed)	0.027	0.533	0.993	-	
	N	88	89	90	-	
BMI	Pearson Correlation	0.074	0.047	-0.125	0.106	-
	Sig. (2-tailed)	0.494	0.661	0.243	0.332	-
	N	88	88	89	85	-

Note: *. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). Note: Scores 2.5 standard deviations above or below the mean were excluded from relevant analyses. This excluded 5 participants based on BMI, 3 for physical activity, 1 for time estimation, and 2 for average heart rate. One individual had an invalid Physical Activity Score and was not included in the correlational analysis involving physical activity.

Regression Results

Table 4. Regression including Mindfulness, IAc, and IAc x Mindfulness interaction predicting Anxiety

	β	t	Sig.
(Constant)		16.35	<.001
Time Estimation	0.13	1.34	0.18
Heartrate	0.12	1.23	0.22
Interoceptive Accuracy (HPT)	0.01	0.04	0.97
Mindfulness (FFMQ total-obs)	-0.48**	-5.18	<.001
Interoceptive Accuracy x Mindfulness	-0.02	-0.92	0.36

Note: **. Prediction is significant at the 0.001 level.

Multiple linear regression was used to examine the effects of mindfulness and heartbeat perception on anxiety. The results are shown in **Table 4**. The overall model including heartbeat perception, mindfulness and the heartbeat perception x mindfulness interaction was significant, $F(5, 85) = 6.944, p < .001$, accounting for 24.8% of the variance in anxiety scores. The main effect of mindfulness was significant, $\beta = -.48, t = -5.18, p < .001$. In contrast to hypothesis 3, the interaction effect of IAc x mindfulness on anxiety was not significant, $\beta = -.02, t = -.92, p = .36$.

Discussion

This study investigated the relationships between interoceptive sensibility, interoceptive accuracy, mindfulness, and anxiety. As predicted in hypothesis 1, we did not find a significant correlation between IAc and IS. This is consistent with previous literature (Forkmann et al.,

2016). This finding suggests that interoception is a multidimensional construct, and IAc and IS should be considered as separate measures, especially when studying emotion regulation.

Contrary to hypotheses 2 and 3, the interaction of mindfulness and IS did not predict anxiety, and neither did the interaction of mindfulness and IAc.

In both regression models, the interaction variable did not significantly predict anxiety. In a linear regression model with mindfulness and IS, the interaction variable mindfulness x IS did not significantly predict anxiety. The relationship was negative and in the hypothesized direction, meaning those who are both high in mindfulness and IS had lower anxiety, but the relationship did not meet criteria for statistical significance ($p = .08$). In a linear regression model with mindfulness and IAc, the interaction variable mindfulness x IAc did not significantly predict anxiety. These findings suggest that mindfulness does not mediate the relationship between interoception and anxiety, and it is not necessarily harmful to have varying levels of mindfulness and interoception (i.e high levels of mindfulness and low levels of interoception, vice versa). If these findings are replicated and high levels of mindfulness are not needed to regulate interoception, those practicing various meditations and well-being practices do not need to be concerned about increasing interoception without simultaneously increasing mindfulness. If there are indeed adverse effects on anxiety due to increased interoception, mindfulness may not be the vehicle to account for these effects.

Time estimation and resting heart rate were found to be significant covariates of HPT. Participants who are able to accurately estimate time intervals may be using their knowledge of their resting heart rate to calculate an estimation of their heart beats during the task. Though this is a theory of the relationship between time estimation and HPT, our current study did not find knowledge of resting heart rate as a significant predictor of HPT. In addition, some previous

literature has not found time estimation to correlate with HPT (Knoll & Hodapp, 1992). Further exploration should be completed on the relationship between time estimation and HPT. Another covariate, resting heart rate, negatively correlated with HPT, suggesting that those with higher heart rates may have a harder time keeping track of their heartbeats, and may end result in less accurate HPT scores. There was an insignificant correlation between resting heart rate and anxiety, meaning that anxiety is not driving the correlation between heart rate and HPT. Time estimation and resting HR were included as covariates in the regression model with HPT.

In both regression models, mindfulness was found to negatively predict anxiety, meaning that participants with higher mindfulness had lower anxiety, supporting prior research (Hoffman et al., 2010). This relationship held regardless of interoception levels. In addition, Noticing (IS) positively predicted anxiety and was trending towards significance. Those who believe they have a heightened ability to detect interoceptive signals in their body may be more susceptible to feelings of anxiety. IS was not correlated with IAc, meaning that participants may not necessarily have a high ability to perceive interoceptive signals even if they believe they do. If increased IS is indeed correlated with increased anxiety, it may be possible that participants are perceiving signals within their body inaccurately, creating issues in emotion regulation. On the other hand, IAc did not have a strong relationship with anxiety, further emphasizing the need to consider IS and IAc as separate components of interoception.

A number of limitations should be considered and addressed in future studies. First, our sample comprised of healthy undergraduates and the results cannot be generalized to other populations, including clinical populations. This study should be followed up in populations with clinical anxiety in order to see if the reactions between mindfulness, interoception, and anxiety are different at clinical levels. Additionally, the Noticing subscale of the MAIA used to

operationalize IS only includes 4 questions. Having few questions decreases the reliability of the measure, and future studies should consider different measures of IS. Finally, the self-report questionnaires did not include an attention check, which would have helped ensure that participants took the proper time to answer questions in the self-report form.

Conclusion

As predicted in hypothesis 1, interoceptive sensibility and interoceptive accuracy were not correlated in the present study, supporting the idea that interoception should be considered as a multidimensional trait. Contrary to hypotheses 2 and 3, mindfulness was not found to be a mediator between interoception and anxiety. Future studies should further investigate these relationships in a clinical sample and explore different measures of IS and IAc.

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