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Interoception and Boredom Proneness: A Novel Finding and a Call for Research[1]

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Abstract: Boredom proneness has been previously shown to be associated with higher levels of alexithymia, the inability to accurately label and represent one's affective states. One prominent model of affective regulation suggests that we make use of interoceptive signals to predict the affective outcomes of intended actions. Given recent neuroimaging work implicating the anterior insular cortex in boredom, a region known to be critical for interoceptive processing, we explored the relations between alexithymia, interoception, and boredom proneness. Results showed strong relations with boredom proneness and attention to interoceptive signals. There were hints that the highly boredom prone also struggle to make sense of those interoceptive signals, however these were not prominent predictors of boredom proneness in regressions. We discuss the results and potential future experiments to explore the relation between boredom proneness and interoceptive processing.

Keywords: Boredom, Interoception, Affective regulation, Alexithymia, Predictive coding.

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1. Introduction

For most, boredom may seem trivial, yet over half a century of research has consistently revealed consequential facets to the experience. Behaviourally characterized by a lack of engagement that is negatively valenced and felt as unpleasant (Goldberg et al., 2011; Van Tilburg and Igou, 2011), boredom is often associated with feelings of agitation and restlessness (Danckert et al., 2018). It is also linked to attentional difficulties in daily life (e.g., lapses in attention such as pouring orange juice on your cereal; Carriere et al., 2008; Cheyne et al., 2006) and when performing tasks in the lab (Hunter and Eastwood, 2018; Malkovsky et al., 2012). Rampant in academic settings and monotonous workplaces, it impairs learning and vigilance (Pattyn et al., 2008; Tze et al., 2016). Finally, boredom proneness – the tendency to experience the state more frequently and intensely, has been consistently associated with negative mental well-being (e.g., higher rates of depression and anxiety; Goldberg et al., 2011). In short, boredom and boredom proneness have consequences both for cognitive control (i.e., poor attention), mental well-being (e.g., higher rates of depression), and potentially maladaptive responding (e.g., problem gambling).

1.1. Boredom and the Insula

Previous neuroimaging work has implicated the default mode network and anterior insular in supporting the state of boredom (Dal Mas and Wittman, 2017; Danckert and Merrifield, 2018; Ulrich et al., 2014; Wang et al., 2021). That is, midline regions of the default mode network including the medial prefrontal cortex, posterior cingulate and precuneus, are consistently activated when people are bored (Danckert and Merrifield, 2018; Ulrich et al., 2014). The posterior midline regions of this network also show diminished grey matter volume in those highly prone to boredom (Wang et al., 2021). Finally, the anterior insular cortex likely plays a key role in the experience of boredom, downregulated when bored (Danckert and Merrifield, 2018) and upregulated when seeking remedies to boredom (Dal Mas and Wittman, 2017; see Drody et al., 2024, for a review of the neuroimaging literature).

The insular cortex forms part of what is known as the salience network – a system that detects behaviourally relevant stimuli in the environment and uses this information to coordinate appropriate responses (Menon and Uddin, 2010). The findings discussed above suggest that when bored, the brain does not only activate the default mode – a network typically associated with off-task thinking or internal thought processes (Buckner et al., 2008), but rather shows signs of attempting (i.e., salience searching) but failing to engage with the environment.

The insular cortex is also critical for interoceptive processing – how the brain perceives internal physiological signals and integrates them with emotional, cognitive, and motivational cues (Craig, 2009). In other words, the insular cortex is involved in representing the physiological perceptions or sensations that are tied to subjective feelings (Namkung et al., 2018). Everyday examples of interoceptive sensations include hunger pangs, thirst, urges to use the bathroom, butterflies in the stomach or a racing heart. One prominent model of insular cortex functioning suggests that the posterior-to-anterior axis represents interoceptive signals in increasingly complex ways, with the anterior insular forming a representation of one's current conscious state (Craig, 2009). Menon and Uddin (2010) depict the anterior insula as a dynamic mediator of interactions between brain networks involved in externally and internally oriented attention to ultimately guide behaviour. Both models of the insular cortex are relevant for boredom, a self-focussed, in-the-moment feeling state (Eastwood et al., 2012) which functions to guide exploratory behaviour (Danckert and Elpidorou, 2023; Elpidorou, 2014;).

1.2. Boredom Proneness and Alexithymia

The insular cortex also plays a role in affective regulation (Craig, 2009; Gu et al., 2013). One recent model of affective regulation suggests that one makes use of interoceptive signals to anticipate the affective outcomes of intended actions (Barrett and Simmons, 2015). This fits well with the notion that the insula integrates external and internal signals in the service of goal-oriented behaviour (Uddin et al., 2015). Intriguingly, recent accounts of boredom proneness suggest that the trait can in part be characterized by a high degree of self-directed attention, coupled with low self-knowledge (Bambrah et al., 2023). In addition, boredom proneness has been associated with high levels of alexithymia—the inability to accurately label one's emotions (Eastwood et al., 2007). In other words, people who get bored easily have a harder time making sense of their emotions.

If the highly boredom prone struggle to make sense of their emotions, this may be reflected in poor use of interoceptive signals, those signals that play a critical role in affective regulation (Barrett and Simmons, 2015). Hogeveen and colleagues (2016) examined the consequences of damage to the insular cortex for the capacity to make sense of one's emotions. Their results showed that levels of alexithymia were highest in patients with substantial insular damage (i.e., 15% or more of the anterior insula damaged [Hogeveen et al., 2016]). As such, the insular cortex is likely critical for accurate representation of affective states. Failure to represent interoceptive signals may in part explain the struggle those high in boredom proneness experience in launching into actions to resolve their boredom (Mugon et al., 2018). That is, if interoceptive signals are not merely important for *representing* affective states, but also for *predicting the affective outcomes of action choices* (Barrett and Simmons, 2015), any failure to represent those signals accurately will compound the challenge of choosing an engaging activity to launch into.

1.3. Research Objectives

Here, we explored for the first time the relation between boredom proneness and interoceptive awareness and accuracy. Given prior work showing that the boredom prone are highly self-focussed but exhibit poor self-knowledge (Bambrah et al., 2023), we predicted that participants who report high levels of boredom proneness would report a higher level of awareness of interoceptive signals (i.e., high self-focus), coupled with difficulty in making sense of those signals (i.e., poor interoceptive accuracy). The latter would also be associated with higher levels of alexithymia.

1.4. Measuring Boredom Proneness

We acknowledge that the boredom proneness scale (either the shortened version employed here or the original, longer version) are not without controversy (Gana et al., 2019; Gorelik and Eastwood, 2024). The scale does not capture all the variance inherent to the trait of boredom proneness, with some suggesting that it is a better measure of how people cope or respond to the experience (Gana et al., 2019). Nevertheless, we chose to use the current version for several reasons. First, much of the controversy regarding the original scale (Farmer and Sundberg, 1986) concerns the inconsistent factor structure of the scale. As such, the shortened version, with no reverse-worded items, has been shown to have a reliable single factor structure (Struk et al., 2017). Second, this shortened version has rapidly become one of the most used metrics of trait boredom proneness (cited more than 300 times since publication in 2017). Finally, given that we were asking participants to complete a relatively large number of scales we wanted to be sure to avoid response fatigue (Meier et al., 2024). Taken together, these pragmatic justifications made the use of the shortened boredom proneness scale seem like the optimal choice to us.

1.5. Measuring Interoception

Garfinkel and colleagues (2015) proposed a tripartite model of interoceptive ability comprising three distinct and dissociable dimensions: 1) interoceptive accuracy, which relates to one's performance on objective behavioural tests such as heartbeat detection tasks; 2) interoceptive sensibility, which is the self-evaluated appraisal of subjective interoception using questionnaires; and 3) interoceptive awareness, which relates to the metacognitive awareness of interoceptive accuracy (i.e., how confident one's feels towards accurately perceiving one's own bodily sensations). Per these distinctions, a self-report instrument that purports to probe interoceptive accuracy may actually be measuring interoceptive sensibility or awareness. Given the fact that the current work was exploratory we chose to use a broad swathe of metrics to encompass several possible dimensions of interoception.

2. Method

2.1. Participants

Participants were adults recruited through the online crowdsourcing platform Mechanical Turk. Responders who completed the surveys in under five minutes (1 SD from the mean) were removed (n=55), as were any respondents with duplicate IP addresses (n=41), abandoned surveys (n=8) and univariate outliers (n=2). After exclusions, the final sample consisted of 226 participants (112*F*, M_{age}=38.65, SD_{age}=11.02).

2.2. Measures

A total of eight surveys were administered. One scale measured boredom proneness and two scales sought to replicate its known relationship with alexithymia (Eastwood et al., 2007) and self-control (Isacescu and Danckert, 2018; Struk et al., 2017). Given that this was an exploratory study we chose to include a wide range of scales to examine potential relations between boredom proneness and interoceptive processing.

2.2.1. Shortened Boredom Proneness Scale (BPS-SF)

The eight-item Short Boredom Proneness Scale (BPS-SF; Struk et al., 2017) measured boredom proneness—i.e., the propensity for an individual to desire, but fail, to engage in satisfying activity (α = .91). This scale was developed as a shorter, single-factor version of Farmer and Sundberg's Boredom Proneness Scale (1986). Participants rated items such as 'I don't feel motivated by most things that I do' using a 5-point scale (1=*strongly disagree* to 5=*strongly agree*), with a higher total score indicating greater boredom proneness.

2.2.2. Toronto Alexithymia Scale (TAS-20)

The 20-item Toronto Alexithymia Scale-20 (TAS-20; Bagby et al., 1994) measured the difficulty identifying and describing feelings (α = .86). Participants rated items such as 'I have feelings that I can't quite identify' using a 5-point scale (1=*strongly disagree* to 5=*strongly agree*), with a higher total score indicating greater difficulties with identifying and describing one's feelings.

2.2.3. Brief Self-Control Scale (BSCS)

The 13-item Brief Self-Control Scale (BSCS, Tangney et al., 2004) measured behaviours that involve self-control such as restraint and self-discipline (α = .81). Participants rated items such as 'I wish I had more self-discipline' using a 5-point Likert scale (1=*not at all like me* to 5=*very much like me*), with a higher score indicating higher levels of self-control. Negatively phrased items were reverse-scored to maintain scoring consistency.

2.2.4. Body Awareness Questionnaire (BAQ)

The 18-item Body Awareness Questionnaire (BAQ; Shields et al., 1989) measured self-reported attentiveness to body processes such as sensitivity to body cycles and small changes in normal functioning (α = .91). Participants rated items such as 'I notice specific bodily reactions to being over-hungry' using a 7-point scale (1=*not at all true of me* to 7=*very true of me*), with a higher score indicating higher attentiveness to normal body processes.

2.2.5. Interoceptive Accuracy Scale (IAS)

The 21-item Interoceptive Accuracy Scale (IAS; Murphy et al., 2019) measures perceived accuracy of representing internal states (α = .94). Participants rated items such as 'I can always accurately perceive when I am hungry' using a 5-point scale (1=*strongly disagree* to 5=*strongly agree*), with a higher score indicating greater self-reported interoceptive accuracy.

2.2.6. Multidimensional Assessment of Interoceptive Awareness (MAIA-2)

The 37-item Multidimensional Assessment of Interoceptive Awareness (MAIA-2; Mehling et al., 2018) comprises 8 subscales to evaluate various dimensions of interoception (α = .85). Examples of dimensions measured include noticing bodily signals ('I notice changes in my breathing, such as whether it slows down or speeds up'), worrying about interoceptive cues ('I start to worry that something is wrong if I feel any discomfort'), and the ability to regulate distress by focusing attention on bodily sensations ('When I am caught up in thoughts, I can calm my mind by focusing on my body/breathing'). Participants used a 5-point scale to rate how frequently each statement occurs in their daily life (0=*never* and 5=*always*). Higher scores indicate a greater ability to notice and process bodily sensations. Nine items were reverse-scored to maintain scoring consistency. Item 29 was missing from the survey in this sample due to an input error on our part. We used the scores from the 28 remaining items and although this meant the scale was not deployed as intended, results demonstrated that it did not correlate with boredom proneness and is unlikely to do so with the addition of the final item.

2.2.7. Self-Awareness Questionnaire (SAQ)

The 28-item Self-Awareness Questionnaire (SAQ; Longarzo et al., 2015) measured interoceptive awareness for commonly felt bodily sensations (α = .98). In contrast to the Interoceptive

Accuracy Scale, this scale asks direct questions about immediate experience (e.g., 'I feel sudden thirst pangs'), whereas the Interoceptive Accuracy Scale asks what could be considered prospective questions (i.e., *anticipating* accuracy of experiences; 'I can always accurately perceive when I am thirsty'). Participants rated how often they experience each statement using a 5-point scale (1=*never*; 2=*sometimes*; 3=*often*; 4=*very often*; 5=*always*), with higher scores indicating higher levels of self-awareness related to bodily sensations.

2.2.8. Interoceptive Sensory Questionnaire (ISQ)

The Interoceptive Sensory Questionnaire (ISQ; Fiene et al., 2018) is a 20-item self-report questionnaire intended to measure interoceptive challenges (i.e., confusion in rating or labelling interoceptive experiences) in autistic adults (α = .98). Participants rated items such as 'Sometimes I don't know how to interpret sensations I feel within my body' using a 7-point Likert scale (1=*not true at all of me*, 7=*very true of me*), with higher scores indicating more difficulty registering or interpreting interoceptive sensations. Three items were reverse-scored to maintain scoring consistency.

3. Results

Table 1 presents the correlation matrix and descriptive statistics of all scales.

Table 1. Correlation Matrix and Descriptive Statistics of the Scales Administered

Variable	*n*	*M*	SD	1	2	3	4	5	6	7	8
1. (BPS-SF) Boredom Proneness	224	23.57	8.07	—							
2. (TAS-20) Alexithymia	213	57.35	12.76	.74*	—						
3. (BSCS) Self-Control	215	41.62	8.63	-.62*	-.60*	—					
4. (BAQ) Body Awareness	216	83.34	18.08	.38*	.24*	.04	—				
5. (IAS) Interoceptive Accuracy	210	76.58	15.74	.24*	-.004	.06	.61*	—			
6. (MAIA-2) Interoceptive Awareness	202	118.76	16.10	.04	-.09	.29*	.56*	.60*	—		
7. (SAQ) Self-Awareness	210	71.02	29.15	.81*	.73*	-.57*	.44*	.25*	.13	—	
8. (ISQ) Interoceptive Sensory	214	74.15	33.14	.75*	.86*	-.57*	.32*	.08	-.00	.76*	—

*$p < .001$.

Results replicated known relationships with boredom proneness. That is, there was a significant, strong positive correlation between boredom proneness and alexithymia, such that those high in boredom proneness also exhibit difficulties in accurately labelling their emotions (Eastwood et al., 2007). Similarly, there was a strong, negative correlation between boredom proneness and self-control, such that those high in boredom proneness tended to exhibit lower levels of self-control (Isacescu et al., 2017).

There was a moderate positive correlation between boredom proneness and bodily awareness indicating that those high in boredom proneness also reported attending to their own body states. This questionnaire is not a direct metric of interoceptive sensations, but a more general measure of how one represents bodily experiences writ large. Contrary to our predictions, boredom proneness also showed a small positive association with interoceptive accuracy. There was no relation between boredom proneness and the Multidimensional Assessment of Interoceptive Awareness Scale.

The strongest correlations with boredom proneness observed in this sample were both positive relations, first with self-awareness (r=0.81) and second with interoceptive confusion (as measured by the Interoceptive Sensory Questionnaire; r=0.75; Table 1). This suggests that those high in boredom proneness also exhibit a strong focus on internal body states but may struggle to make sense of those states.

3.1. Forward Stepwise Regression

First, we conducted a forward stepwise regression to determine which of our interoceptive metrics may best predict boredom proneness. From the null model, this type of regression adds one predictor at a time, starting with the predictor with the largest correlation with the dependant variable. Each predictor must satisfy the criterion for entry. In this model, the criterion was a probability of $F \leq .05$ when testing the significance of the group of variables. With each step, the next independent variable with the largest partial correlation is considered next. The procedure adds and removes predictors until the model is no longer improved. While there are limitations to using stepwise selections to carry out regressions (Olusegun et al., 2015; Smith, 2018), our aim was to obtain a comparator to our subsequent theory-informed hierarchical model. Table 2 presents the forward stepwise regression results for boredom proneness with all seven predictors entered.

The final forward stepwise regression model included five predictors and accounted for a significant amount of variance in boredom proneness, $F(1, 140) = 4.04$, $p < .05$, $R^2 = .73$. The first predictor to be included was self-awareness (SAQ) which accounted for 63% of the variance in boredom proneness. The second step included alexithymia (TAS-20) which explained an additional 7% of variance for this sample. The magnitude of the variance accounted for by the rest of the predictors individually was more modest. Each of the remaining predictors was entered one at a time in the following order: self-control (BSCS), $\Delta R^2 = .01$, p<.01; body awareness (BAQ), $\Delta R^2 = .02$, p<.01; and interoceptive confusion (ISQ); $\Delta R^2 = .01$, p<.05. Together these variables explained an additional 4% of variance in boredom proneness. Notably, interoceptive awareness (MAIA-2) and interoceptive accuracy (IAS) were not included in this model indicating that they did not improve the fit based on the selection criterion.

Table 2. Forward Stepwise Regression Results for Boredom Proneness

Variable	B	95% CI		*SE* B	*β*	R^2	ΔR^2
		LL	UL				
Step 1						.63	.63***
Constant	7.57**	5.41	9.73	1.10			
(SAQ) Self-Awareness	0.22***	0.19	0.25	0.01	0.79***		
Step 2						.69	.07***
Constant	0.05	-3.29	3.39	1.69			
(SAQ) Self-Awareness	0.15***	0.11	0.18	0.02	0.52***		
(TAS-20) Alexithymia	0.23***	0.15	0.31	0.04	0.38***		
Step 3						.70	0.01**
Constant	8.73*	1.31	16.15	3.76			
(SAQ) Self-Awareness	0.14***	0.06	0.10	0.17	0.48***		
(TAS-20) Alexithymia	0.19***	0.10	0.28	0.04	0.31***		
(BSCS) Self-Control	-0.14**	-0.31	-0.24	-0.03	-0.15**		
Step 4						0.72	0.02**
Constant	7.83*	0.55	15.11	3.68			
(SAQ) Self-Awareness	0.11***	0.06	0.15	0.02	0.37***		
(TAS-20) Alexithymia	0.19***	0.11	0.28	0.04	0.31***		
(BSCS) Self-Control	-0.20***	-0.31	-0.09	0.06	-0.22***		
(BAQ) Body Awareness	0.07**	0.02	0.11	0.02	0.15		
Step 5						0.73	0.01*
Constant	10.40**	2.77	18.03	3.86			
(SAQ) Self-Awareness	0.09***	0.05	0.14	0.02	0.33***		
(TAS-20) Alexithymia	0.11	-0.00	0.23	0.06	0.18		
(BSCS) Self-Control	-0.19***	-0.30	-0.09	0.06	-0.22***		
(BAQ) Body Awareness	0.06**	0.01	0.11	0.02	0.14**		
(ISQ) Interoceptive Sensory	0.05*	0.00	0.09	0.02	0.19*		

Note. CI = confidence interval; LL = lower limit; UL = upper limit; (TAS-20) Alexithymia = difficulty labeling emotions; (ISQ) Interoceptive Sensory = measure of interoceptive confusion intended for autistic adults. For each of the predictors, the variance inflation factor was < 4.7.
$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$

3.2. Hierarchical Regression

Next, we conducted a hierarchical regression to explore the variance explained by our predictors of interest while controlling for known relationships such as self-control and alexithymia. To build a parsimonious model, we selected the variables based on our hypothesis and on the findings reported in the correlation matrix (Table 1). Given that: 1) the MAIA-2 did not correlate with boredom proneness; 2) the IAS revealed only a small correlation (*r*=.24); and 3) neither was included in the forward stepwise regression above, we elected to exclude both scales from this model. Table 3 presents the hierarchical regression results for boredom proneness.

Table 3. Hierarchical Regression Results for Boredom Proneness

Variable	B	95% CI		*SE* B	β	R^2	ΔR^2
		LL	UL				
Step 1						.61	.61***
Constant	12.25**	4.34	20.15	4.00			
(TAS-20) Alexithymia	0.37***	0.30	0.45	0.04	0.59***		
(BSCS) Self-Control	-0.24***	-0.34	-0.13	0.05	-0.26***		
Step 2						.68	.07***
Constant	9.62**	2.37	16.88	3.68			
(TAS-20) Alexithymia	0.30***	0.22	0.37	0.04	0.47***		
(BSCS) Self-Control	-3.17***	-0.42	-0.22	0.05	-0.36***		
(BAQ) Body Awareness	0.12***	0.08	0.17	0.02	0.28***		
Step 3						.73	0.05***
Constant	9.34**	2.37	16.31	3.53			
(TAS-20) Alexithymia	0.15**	0.04	0.25	0.05	0.23*		
(BSCS) Self-Control	-0.20***	-0.31	-0.10	0.05	-0.23**		
(BAQ) Body Awareness	0.07**	0.02	0.11	0.02	0.15**		
(SAQ) Self-Awareness	0.09***	0.05	0.13	0.02	0.32***		
(ISQ) Interoceptive Sensory	0.03	-0.01	0.07	0.02	0.14		

Note. CI = confidence interval; LL = lower limit; UL = upper limit; (TAS-20) Alexithymia = difficulty labeling emotions; (ISQ) Interoceptive Sensory = measure of interoceptive confusion intended for autistic adults. For each of the predictors, the variance inflation factor was < 4.5.
*p < .05. **p < .01. ***p < .001

We proceeded by entering alexithymia and self-control as known relations with boredom proneness in step 1. Alexythimia and self-control positively predicted boredom proneness and explained 61% of variance (Table 3). In the second step, we added body awareness which accounted for another 7% of the variance in boredom proneness. Lastly, self-awareness and the ISQ were added to the last step and together explained an additional 5% of the variance in boredom proneness. Overall, the results showed that the hierarchical model was significant. Interestingly, the ISQ was not a significant predictor of boredom proneness despite the magnitude of its correlation with the trait (*r*=0.75; Table 1).

4. Discussion

Aside from replicating known correlations linking boredom proneness to alexithymia and self-control, our exploratory sample revealed intriguing relationships between boredom proneness and interoception. The strong positive correlations that linked self-awareness (r=.81, p<.001; SAQ) and interoceptive confusion (r=75, p<.001; ISQ; Table 1) support recent accounts of boredom proneness that suggest the trait is characterized by high self-focus yet poor self-knowledge (Bambrah et al., 2023). That is, our own sample shows a high focus on internal states (the Sensory Awareness Questionnaire) coupled with a struggle to make sense of those states as measured by the Interoceptive Sensory Questionnaire, which has been used to explore interoceptive confusion in adults with autism (Fiene et al, 2018).

By examining measures of interoceptive ability such as awareness and accuracy in the context of boredom, our study has exposed several questions regarding the definition of these constructs in the literature and how various scales might be used to measure them. Indeed, the sample yielded a significant, albeit modest, positive correlation between boredom proneness and interoceptive accuracy (IAS, r=.24, p<.001; Table 1). At first glance, this finding seems to contradict our predictions. However, a closer look at the format of the questions used in this scale and at a prevalent theoretical account of distinct dimensions of interoceptive ability, may partially explain these results. As mentioned earlier, Garfinkel and colleagues (2015) proposed a tripartite model of interoceptive ability comprising three distinct and dissociable dimensions: 1) interoceptive accuracy (i.e., one's *performance* on objective behavioural tests such as heartbeat detection tasks; 2) interoceptive sensibility (i.e., the self-evaluated appraisal of subjective interoception using questionnaires); and 3) interoceptive awareness (i.e., how confident one's feels towards accurately perceiving bodily sensations). According to Garfinkel and colleagues' model, a self-report scale that intends to measure interoceptive accuracy may actually be probing for interoceptive sensibility or awareness. For instance, the Interoceptive Accuracy Questionnaire (IAS) includes a common stem to all questions: 'I *can always* accurately perceive [insert interoceptive signal]' (we have added the emphasis here to indicate the prospective nature of this stem). This structure likely blurs the lines between asking participants to evaluate how well they can notice their internal bodily signals (i.e., evaluate their sensibility) and rating how confidently (1=*strongly disagree* to 5=*strongly agree*) they feel they can perceive those bodily sensations with accuracy per se. In other words, the IAS may more concisely be tapping into metacognitive awareness rather than accuracy when representing interoceptive states.

Nonetheless, the strongest correlations in our findings (SAQ, r=.81, and ISQ, r=0.75, both p<.001; Table 1) suggest that boredom prone individuals may be hyperaware of their interoceptive cues but struggle to make meaningful sense of those signals. The exclusion of the predictors of interoceptive awareness (MAIA-2) and interoceptive accuracy (IAS) in the forward stepwise model (Table 2) underlines the need for further examination of the different dimensions and items used by the instruments available to evaluate the relationship between interoception and boredom proneness. Given that the Interoceptive Sensory Questionnaire (ISQ) did not function as a significant predictor of boredom proneness despite being strongly correlated with the state highlights the need for direct testing of the connection between interoceptive ability and both state and trait boredom.

5. Future Work

First and foremost is the need to replicate the current findings in another sample. Second, future work should employ a variety of interoceptive accuracy tasks from the common heart rate counting task (Hickman et al., 2020), to more sophisticated heart rate phase adjustment tasks (Plans et al., 2021) to directly examine the association between boredom proneness and interoceptive accuracy. One further potential avenue would involve inducing changes in interoceptive signals. For instance, using exercise to modulate heart rate, we could examine the capacity of the highly boredom prone to detect *changes* in interoceptive signals. Lastly, paradigms could test predictive coding accounts to explore whether boredom prone individuals fail to accurately anticipate both changes in interoception and the affective outcomes associated with those changes. What emerged from the current work is that the highly boredom prone seem to attend to their body states assiduously but may struggle to use what they perceive in adaptive ways. We expect the present work to spark new research efforts to test the proposed hypothesis.

References

Bagby, R. M., Parker, J. D., and Taylor, G. J. (1994). The Twenty-item Toronto Alexithymia Scale—I. Item Selection and Cross-validation of the Factor Structure. *Journal of Psychosomatic Research*, *38*(1), 23–32. https://doi.org/10.1016/0022-3999(94)90005-1

Bambrah, V., Moynihan, A. B., and Eastwood, J. D. (2023). Self-focused but Lacking Self-knowledge: The Relation Between Boredom and Self-perception. *Journal of Boredom Studies*, *1*. https://doi.org/10.5281/zenodo.7612345

Barrett, L. F., and Simmons, W. K. (2015). Interoceptive Predictions in the Brain. *Nature Reviews Neuroscience*, *16*(7), 419–429. https://doi.org/10.1038/nrn3950

Buckner, R. L., Andrews-Hanna, J. R., and Schacter, D. L. (2008). The Brain's Default Network: Anatomy, Function, and Relevance to Disease. *Annals of the New York Academy of Sciences*, *1124*(1), 1–38. https://doi.org/10.1196/annals.1440.011

Carriere, J. S., Cheyne, J. A., and Smilek, D. (2008). Everyday Attention Lapses and Memory Failures: The Affective Consequences of Mindlessness. *Consciousness and Cognition*, *17*(3), 835–847. https://doi.org/10.1016/j.concog.2007.04.008

Cheyne, J. A., Carriere, J. S., and Smilek, D. (2006). Absent-mindedness: Lapses of Conscious Awareness and Everyday Cognitive Failures. *Consciousness and Cognition*, *15*(3), 578–592. https://doi.org/10.1016/j.concog.2005.11.009

Craig, A. (2009). How Do You Feel—Now? The Anterior Insula and Human Awareness. *Nature Reviews Neuroscience*, *10*(1), 59–70. https://doi.org/10.1038/nrn2555

Dal Mas, D. E., and Wittmann, B. C. (2017). Avoiding Boredom: Caudate and Insula Activity Reflects Boredom-elicited Purchase Bias. *Cortex*, *92*, 57–69. https://doi.org/10.1016/j.cortex.2017.03.008

Danckert, J., and Merrifield, C. (2018). Boredom, Sustained Attention and the Default Mode Network. *Experimental Brain Research*, *236*, 2507–2518. https://doi.org/10.1007/s00221-016-4617-5

Danckert, J., and Elpidorou, A. (2023). In Search of Boredom: Beyond a Functional Account. *Trends in Cognitive Sciences*, *27*(5), 494–507. https://doi.org/10.1016/j.tics.2023.02.002

Danckert, J., Mugon, J., Struk, A., and Eastwood, J. (2018). Boredom: What Is It Good for? In H. C. Lench (Ed.), *The Function of Emotions: When and Why Emotions Help Us* (pp. 93–119). Springer.

Drody, A., Yakobi, O., and Danckert, J. (2024). Boredom on the Brain: What Can Neuroimaging Tell Us about Boredom? In M. Bieleke, W. Wolff and M. Martarelli (Eds.), *The Routledge International Handbook of Boredom* (pp. 178–190). Routledge.

Eastwood, J. D., Cavaliere, C., Fahlman, S. A., and Eastwood, A. E. (2007). A Desire for Desires: Boredom and Its Relation to Alexithymia. *Personality and Individual Differences*, *42*(6), 1035–1045. https://doi.org/10.1016/j.paid.2006.08.027

Eastwood, J. D., Frischen, A., Fenske, M. J., and Smilek, D. (2012). The Unengaged Mind: Defining Boredom in Terms of Attention. *Perspectives on Psychological Science*, *7*(5), 482–495. https://doi.org/10.1177/1745691612456044

Elpidorou, A. (2014). The Bright Side of Boredom. *Frontiers in Psychology*, *5*, 1245. https://doi.org/10.3389/fpsyg.2014.01245

Farmer, R., and Sunberg (1986). Boredom Proneness—The Development and Correlates of a New Scale. *Journal of Personality Assessment*, *50*(1), 4–17. https://doi.org/10.1207/s15327752jpa5001_2

Fiene, L., Ireland, M. J., and Brownlow, C. (2018). The Interoception Sensory Questionnaire (ISQ): A Scale to Measure Interoceptive Challenges in Adults. *Journal of Autism and Developmental Disorders*, *48*(10), 3354–3366. https://doi.org/10.1007/s10803-018-3600-3

Gana, K., Broc, G., and Bailly, N. (2019). Does the Boredom Proneness Scale Capture Traitness of Boredom? Results from a Six-year Longitudinal Trait-state-occasion Model. *Personality and Individual Differences*, *139*, 247–253. https://doi.org/10.1016/j.paid.2018.11.030

Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., and Critchley, H. D. (2015). Knowing Your Own Heart: Distinguishing Interoceptive Accuracy from Interoceptive Awareness. *Biological Psychology*, *104*, 65–74. https://doi.org/10.1016/j.biopsycho.2014.11.004

Goldberg, Y. K., Eastwood, J. D., LaGuardia, J., and Danckert, J. (2011). Boredom: An Emotional Experience Distinct from Apathy, Anhedonia, or Depression. *Journal of Social and Clinical Psychology*, *30*, 647–666. https://psycnet.apa.org/doi/10.1521/jscp.2011.30.6.647

Gorelik, D., and Eastwood, J. D. (2024). Trait Boredom as a Lack of Agency: A Theoretical Model and a New Assessment Tool. *Assessment*, *31*(2), 321–334. https://doi.org/10.1177/10731911231161780

Gu, X., Hof, P. R., Friston, K. J., and Fan, J. (2013). Anterior Insular Cortex and Emotional Awareness. *Journal of Comparative Neurology*, *521*(15), 3371–3388. https://doi.org/10.1002%2Fcne.23368

Hickman, L., Seyedsalehi, A., Cook, J. L., Bird, G., and Murphy, J. (2020). The Relationship Between Heartbeat Counting and Heartbeat Discrimination: A Meta-analysis. *Biological Psychology*, *156*, 107949. https://doi.org/10.1016/j.biopsycho.2020.107949

Hogeveen, J., Bird, G., Chau, A., Krueger, F., and Grafman, J. (2016). Acquired Alexithymia Following Damage to the Anterior Insula. *Neuropsychologia*, *82*, 142–148. https://doi.org/10.1016/j.neuropsychologia.2016.01.021

Hunter, A., and Eastwood, J. D. (2018). Does State Boredom Cause Failures of Attention? Examining the Relations Between Trait Boredom, State Boredom, and Sustained Attention. *Experimental Brain Research*, *236*, 2483–2492. https://doi.org/10.1007/s00221-016-4749-7

Isacescu, J., Struk, A. A., and Danckert, J. (2017). Cognitive and Affective Predictors of Boredom Proneness. *Cognition and Emotion*, *31*(8), 1741–1748. https://doi.org/10.1080/02699931.2016.1259995

Isacescu, J., and Danckert, J. (2018). Exploring the Relationship Between Boredom Proneness and Self-control in Traumatic Brain Injury (TBI). *Experimental Brain Research*, 236, 2493–2505. https://doi.org/10.1007/s00221-016-4674-9

Longarzo, M., D'Olimpio, F., Chiavazzo, A., Santangelo, G., Trojano, L., and Grossi, D. (2015). The Relationships Between Interoception and Alexithymic Trait. The Self-Awareness Questionnaire in Healthy Subjects. *Frontiers in Psychology*, *6*, 1149. https://doi.org/10.3389/fpsyg.2015.01149

Malkovsky, E., Merrifield, C., Goldberg, Y., and Danckert, J. (2012). Exploring the Relationship Between Boredom and Sustained Attention. *Experimental Brain Research*, *221*, 59–67. https://doi.org/10.1007/s00221-012-3147-z

Mehling, W. E., Acree, M., Stewart, A., Silas, J., and Jones, A. (2018). The Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2). *PloS one*, *13*(12), e0208034. https://doi.org/10.1371%2Fjournal.pone.0208034

Meier, M., Martarelli, C. S., and Wolff, W. (2024). Is Boredom a Source of Noise and/or a Confound in Behavioral Science Research? *Humanities and Social Sciences Communications*, *11*(1), 1–8. https://doi.org/10.1057/s41599-024-02851-7

Menon, V., and Uddin, L. Q. (2010). Saliency, Switching, Attention and Control: A Network Model of Insula Function. *Brain Structure and Function*, *214*, 655–667. https://doi.org/10.1007/s00429-010-0262-0

Mugon, J., Struk, A., and Danckert, J. (2018). A Failure to Launch: Regulatory Modes and Boredom Proneness. *Frontiers in Psychology*, *9*, 1126. https://psycnet.apa.org/doi/10.3389/fpsyg.2018.01126

Murphy, J., Brewer, R., Plans, D., Khalsa, S. S., Catmur, C., and Bird, G. (2019). Testing the Independence of Self-reported Interoceptive Accuracy and Attention. *Quarterly Journal of Experimental Psychology*, *73*(1), 115–133. https://doi.org/10.1177/1747021819879826

Namkung, H., Kim, S. H., and Sawa, A. (2018). The Insula: An Underestimated Brain Area in Clinical Neuroscience, Psychiatry, and Neurology. *Trends in Neuroscience*, *40*(4), 200–207. https://doi.org/10.1016/j.tins.2017.02.002

Olusegun, A. M., Dikko, H. G., and Gulumbe, S. U. (2015). Identifying the Limitation of Stepwise Selection for Variable Selection in Regression Analysis. *American Journal of Theoretical and Applied Statistics*, *4*(5), 414–419. https://doi.org/10.11648/j.ajtas.20150405.22

Pattyn, N., Neyt, X., Henderickx, D., and Soetens, E. (2008). Psychophysiological Investigation of Vigilance Decrement: Boredom or Cognitive Fatigue? *Physiology & Behavior*, *93*(1–2), 369–378. https://doi.org/10.1016/j.physbeh.2007.09.016

Plans, D., Ponzo, S., Morelli, D., Cairo, M., Ring, C., Keating, C. T. and Bird, G. (2021). Measuring Interoception: The Phase Adjustment Task. *Biological Psychology*, *165*, 108171. https://doi.org/10.1016/j.biopsycho.2021.108171

Shields, S. A., Mallory, M. E., and Simon, A. (1989). The Body Awareness Questionnaire: Reliability and Validity. *Journal of Personality Assessment*, *53*(4), 802–815. https://psycnet.apa.org/doi/10.1207/s15327752jpa5304_16

Smith, G. (2018). Step away from Stepwise. *Journal of Big Data*, *5*(1), 1–12. https://doi.org/10.1186/s40537-018-0143-6

Struk, A. A., Carriere, J. S., Cheyne, J. A., and Danckert, J. (2017). A Short Boredom Proneness Scale: Development and Psychometric Properties. *Assessment*, *24*(3), 346–359. https://doi.org/10.1177/1073191115609996

Tangney, B., Baumeister, R. F., and Boone, A. L. (2004). High Self-control Predicts Good Adjustment, Less Pathology, Better Grades, and Interpersonal Success. *Journal of Personality*, *72*(2), 272–322. https://doi.org/10.1111/j.0022-3506.2004.00263.x

Tze, V. M., Daniels, L. M., and Klassen, R. M. (2016). Evaluating the Relationship Between Boredom and Academic Outcomes: A Meta-analysis. *Educational Psychology Review*, *28*(1), 119–144. https://doi.org/10.1007/s10648-015-9301-y

Uddin, L. Q. (2015). Salience Processing and Insular Cortical Function and Dysfunction. *Nature Reviews Neuroscience*, *16*(1), 55–61. https://doi.org/10.1038/nrn3857

Ulrich, M., Keller, J., Hoenig, K., Waller, C., and Grön, G. (2014). Neural Correlates of Experimentally Induced Flow Experiences. *Neuroimage*, *86*, 194–202. https://doi.org/10.1016/j.neuroimage.2013.08.019

Van Tilburg, W. A. P., and Igou, E. R. (2011). On Boredom and Social Identity: A Pragmatic Meaning-regulation Approach. *Personality and Social Psychology Bulletin*, *37*, 1679–1691. https://doi.org/10.1177/0146167211418530

Wang, X., Zhang, R., Chen, Z., Zhou, F., and Feng, T. (2021). Neural Basis Underlying the Relation Between Boredom Proneness and Procrastination: The Role of Functional Coupling Between Precuneus/Cuneus and Posterior Cingulate Cortex. *Neuropsychologia*, *161*, 107994. https://doi.org/10.1016/j.neuropsychologia.2021.107994