Cognitive homeostasis: Boredom as a drive for optimal engagement

by

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Statement of Contributions

All of the projects presented in this thesis were made possible through the leadership of my supervisor Dr. James Danckert. The studies and experiments reported herein were conducted in collaboration with Joshua R. C. Budge. Kelly Monk and Daniela Pasqualini contributed to data collection.

For the work presented in Chapter 5, Dr. Michael Dixon provided guidance and intellectual input and his student Tyler Kruger contributed to curation and analysis of the psychophysical data using LabChart.

Research presented in Chapter 2:

The model presented in this chapter was developed by Chantal Trudel and Dr. James Danckert under the guidance of several leading researchers in the field including Dr. John Eastwood, Dr. Wijnand Van Tilburg, Dr. Andreas Elpidorou and Dr. Evan Risko.

Research presented in Chapter 3:

This research was conducted at the University of Waterloo under the supervision of Dr. James Danckert. Joshua R. C. Budge and Daniela Pasqualini collected data. Chantal Trudel drafted the manuscript and Dr. Danckert provided intellectual input on manuscript drafts.

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Abstract

Boredom is the feeling of wanting but failing to engage the mind. The first part of this thesis proposes a theory that casts boredom as a signal of suboptimal utilization of cognitive resources. Homeostasis is used as an analogy that frames the in-the-moment feeling of boredom as a deviation from optimal engagement. It also offers an allostatic account for chronic boredom (i.e., trait boredom proneness) and briefly explores potential neural indicators of both boredom and cognitive engagement before considering related processes of meaning making. This model of boredom characterizes the experience as a dynamic response to both internal and external exigencies and leads to testable hypotheses for both the nature of the state and the trait disposition to experience the state frequently and intensely. Furthermore, it casts a more general hypothesis that humans strive to optimally engage with their environs, in order to maintain a kind of cognitive homeostatic set point. The second part of the thesis consists of a study, its replication, and an experiment derived from the theory. The study is resting on a prominent model of affective regulation suggesting that interoceptive signals are used to predict the affective outcomes of intended actions paired with recent neuroimaging work implicating the anterior insular cortex in boredom. Results showed strong relations with boredom proneness and attention to interoceptive signals. Data also showed that high boredom prone individuals tend to struggle to make sense of interoceptive signals. The experiment that followed made use of a heartbeat counting task to objectively test interoceptive accuracy as a function of boredom proneness. Heart rate variability was also measured while inducing moods of boredom and interest. While poor performance did not correlate with chronic boredom, induced state boredom triggered a higher stress response as indicated by cardiac vagal tone. These results characterize state boredom as a physiological

stressor that fits well within the model proposed as a push to restore cognitive homeostasis by prompting the agent to find a more positively valenced endeavour.

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Chapter 1: Introduction

Boredom is in part a disengaged state (Eastwood et al., 2012). When bored, people fail to effectively engage their cognitive resources with the task at hand, or more broadly with their current environs. That lack of engagement is felt as unpleasant, with boredom commonly rated to be negatively valenced (Goldberg et al., 2011; Van Tilburg & Igou, 2011) and associated with feelings of agitation and restlessness (e.g., Danckert et al., 2018a). In the context of this phenomenological description of the state, functional accounts suggest that boredom arises when one is not adequately utilizing cognitive resources and signals a need to explore the environs for a more satisfying outlet for action (Bench & Lench, 2013; Danckert, 2019; Danckert & Elpidorou, 2023; Elpidorou, 2014, 2018a, 2023; Tam et al., 2021; Westgate & Wilson, 2018). Boredom vanishes once an endeavor deemed worthy is found and effective cognitive engagement can resume. Indeed, one could suggest that boredom's ultimate goal is to eliminate itself. This engagement-disengagement cycle represents a kind of feedback loop (Tam et al., 2021) needed to maintain some optimal level of cognitive engagement. What determines optimal cognitive engagement in this instance likely depends on context, effort, motivation, meaning, goals, and environmental constraints, among other possibilities. While the extent of engagement may differ in degree (i.e., a person can be slightly, moderately, or fully engaged), *the drive to be engaged* fulfils a basic human need—to optimally deploy cognitive resources. By analogy, such a self-regulatory process shares commonalities with homeostatic systems, which strive to maintain the internal stability of an organism by adjusting to the fluctuations of the external environment (Billman, 2020). This thesis proposes that people strive to maintain a suitable cognitive range of engagement within adaptive internal boundaries in response to external perturbations (Turner, 2019). Through the establishment and maintenance of cognitive homeostasis, cognitive-affective resources are managed dynamically and responsively in light of both internal and external changes.

In the model proposed here, the values attached to the limits of a desired cognitive set point are flexible and context-dependent, in which feelings of boredom operate as just one of several self-regulatory signals, indicative of a departure from that set point. Falling outside of one's cognitive homeostatic set point is not only felt as unpleasant but is also detrimental to the organism in terms of performance and mental well-being. Next, the model posits that several signaling mechanisms are activated when one is outside of *either* the lower or upper bounds of the purported cognitive set point. These signals include, but are not limited to, boredom, effort and anxiety. This thesis focuses on boredom as a signal of particular interest in light of the recent surge of research into this experience (Westgate & Steidle, 2020), and the considerable literature that has linked it to markers of inadequate cognitive utilization. Further, it explores the trait propensity to experience boredom as an indication of dysfunctional regulation of the cognitive set point. The latter raises an intriguing distinction between homeostatic and allostatic regulatory mechanisms that provides a promising avenue for further research.

Research on boredom has accelerated over the past two decades (Westgate & Steidle, 2020). Despite this increase in interest, controversies in the literature persist, particularly around the definition of the state and whether there are several "types" of boredom (Elpidorou, 2021; Goetz et al., 2014; Westgate & Wilson, 2018). Nevertheless, most definitions of boredom converge on one characterization: boredom represents a lack of sufficient cognitive engagement which is felt as uncomfortable and is negatively valenced (Danckert & Elpidorou, 2023; Eastwood et al., 2012; Goldberg et al., 2011; Mugon et al., 2018; Tam et al., 2021; Van Tilburg & Igou, 2011).

Casting boredom in information processing terms, something first proposed by sociologist Orin Klapp (1986; see Danckert & Gopal, 2024), offers a useful model to explicate the distinct pathways that lead to the lack of cognitive engagement characteristic of boredom. Specifically, utilization of cognitive resources can be said to depend on the capacity to extract signal from noise within a given context or environment. On the one hand, extraction of meaning can be difficult when faced with a constantly changing or chaotic barrage of information. In such circumstances one may simply stop trying to make sense of the information resulting in the underutilization of cognitive resources and ensuing boredom. On the other hand, when faced with a monotonous circumstance that presents an overabundance of repetition, one's cognitive resources are underutilized because there is no *additional* discernable meaning to extract from the redundancy. Once again, cognitive resources are underutilized leading to feelings of boredom (Seiler et al., 2022).

Evidence supports the existence of both of these potential pathways to the underutilization of cognitive resources: (a) research shows that feelings of boredom are experienced when information is so complex it becomes impenetrable (Fahlman et al., 2013; Struk et al., 2021), and (b) it is incontrovertible that boredom commonly arises in monotonous environs or when repetitive tasks require or afford little from people as cognitive agents (Thackray, 1980, 1981; Thackray et al., 1977). This proposed account of boredom as a signal of suboptimal utilization of cognitive resources is also consistent with evidence from educational psychology where research on the Control-Value theory of achievement emotions (Pekrun, 2006) indicates that *both* over- and underchallenging tasks that lack value to the individual are prime determinants of boredom (see also Nett et al., 2011; Westgate & Wilson, 2018). Thus, when one falls outside of the cognitive utilization set point—either because the environment is too stimulating, challenging, and varied, or because it is not sufficiently stimulating, challenging, and varied—the feeling of boredom (i.e., a signal of cognitive underutilization) arises and can regulate behavior.

It should be noted that boredom is not solely determined by the environmental exigencies hinted at above. The individual, through self-regulatory mechanisms, has a say in how boredom unfolds. Indeed, boredom has a motivational character—being bored implies a strong desire to do something other than what one is doing. Therefore, in-the-moment feelings of boredom represent an unsatiated motivational state—one wants something to engage with but doesn't want anything currently available. It is also possible that when bored one recognizes the will to be engaged but struggles to articulate what it is that would satisfy that yearning. Either way, this desire bind (Eastwood & Gorelik, 2019) highlights the key component of boredom that this thesis is emphasizing: a state symptomatic of the fact that the deployment of cognitive resources is currently suboptimal. Therefore, boredom involves a strong, even if unarticulated, desire for change and for restoration of an optimal cognitive set point.

Within this characterization of boredom there is an important distinction to be made between optimal deployment of cognitive resources and the purported tendency for humans to be cognitive misers (Stanovich, 2018; Fiske & Taylor, 1984; Tversky & Kahneman, 1974). That is, past work has suggested that people strive to preserve their resources when engaging with the world, which seems to be in opposition to the claim that boredom drives us towards *optimal* resource use. This can be resolved in a number of ways. First, if we consider the interplay between the twin drives of exploration and exploitation (Danckert, 2019), resource deployment may function distinctly for each drive (see also Agrawal et al., 2022). When *exploiting* known resources, it may make sense to be miserly with our cognitive capacities to efficiently exploit without depletion. On the other hand, exploration may demand a different kind of action, one that meets the exigencies of the task at hand in some kind of optimal manner. Second, optimal engagement need not necessitate exhaustion of available resources. It could in fact be optimal to be a miser. Finally, there are many activities that humans engage in that demand full exertion of available resources. People certainly do things that, at first blush, would seem to make little sense in the context of miserly deployment of resources. Why do people dance, play sports, make music, or build model cathedrals out of toothpicks? These activities do not agree with conserving cognitive energy or resources. A key distinction here might be how our deployment of cognitive resources *feels* (Gorelik & Eastwood, 2019). We may tend towards miserliness when the demands of the task engender a feeling of what Gorelik and Eastwood call 'mental strain' (Gorelik & Eastwood, 2019). But as the activities just listed suggest (sports, music, crafts), we commonly engage in effortful tasks. Such engagement may not feel effortful because the tasks themselves function well as a way to optimally deploy cognitive resources.

This thesis is structured in two parts. First, the model of boredom as a signal of deviation from a cognitive set point briefly outlined above is fleshed out in more detail. Second, a study and an experiment that naturally arise from the model are presented. The study explores boredom proneness as an indication of dysfunctional regulation of the cognitive setpoint by measuring for the first time its relations with interoceptive awareness and accuracy. Previous neuroimaging work has implicated activation of the default mode network and anterior insular in the state of boredom (Danckert & Merrifield, 2018; Ulrich et al., 2014; Dal Mas & Wittman, 2017; 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 & Merrifield, 2018; Ulrich et al., 2014). The insular cortex is also critical for interoceptive processing—the perception and integration by the brain of internal physiological signals with emotional, cognitive, and motivational cues (Craig, 2009). In other words, it is involved in representing the physiological sensations directly 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. Failure to represent interoceptive signals of this kind 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, without an accurate representation of internal states the individual may struggle to either label those states or anticipate what future states may resolve them–or both. 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. In addition, two scales sought to replicate the known relationship between boredom proneness and alexithymia (i.e., the inability to accurately label affective states; Eastwood et al., 2007) and self-control (i.e., difficulty in marshaling one's thoughts, actions, and emotions in the pursuit of goals; Struk et al., 2015; Isacescu & Danckert, 2016). A failure to accurately represent or make use of internal signals may in part be responsible for the challenge boredom poses in maintaining effective engagement. According to the model proposed in this thesis, effective engagement involves staying within the cognitive homeostatic setpoint.

The experiment presented in Chapter 5 followed up on the subjective self-report examination of interoceptive accuracy collected in the studies presented in Chapters 3 and 4 with an objective task –a heart rate counting task. Performance was examined in relation to trait boredom proneness, as well as self-awareness and interoceptive confusion, factors found in the study to be associated with boredom proneness. The experiment also involved the collection of psychophysiological markers such as heart rate variability (HRV) while inducing participants into states of boredom or interest. This represents a partial replication of prior work showing that when bored people exhibit higher heart rate (Merrifield & Danckert, 2014). In addition, it enabled an examination of this variable while participants performed the heart rate counting task.

Chapter 2: Model

Boredom as a signal of deviation from a cognitive homeostatic set point

If boredom represents a deviation from an optimal cognitive set point, then there ought to be negative consequences for falling outside that range. By analogy with homeostasis, a drop in core body temperature can become fatal to the organism if it goes unaddressed. Does a deviation from an optimal cognitive set point similarly have negative consequences that demand action? There is ample evidence that it does in terms of the raft of maladaptive behavioral and affective consequences that befall those in a bored state or those highly prone to boredom (Westgate & Steidle, 2020). In these cases, the in-the-moment experience of boredom signals a concrete need to initiate actions that promote cognitive engagement in both the short and long term.

A clear example of the negative consequences associated with an inability to initiate actions so that one is operating within their cognitive set point (i.e., avoiding boredom) can be found in research showing that those who are prone to boredom also suffer from higher rates of depression and anxiety (Bargdill, 2019; Constant et al., 2021; LePera, 2011). For the highly boredom prone, there are also strong associations with increased drug and alcohol use and problem gambling (although this latter relation may depend more on the nature of the scales used to measure boredom; Biolcati et al., 2016; Blaszczynski et al., 1990; Krotava & Todman, 2014; Mercer & Eastwood, 2010; Orcutt, 1984; Weiss et al., 2022). There is even some indication from epidemiological work that chronic boredom may be associated with poor heart health (Britton & Shipley, 2010). What all of this suggests is that a *chronic* failure to maintain cognitive engagement within a healthy set point may have long-term consequences for an individual's well-being.

There also appear to be more near-term consequences of boredom. For example, using in-lab tasks, it has been shown that both state and trait boredom are associated with deficient performance on standard tasks of sustained attention (Hunter & Eastwood, 2018; Malkovsky et al., 2012). In addition, using self-report metrics, research has shown that higher boredom proneness is associated with increases in everyday lapses in attention (e.g., pouring orange juice on your cereal; Cheyne et al., 2006; Carriere et al., 2008). In the current framework, one way to understand performance decrements associated with boredom is to assume that the cognitive set point is typically set at a level that would afford meeting the demands of one's current task. While this need not be the case for every single task, individuals do appear to have a desire to feel efficacious and this seemingly supports the existence, at least in the aggregate, of a positive association between one's cognitive set point and task demands. Accepting this association would lead to the prediction that state boredom should signal a deviation from optimal engagement in terms of the task at hand, and hence a link between boredom and performance decrements.

A different way to understand performance decrements associated with boredom is that they arise *as a result* of attempts to restore optimal cognitive engagement. For example, boredom is associated with increased rates of mind-wandering (Isacescu et al., 2017). While mind-wandering could offer a means of restoring cognitive engagement to an appropriate level, the resultant extraction of the focus of attention from the primary task will also lead to performance decrements in that task (e.g., detecting an infrequent target). This mechanism for understanding performance decrements may also provide a natural explanation for associations between boredom and increased risk-taking on self-report measures and lab-based tasks (Bench et al., 2021; Biolcati et al., 2018; Dahlen et al., 2005; Kılıç et al., 2020; although see Yakobi et al., 2021). Namely, action choices born of boredom may reflect searching for something *different* to engage with where just about anything will suffice, even if it appears to be against one's longer-term self-interest (Bench & Lench, 2019; Boylan et al., 2021; Wolff et al., 2020; Weiss et al., 2022). There is certainly recent evidence to suggest that boredom can prompt maladaptive action choices, from viewing more negatively valenced images (Bench & Lench, 2019), to choosing to engage in sadistic behaviors (Pfattheicher et al., 2021). From this perspective, boredom, as a feeling of deviation from an optimal cognitive set point, could prompt a search for novelty in the hopes of finding an experience more cognitively engaging (Bench & Lench, 2013) and in some cases this search will lead to maladaptive behaviors.

In sum, boredom indicates a departure from some kind of optimal cognitive set point. If being at such a cognitive set point is adaptive, then departures from this set point should lead to negative consequences for the organism. Indeed, outlined above are numerous pieces of evidence consistent with this general idea. Ultimately, both residing at one's optimal cognitive set point and engaging in adaptative remediation to deviations from such a set point are important in preventing a host of negative consequences that straying from that set point may bring.

While the boredom symptomatic of a deviation from a cognitive set point yields predominantly negative outcomes for the individual, one domain in which boredom may be associated with positive action choices relates to creative pursuits. However, while there are certainly many anecdotal examples of boredom acting as a prompt to creativity, the research evidence for this is not strong (Gasper et al., 2014; Haager et al., 2018; Mann & Cadmann, 2014; Larson, 1990; Nettinga et al., 2023). This may be due to a wide range of factors including the sensitivity (or lack thereof) of the tools used to measure creativity, the ability of these measures to differentiate effectively between creativity writ large and more specific cognitive functions associated with creativity (e.g., divergent thinking), and the role of practice or repetition. Moreover, the possibility that boredom itself won't *induce* creative skill where none were fostered beforehand ought to be taken seriously. Indeed, recent work shows that at best there is no correlation between state boredom and creativity, and at worst, the relation is negative (higher ratings of boredom associated with lower performance on tasks tapping into creative processes; Nettinga et al., 2023). Regardless, the intriguing possibility of a relation between state boredom and creativity fits well with the notion that the signal implies deviation from optimal engagement and that creative pursuits would function superbly, for creative individuals, to bring them back within those boundaries of an ideal cognitive set point.

Signaling a deviation from the cognitive set point

Boredom is presented here as a case in point for the hypothesis that humans strive to maintain a cognitive set point. As hinted at from the outset, boredom is likely not the only signal that one has deviated from that set point. In considering what signals might be associated with such a deviation, changes in arousal levels may seem an obvious choice. On the one hand, when a situation is monotonous and the rate of information gain/change is minimal or redundant, accompanying lowered arousal levels may reflect low cognitive utilization. On the other hand, feeling overwhelmed by constantly changing environs or tasks beyond one's skill set likely leads to elevated arousal levels. As noted above, both situations underline the relation between boredom and arousal which has represents a longstanding contentious issue (Danckert et al., 2018a; Elpidorou, 2021; Tam et al., 2021). That is, should boredom be considered a high or low arousal experience, or is it best characterized as a mixed arousal state? Self-report metrics most often indicate that people rate boredom to be a low arousal experience (e.g., Van Tilburg & Igou, 2012), but psychophysiological metrics (e.g., heart rate, skin conductance levels) show mixed results, split almost perfectly between findings of high and low arousal (Merrifield & Danckert, 2014; Barmack, 1939; Giewitz, 1966; Pattyn et al., 2008; Berlyne, 1960; London et al. 1972; Ohsuga et al., 2001). One recent suggestion is that arousal should not be considered a key component of the *definition* of state boredom (Elpidorou, 2021). It should be noted that this stance does not preclude the possibility that *changes* in arousal are associated with a deviation from an optimal cognitive engagement set point. Thus, on this account, there is unlikely to be a direct relation between high and low arousal and boredom. Instead, there ought to be a relation between an arousal-based indicator of a deviation from a cognitive set point and boredom. Understanding the former, of course, will be complicated and this, in and of itself, might provide some insight into why the relation between arousal and boredom has been difficult to get a grip on. To test these notions, experiments that captured continuous psychophysiological data associated with self-report metrics could prove useful. While challenging, this is not impossible (Hoemann et al., 2020, 2021). Recent work did just that using changes in various heart rate metrics to trigger self-report prompts. The results showed no clear evidence for a *fingerprint* hypothesis of affective experiences (Hoemann et al., 2020, 2021). Specifically, discrete self-reports were not associated with discriminable psychophysiological signatures. What a study like this does promise, however, is the capacity to track the dynamics of psychophysiological experiences over time and to associate those dynamics with both discrete affective episodes and chronic dispositions. This method could be capitalized on to examine not only the specific deviations from the cognitive set point that interest us (i.e., episodes of boredom), but also any occurrences of successful cognitive engagement.

Cognitive failure is another plausible signal of deviation from an optimal cognitive set point. That is, recognition, either implicitly or explicitly, that one has erred on a task may be enough to indicate a more general deviation from optimal cognitive engagement (see O’Connell et al., 2004 and McAvinue et al., 2005 for work on error awareness in ADHD and traumatic brain injury respectively). In other words, changes in arousal are unlikely to be the *only* factor indicative of a deviation from optimal engagement. Thus, dynamic changes in arousal, errors in performance and other more “cognitive” appraisals of one’s circumstances may all be associated with deviation from optimal engagement. Given the claim that boredom belongs to this category, one would expect associations between these signals and boredom. As outlined above, it is certainly true to suggest that failures of attention on traditional lab-based tasks (Robertson et al., 1997), are associated with post-task ratings of boredom (Hunter & Eastwood, 2018; see also Yakobi et al., 2021, Yakobi & Danckert, 2021 for similar findings correlating differences in ERPs with pre- and post-task boredom ratings).

Feelings of effort may represent an alternate signal of deviance from a cognitive set point (Inzlicht et al., 2018; Kurzban et al., 2013). Effort has long proved a hard nut to crack both in terms of cognitive mechanistic accounts and the search for an associated physiological signature (see Kurzban et al., 2013 for review). Humans are generally averse to the experience of effort. That is, like boredom, effort is generally rated to be negatively valenced and when presented with options one often “satisfices”—choosing the action option that leads to a “good enough” solution as opposed to striving for some maximal performance (e.g., cognitive misers; Kool et al., 2010; Tyson, 2008). One recent theory of effort regulation cast it in terms of opportunity costs (Kurzban et al., 2013). Specifically, any given action comes with the cost of foregoing potentially higher rewards inherent to alternate (but often unknown) options (Charnov, 1976; Gallistel, 1990). That is, rising feelings of effort on a given task are coded as rising opportunity costs (Kurzban et al., 2013). Within the analogy of homeostasis offered here, effort may function at the upper bounds of a cognitive set point—that is, when cognitive capacity is overtaxed.

It has been noted that the feelings of effort and boredom are commonly correlated (Mulder, 1986; O’Hanlon, 1981; Sawin & Scerbo, 1995). This aligns with the information processing account which suggests that boredom arises when information gain is *either* non-existent (i.e., redundancy is high) *or* impossible (i.e., high levels of noise, making signal detection challenging; Klapp, 1986). In both cases, this leaves us cognitively unengaged. Effort, at least in terms of processing complexity (as opposed to compensatory control), in this framework would track closely with boredom. When things are redundant and monotonous, they likely feel boring *and* underchallenging—in other words, low in effort. When information gain is precluded, feelings of effort will be high, at least for a period of time as one attempts to get an intellectual foothold and become engaged, prevention of which will lead to boredom (Fahlman et al., 2013). So, boredom and effort might both signal that deviation from an ideal zone of cognitive engagement.

One recent computational account of cognitive control would suggest different functional properties for boredom and effort (Agrawal et al., 2022). In this model, boredom prompts exploration only when information is redundant (and presumably effort is low). The function of rising feelings of effort in this account is to prompt the system to retreat into behaviors that test the veracity of an already established mental model (Agrawal et al., 2022). That is, rising feelings of effort push the actor away from the uncertainty of exploratory behaviors and toward the familiarity of established models of how the world typically functions. In a sense then, this model deals with the action *outcomes* of feelings of boredom and effort—how people typically might respond to the different states—and not the broader conception proposed here, that both effort and boredom function to indicate a deviation from an optimal set point to the organism.

In addition, it is possible to be in a low effort condition without experiencing boredom. Relaxation comes to mind (or daydreaming, or fantasizing; Klinger, 2009). It is difficult to imagine a circumstance in which relaxation feels effortful. And yet, being relaxed is antithetical to being bored, suggesting that boredom and effort do not track perfectly together. Similarly, people can find themselves in a highly effortful situation, such as learning a skill for the first time, and nevertheless persist with it if they deem it to be intrinsically motivating. Things that are intrinsically motivating are also clearly rich in meaning. This raises the possibility of yet another signal of deviation from a cognitive-affective set point; changes in situational meaning from one moment to the next may function as implicit cues that engagement is no longer optimal. What this exploration of effort regulation might suggest is that, like the signals of homeostasis (and the various neuromodulatory systems briefly touched on below), these numerous signals of deviation from a cognitive set point—boredom, effort, motivation, meaning—likely interact in complex ways to help maintain engagement.

What about signals indicating that engagement within an optimal cognitive set point *has* been achieved? Curiosity, interest, and fluency may signal effective engagement and may promote persistence with a goal (Renninger & Su, 2012). In some sense, any experience that draws on curiosity, interest or fluency, could be said to be indicative of living at the upper bounds of the cognitive set point—fully engaged in a task that is intrinsically motivating. As mentioned above, relaxation (when successful) may also indicate engagement within an optimal set point, in this instance at the lower bounds of the range, experiencing little effort, not bored, but with no desire for increased cognitive engagement. Finally, the state of flow may represent a narrowing of the range that defines the cognitive set point. The state of flow involves the experience of a very specific confluence of factors (i.e., the state is defined by no fewer than nine distinct elements; Nakamura & Csikszentmihalyi, 2014; Csikszentmihalyi et al., 2014). These distinct experiences of optimal engagement raise difficult experimental challenges. One would first need to characterize the variables (and their upper and lower bounds) that are indicative of performing within or deviating from the optimal cognitive set point. Whether these are derived from task performance (e.g., errors on sustained attention tasks), self-reports (e.g., probes triggered by changes in other variables), physiological metrics of arousal (e.g., HRV, SCL, pupillometry), or more likely some combination of these, is yet to be determined. As with biological processes of homeostasis, the conceptualization here is not intended to suggest all signals of deviation from optimal are the same, but rather that they share a functional goal—to return the system to an optimal range of engagement (see Eastwood & Gorelik, 2019 for deeper discussion of the feeling of thinking and the challenge of defining mental effort).

Homeostasis and allostasis: reactive and predictive maintenance of cognitive engagement

Homeostasis is classically defined as a regulatory mechanism or mechanisms aimed at regulating physiological parameters (e.g., heart rate, blood pressure, temperature) within a range of values (the so-called set point) to ensure viability of the organism (see Cooper, 2008 for an historical review). In this sense, homeostatic mechanisms can be considered *reactive* since the perturbations of the physiological system that push parameters outside the set point represent the data used to engage corrective responses intended to preserve values optimal for survival (Schulkin & Sterling, 2019; Sterling, 2020). On the other hand, allostatic mechanisms are predictive. Forward models in the brain anticipate the outcomes of action choices and utilize prediction errors to alter future behaviors, all in the service of the same goal as homeostatic mechanisms—viability of the organism (Schulkin & Sterling, 2019). It is likely the case that both homeostatic and allostatic mechanisms are needed for flexible control of behavior (Schulkin & Sterling, 2019). Not all circumstances lend themselves to sensible predictions, thus requiring a good deal of reactive responding, and yet behavior would be inordinately susceptible to varying contexts were humans to rely solely on reactive processing.

The conceptualization of boredom presented here suggests that it reflects the underutilization of cognitive resources, with boredom's opposite—cognitive engagement—indicative of optimal deployment of cognitive resources. In suggesting that boredom arises when there is a failure to engage cognitive resources, the signal is cast in a reactive sense—closer to homeostasis than allostasis. That is, in-the-moment feelings of boredom may engage a kind of homeostatic correction by reacting to unanticipated external exigencies—monotony for example—that pushed us away from the set point (a range of values) that represents cognitive engagement. In contrast, predictive allostatic processes may provide insights into understanding trait boredom proneness. As discussed in more detail below, faulty predictive mechanisms, deficits in comparator processes contrasting expected and actual levels of engagement, or both, may underlie the highly boredom prone individual's challenges in instigating or maintaining optimal levels of cognitive engagement (Danckert & Elpidorou, 2023).

Research could address hypotheses regarding homeostatic responses to perturbations from an optimal cognitive engagement set point by using continuous measures of physiological data associated with either task performance, on the one hand, or thought probes/affective state prompts, on the other (e.g., Hoemann et al., 2020, 2021). Note that this approach would not be aiming to determine the psychophysiological fingerprint of either boredom or cognitive engagement (as there may not be such a signature), but rather would seek to determine *inflection points*, namely, the appropriate metrics (e.g., HR, pre-ejection phase, heart rate variability, skin conductance, pupillometry, etc.) that reliably signal deviation from an optimal engagement set point. It is worth noting here that these are not the only metrics that may prove useful. Other measurable behaviors such as eye movements, fidgeting, and even facial expressions, may prove useful in determining what signals the onset of a boredom episode specifically, or deviation from an optimally engaged state more broadly (D'Mello et al., 2017).

Computational modeling represents another potential avenue for testing the proposal that people strive to maintain active engagement, with boredom signaling deviation from that optimal zone. Several recent computational models have attempted to characterize boredom in terms of opportunity costs and predictive coding (Agrawal et al., 2022; Gomez-Ramirez & Costa, 2017; Yu et al., 2019). With respect to opportunity costs, any given action choice incurs the cost of foregoing other, potentially more rewarding, avenues for engagement. In this sense, boredom arises in lockstep with increasing opportunity costs and functions as a prompt to seek alternative options for engagement (Agrawal et al., 2022; Bench & Lench, 2013; Danckert, 2019; Danckert & Elpidorou, 2023; Elpidorou, 2014, 2018a, 2018b, 2023; Kurzban et al., 2013; Struk et al., 2020; Yu et al., 2019). In terms of predictive coding, boredom has been proposed as both a solution to the dark room problem (Gomez-Ramirez & Costa, 2017; Friston et al., 2012) and as a self-regulatory signal prompting exploratory behavior (Agrawal et al., 2022). These models can be cast as computational implementations of the concept raised here of a cognitive set point. That is, the function served by exploratory behaviors driven by feelings of boredom is to keep the individual within an optimal cognitive set point.

As outlined above, homeostasis reflects a *reactive* mechanism for maintaining physiological conditions that promote survival of the organism (Sterling, 2020). A common example would be the sleep-wake dependent homeostatic process that regulates human rest (Dijk & Archer, 2009). Using late-night drowsy driving as a relatable context, vigilance decrement is among the many signals of fatigue associated with the need to rest (Lim & Dinges, 2010). When examining boredom through the lens of the homeostatic circuit, the model proposed here suggests this state would be a signal (among other possible signals) associated with a drive to restore optimal engagement. A more recent model of affective regulation suggests that allostatic regulation of emotions operates in the service of *predictive* resource allocation (Barrett, 2017; Barrett & Simmons, 2015; Barrett et al., 2016). This is an active inference account that proposes that interoceptive sensations are predicted by an internal model that anticipates the outcomes of actions, choosing specific courses of action to maintain an optimal physiological regulatory set point for the organism—i.e., allostasis (Barrett & Simmons, 2015). A key theoretical difference between homeostasis and allostasis is that the latter, which literally means “stability through change” (Sterling, 2020), involves regulated variables that are not fixed (Sterling & Eyer, 1988;

Schulkin & Sterling, 2019). Therefore, the “desired” or “set” range of values for the regulated variable can and should change, to better promote the regulatory goal of engagement. In the context of the model of affect regulation briefly outlined above, chronic boredom may arise due to a faulty internal model (i.e., inefficient representation of cognitive needs), or elevated prediction error (i.e., that actions have higher than realistic expected reward values), or some combination of both (Danckert & Elpidorou, 2023).

Computational models could directly examine the assumption that boredom signals deviation from an optimal cognitive set point from both homeostatic and allostatic perspectives. If, as suggested above, boredom arises when cognitive resources are not optimally engaged (e.g., Hunter & Eastwood, 2018), it may be the case that a homeostatic mechanism more accurately captures the role of in-the-moment feelings of boredom in maintaining a cognitive set point. In this case, any action taken to redress deviation from an optimal set point is first engaged *as a reaction to rising feelings of boredom*. But it may also prove to be important to test allostatic models in the context of dispositional differences in trait boredom proneness. This would account for the fact that internal mental models are built over long-time scales—an individual’s lifetime in many instances. For those chronically prone to boredom then, mental models may not accurately represent their needs based on previous experiences. Consistent failures to engage meaningfully with the world may have established an unrealistic cognitive set point. Stuck in an updating loop that discounts the effectiveness of any possibilities present in the environment, the faulty model is consolidated, and boredom is perpetuated. This may arise for several reasons, for example through the setting of too narrow a range for engagement (i.e., a Goldilocks zone for engagement that demands very specific conditions), or unrealistic expectations of reward values. For example, research has consistently shown a correlation between boredom proneness and higher levels of sensation seeking (Dahlen et al., 2005; Kass & Vodanovich, 1990; Zuckerman, 2007). This relation may reflect a faulty internal representation of needs for successful engagement that ultimately leads to a vicious cycle: the highly boredom prone individual seeks increased stimulation to eliminate their boredom, few options for engagement satisfy the inappropriately high threshold set for engagement, and boredom ensues. Claims of this kind are challenging to test in the lab but would be amenable to computational approaches.

Searching for a set point in the brain

What might the neural signal of being within an optimal cognitive set point look like? In essence, the past few decades of functional neuroimaging work could be cast as a vast endeavor to address that very question. When we examine the neural correlates of x, whether x is attention or working memory or decision-making or empathy, we are assuming that the participants we scan are, at the very least, attempting to utilize their cognitive resources in an optimal manner to complete the task at hand. There are several problems with this assumption. First, the tasks typically used to explore cognition and affect are generally uninteresting. Interesting environs and tasks are typically sacrificed at the altar of experimental control and statistical power, leading to excessive repetition (a grand recipe for boredom) and sparse environmental detail (the icing on boredom's cake). Thus, participants in experimental tasks may be routinely *underutilizing* cognitive resources. Second, while researchers often assume their definitions of concepts and domains are clear (to them at least), there is an enormous potential for these to be misconstrued—one neuroscientist's working memory is another's attention or worse, one neuroscientist's working memory is defined in demonstrably distinct ways from another's—a problem of ontology (Poldrack & Yarkoni, 2016). Thus, agreeing on how best to operationalize underutilization of cognitive resources and deviation from an optimal cognitive set point is a considerable challenge. Finally, the design of most neuroimaging work of the past three decades rests on subtraction logic. Therefore, we are bound to find distinct neural networks when examining any definition chosen for attention, working memory or any other cognitive-affective domain, despite the fact that all instances may reflect varying degrees of cognitive utilization. What is needed here is not simply to *image* the engaged brain, but to *imagine* first what it might look like.

Focusing on the disengaged brain could be a worthy starting point, for example, by exploring the neural networks associated with being bored, or with mind-wandering, or any state in which engagement is clearly suboptimal (Christoff et al., 2009; Chou et al., 2017; Dal Mas & Wittmann, 2017; Danckert & Merrifield, 2018; Mason et al., 2009; Rafaelli et al., 2018; Smallwood & Schooler, 2015; Ulrich et al., 2014). There is scant work examining the neural correlates of boredom, much of which confirms the association between boredom and failures of attention (Yakobi et al., 2021, Yakobi & Danckert, 2021). Contrasting the state of boredom with either flow (Ulrich et al., 2014) or interest (Danckert & Merrifield, 2018) highlights default mode activation in the bored state, but what this network of brain regions represents exactly is not entirely clear. It is conceivable, for instance, that the default mode is activated when one is engaged in prospective planning, nostalgic reverie or other forms of self-referential thought (Buckner & DiNicola, 2019). Boredom is certainly a self-referential experience; "*I* am bored." So, what this default mode activity represents may not be disengagement so much as it is a self-focused thought, rumination of a sort on the feeling of being bored (Bambrah et al., 2023). In that context, it is more than feasible to be engaged in (and by) self-referential thought—think of the contrast between daydreaming and mind-wandering.

There is some suggestion that the anterior insula cortex, a brain region that forms a key node of the so-called salience network (Craig, 2009; Uddin, 2015), also plays a role in boredom, down-regulated when induced into a bored state (Danckert & Merrifield, 2018), and up-regulated when associated with desires to escape boredom (Dal Mas & Whitman, 2017). But this work suffers from the problem of subtraction logic raised above; change the contrast conditions and distinct patterns of activation will likely be found. Exploring a particular species of cognitive engagement—for example, mindfulness (Falcone & Jerram, 2018)—doesn't solve the challenge either. Here, a great deal could be learned about *a specific kind* of cognitive engagement, but less about the *drive* to maintain a cognitive set point writ large.

Resting state scans and asymmetries in EEG power may also tell us something about the unengaged brain (and by extension what neural activity would reflect being within a cognitive set point). Recent work demonstrated an asymmetry in frontal alpha associated with boredom susceptibility (Santesso et al., 2008), and a negative correlation between trait boredom proneness and power in both the alpha and theta spectra (Yakobi et al., 2021). Interrogating EEG data in this manner may prove useful in characterizing dispositional propensities for engagement. What is needed are large data sets with multiple task environments to determine not what is *uniquely* associated with a given task, but rather what is *common* across multiple sensory domains and different goals. This is somewhat akin to the endeavor that discovered the default mode network in the first instance and has more recently been used to theorize about large-scale neural networks active across a broad range of tasks and stimulus domains (Shine & Poldrack, 2018). The question being asked is not what *specific* brain regions constitute optimal utilization of cognitive resources, but rather, what do the neural dynamics of being within that set point across a broad range of domains present as in fMRI, EEG, etc.?

One promising analysis technique along these lines is known as network topology (Shine & Poldrack, 2018). Where traditional analyses examine any regions of activation using subtraction logic, or functional connectivity—essentially exploring the correlations between regions of activation in a given task—network topology examines the extent to which activation is integrated across the whole brain (Shine & Poldrack, 2018; Shine, 2019). This approach conceptualizes the brain as a complex collection of discrete nodes that interact in measurable ways and examines the patterns (or topology) of interactions across nodes (Glasser et al., 2016; Shine & Poldrack, 2018; Shine, 2019). Structural connectivity in the brain exhibits a small world configuration (local connectivity) mediated by a rich club of highly interconnected hubs (e.g., regions such as the insula, temporo-parietal junction, dorsal and medial prefrontal cortex). These regions demonstrate high levels of connectivity with the rest of the brain. Less concerned with *which* brain regions are activated, the approach explores the extent to which a given task environment demands more or less integration of activation across the whole brain.

While it is beyond the scope of the current model to fully examine this account of brain activity (see Shine, 2019 for review), it is worth a cursory examination to explore how it might inform the drive to maintain a cognitive set point. For simple tasks that do not require complex cognitive resources (e.g., simple motor and sensory tasks) network topology is more segregated, perhaps reflective of the low demands of the task. With more complex tasks, for example, n-back working memory tasks, the topology becomes more integrated. The suggestion here is not that either a segregated or integrated brain state reflects an optimal cognitive set point, but rather that the demands of any given context will determine *the extent to which* the brain *ought* to be segregated or integrated. That is, the ascending arousal system (noradrenergic projections originating from the locus coeruleus and cholinergic projections from the basal forebrain) act as neuromodulatory control systems flexibly altering the degree of network segregation/integration (Shine, 2019). While the cholinergic system may promote segregation given associations with serotonin and selective attention (e.g., Noudoost & Moore, 2011; Yu & Dayan, 2005), the noradrenergic system may promote integration given associations with exploratory behavior (Aston-Jones & Cohen, 2005). In other words, both neuromodulatory systems could be said to promote cognitive homeostasis in distinct ways.

Interestingly, recent work suggests that hallucinations in patients with Parkinson's Disease are associated with greater between-node activation, or more specifically, greater network integration (Hall et al., 2019). The importance of this finding is in showing that there is indeed a dysfunction at some *upper* bound of network integration. In other words, more integration is not ubiquitously desired. Instead, some optimal level of integration (and, by inference, segregation in other circumstances) is needed, dependent on the task and goal contexts.

An important point here is that the neuromodulatory systems briefly discussed above (and others not mentioned) do not work in isolation, but rather form a coordinated response to changing sensory inputs, current goals, and motivational/affective states by striking a balance between segregated and integrated network states (Shine, 2019). Each of these ascending neuromodulatory systems in turn receives descending input from particular brain regions. Descending projections to the cholinergic system from the paralimbic and frontopolar regions may facilitate segregation and be important for tasks in which greater focus of resources are required. Dysregulation of this interplay may present as a failure to sustain attention on a task—a common driver of boredom (Hunter & Eastwood, 2018; Malkovsky et al., 2012). Alternatively, the noradrenergic system receives descending inputs from the dorsolateral prefrontal cortex and anterior cingulate, regions commonly involved in complex cognitive tasks and exploratory behaviors (Donoso et al., 2014; Koechlin, 2016). Again, dysregulation within this system may be felt as boredom; a failure to satisfy the desire to be engaged in meaningful goal pursuit (Eastwood et al., 2012; Gorelik & Eastwood, 2023). This systems neuroscience approach offers an objective characterization of large-scale brain activity associated with a broad range of task conditions and affective responses enabling the objective testing of the proposal that humans seek a cognitive set point.

A word on meaning

So far, this model of boredom has said little about meaning perceptions and pursuits. Rather, it focuses primarily on boredom from a cognitive engagement vantage point. This does not mean that the present account cannot be integrated with models that cast boredom as a protagonist in the pursuit of meaning. That is, cognitive engagement can be said to depend on one's capacity to extract meaning from their activities. A great deal of research has shown that boredom and boredom proneness are associated with a perceived lack of meaning both for the situation at hand and for a more general sense of life meaning (Fahlman et al., 2009; Van Tilburg & Igou, 2011, 2012, 2017; Van Tilburg et al., 2013). Whether information is considered meaningful or not likely depends on a range of factors including whether it is consistent with existing knowledge structures (Heine et al., 2006), whether it is relevant to goal pursuit (Van Tilburg & Igou, 2013), and its personal significance (Kim & Johnson, 2015). Extracting meaning at either end of the spectrum (when the rate of change of information is either too high or too low) would, in this analogy, define both boundaries of the cognitive set point. For example, not only is repetition a good determinant of boredom but it has also been shown to limit the capacity for semantic processing (Smith & Klein, 1990), and to guide decision-making away from monotony (i.e., when entropy is low; Seiler et al., 2022). It is also plausible that meaning can render repetition absent of boredom. Rituals are repetitious events imbued with meaning (e.g., regular family meals) that are typically not seen as boring (Klapp, 1986). At the other extreme, where the rate of information change *exceeds* the capacity to extract meaning, boredom is also a likely outcome (Fahlman et al., 2013; see also Struk et al., 2021; Westgate & Wilson, 2018).

In addition, perceptions of what is and is not meaningful to individuals in a given context may help to understand the *specific* actions that will restore cognitive engagement under boredom. Activities that align with one's values or cultural worldviews (and hence are seen as more meaningful; Heine et al., 2006; Van Tilburg et al., 2013) may offer a better opportunity for becoming cognitively engaged. As an example, work has shown that state boredom comes with an elevated desire to engage in meaningful action and increases donation intentions to a charity, provided that this behavior is seen as contributing to one's prosocial goals (Van Tilburg & Igou, 2017). As another example, momentary boredom causes people to ponder meaningful nostalgic memories (Van Tilburg, Igou & Sedikides, 2013). The opportunity to reflect on these personally significant nostalgic memories possibly offers more cognitive engagement than the ordinary event memories that featured in the control conditions of this research. While still rather speculative, the possibility that meaning perceptions and the pursuit of meaning under boredom may be manifestations of a more basic mechanism in a symbolic world is consistent with recent theorizing on the role of meaning under boredom and the pursuit of satisfactory—i.e., cognitively engaging—activity (Elpidorou, 2014; Moynihan et al., 2021).

Conclusion

Boredom is a ubiquitous human experience, one that has been shown to be on the rise in teenagers over the past decade or so (Weybright et al., 2020). The disposition to experience boredom frequently and intensely is consequential, with a long list of negative outcomes and maladaptive behaviors associated with boredom proneness (Danckert et al., 2018b for review). Models of boredom have focused on isolated domains to explain the experience, ranging from attentional challenges (Eastwood et al., 2012; Tam et al., 2021), to novelty seeking (Bench & Lench, 2013), and meaning making (Van Tilburg & Igou, 2012, 2017; Westgate & Wilson, 2018). More recently, the need for agency has been proposed as an overarching framework for understanding trait boredom proneness (Danckert & Eastwood, 2020; Gorelik & Eastwood, 2023). Functional accounts that cast boredom as a call to action, provide a broad framework for bringing together these disparate facets of the experience, but do not provide a mechanism for *how* boredom might lead to action (Danckert & Elpidorou, 2023). What we have proposed here casts the state and trait within a motivational framework, such that boredom signals the need to maintain an optimal level of engagement of one's cognitive resources. For the state, future research endeavors could explore whether boredom operates in the same manner at both the upper and lower bounds of a purported cognitive set point. Do other signals of deviation from optimal deployment of cognitive resources—rising feelings of effort, frustration, or anxiety as just some examples—have differential or additive effects with feelings of boredom? For the trait disposition, do the highly boredom prone set unrealistic boundaries on what constitutes optimal engagement? This possibility is particularly intriguing in the context of boredom interventions: can inappropriate expectations for engagement be reset for the highly boredom prone? Alternatively, do the highly boredom prone struggle to accurately monitor ongoing behavior and to flexibly adjust both expectations for engagement and decisions related to coping with boredom? What does the neural signature of both boredom and optimal deployment of cognitive resources look like? All these questions become feasible within the context of a drive to maintain some form of cognitive homeostasis wherein resource allocation is driven to enable optimal engagement.

Chapter 3: Interoception and Boredom Proneness

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).

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;).

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.

Research Objectives

The study 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), it was 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.

Measuring Boredom Proneness

It should be noted 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, the scale was used here for several reasons. First, much of the controversy regarding the original scale (Farmer and Sundberg, 1986) concerns the inconsistent factor structure. 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 participants were asked to complete a relatively large number of scales it was important to avoid response fatigue by using shorter scales where possible (Meier et al., 2024). Taken together, these pragmatic justifications made the use of the shortened boredom proneness scale seem like the optimal choice.

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 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, a broad swathe of metrics was chosen to encompass several possible dimensions of interoception.

Method

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 years).

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, a wide range of scales were included to examine potential relations between boredom proneness and interoceptive processing.

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.

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.

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.

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.

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.

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.

Self-Awareness Questionnaire (SAQ)

The 28-item Self-Awareness Questionnaire (SAQ; Longarzo et al., 2015) measured interoceptive awareness for commonly felt bodily sensations ($\alpha = .98$). 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.

Interoceptive Sensory Questionnaire (ISQ)

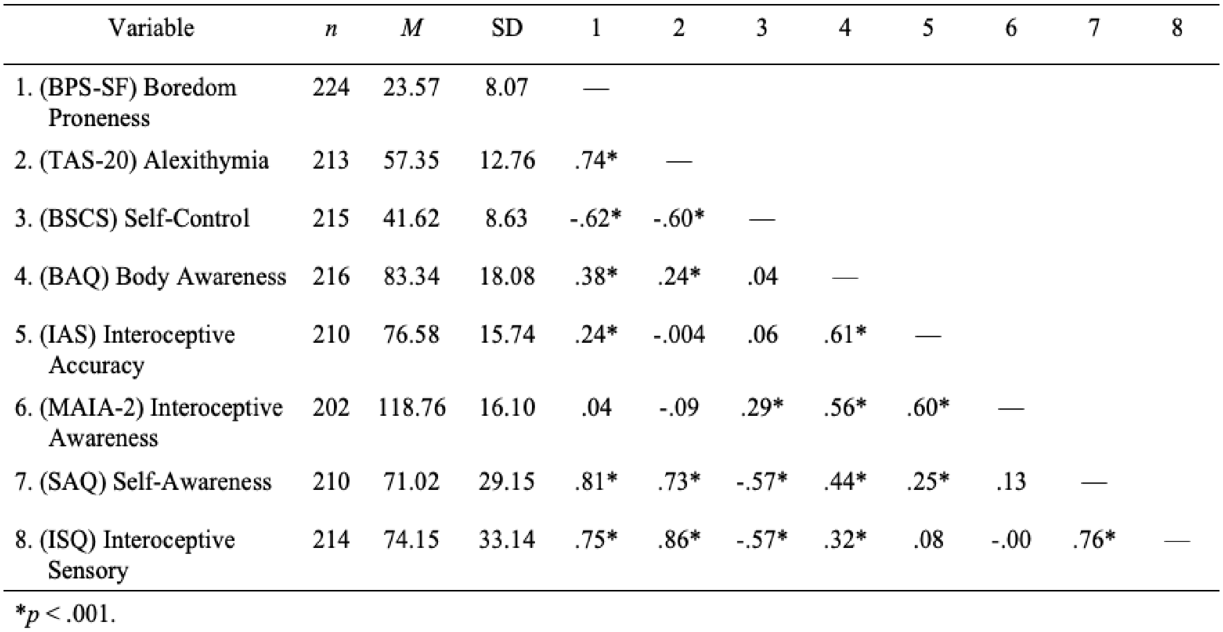
The Interoceptive Sensory Questionnaire (ISQ; Fiene et al., 2018) is a 20-item self-report questionnaire intended to measure interoceptive challenges (i.e., confusion in rating or labelling interoceptive experiences) in autistic adults ($\alpha = .98$). Participants rated items such as 'Sometimes I don't 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.

Results

The correlation matrix and descriptive statistics of all scales are presented in Table 1.

Table 1

Survey Study Descriptive Statistics and Bivariate Correlations



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.

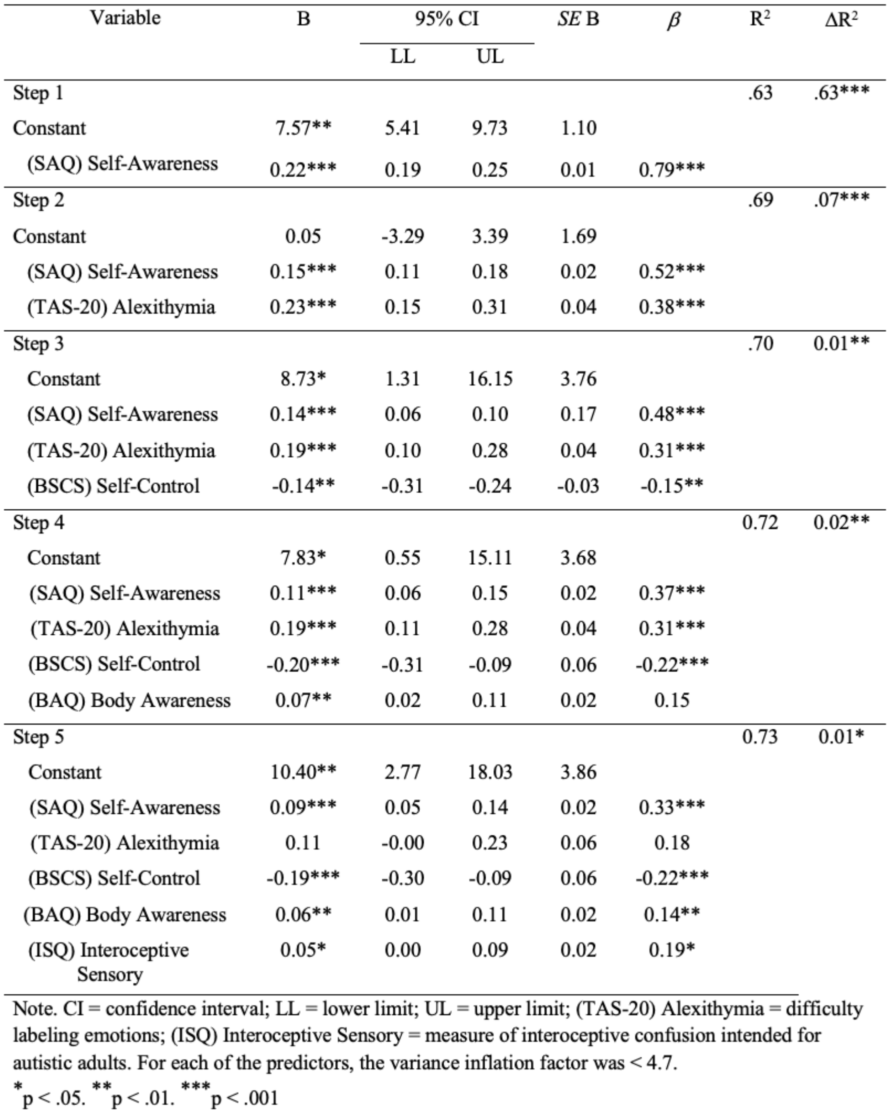
Forward Stepwise Regression

First, a forward stepwise regression was conducted 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), ΔR^2 = .01, p<.01; body awareness (BAQ), ΔR^2 = .02, p<.01; and interoceptive confusion (ISQ); ΔR^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.

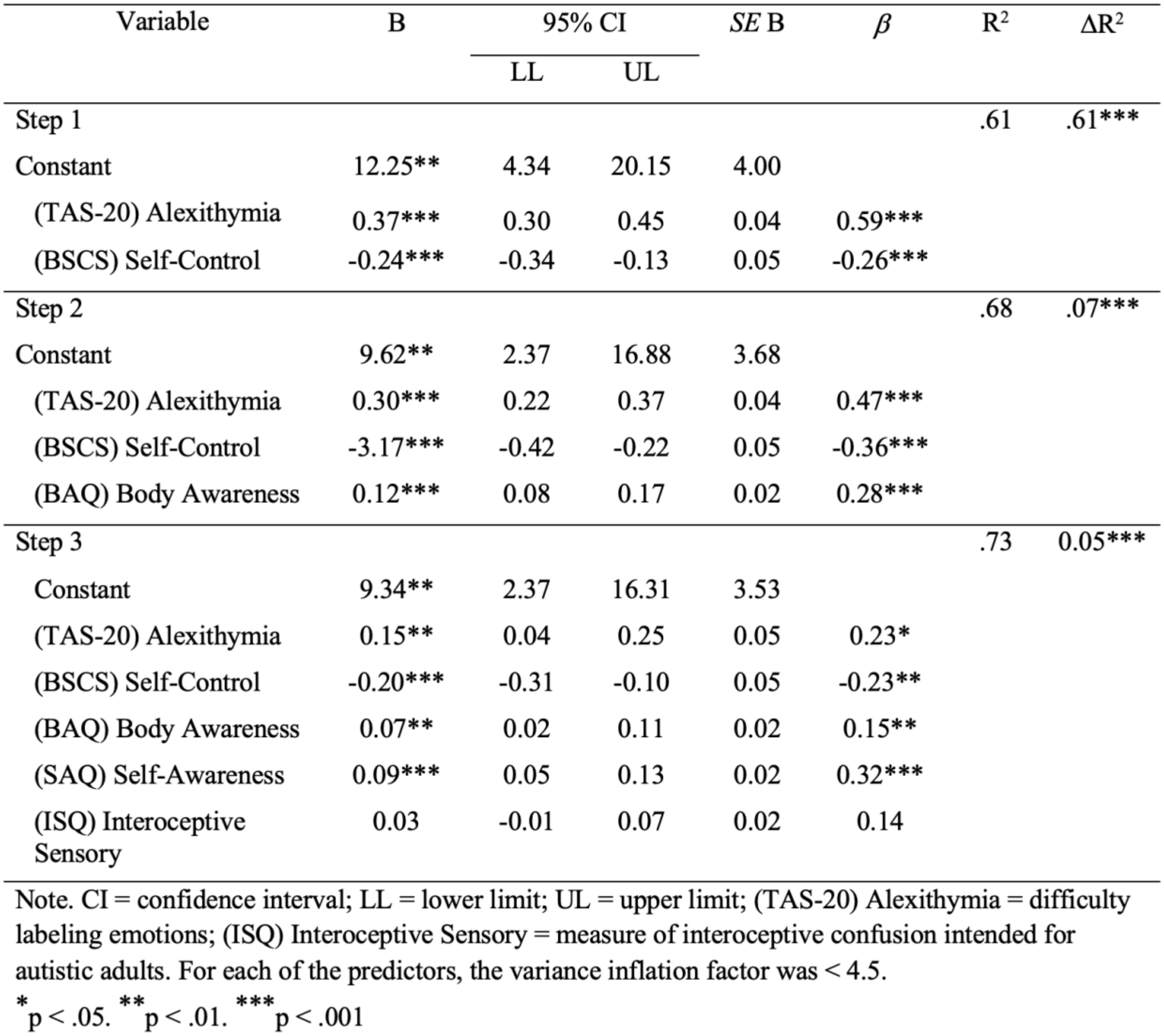
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$

Hierarchical Regression

Next, a hierarchical regression was conducted 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, variables based on the hypothesis and on the findings reported in the correlation matrix (Table 1) were selected. Given that: i) the MAIA-2 did not correlate with boredom proneness; ii) the IAS revealed only a small correlation (*r*=.24); and iii) neither was included in the forward stepwise regression above, both scales were excluded from this model. Table 3 presents the hierarchical regression results for boredom proneness. In the first step, alexithymia and self-control were entered as known relations with boredom proneness. Alexythimia and self-control positively predicted boredom proneness and explained 61% of variance (Table 3). In the second step, body awareness was added and 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).

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.

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$

Discussion

Aside from replicating known correlations linking boredom proneness to alexithymia and self-control, this exploratory study 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, the current 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, this 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 the a priori predictions that the highly boredom prone would have diminished interoceptive accuracy. 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: i) interoceptive accuracy (i.e., one's *performance* on objective behavioural tests such as heartbeat detection tasks; ii) interoceptive sensibility (i.e., the self-evaluated appraisal of subjective interoception using questionnaires); and iii) 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]’ (emphasis is added 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 the current 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.

Chapter 4: Replication Study

Sample 2

To build confidence in the results reported in Chapter 3, a replication study was conducted, and a second sample was collected.

Method

Participants

The same data screening reported above was applied to the replication sample (see the section Method on page 31 above for a full description). Responders who completed the surveys in under five minutes were removed (n=59), as were any respondents with duplicate IP addresses (n=61) and abandoned surveys (n=12). After exclusions, the final sample consisted of 124 participants (45*F*, M_{age}=37.55, SD_{age}=10.75).

Measures

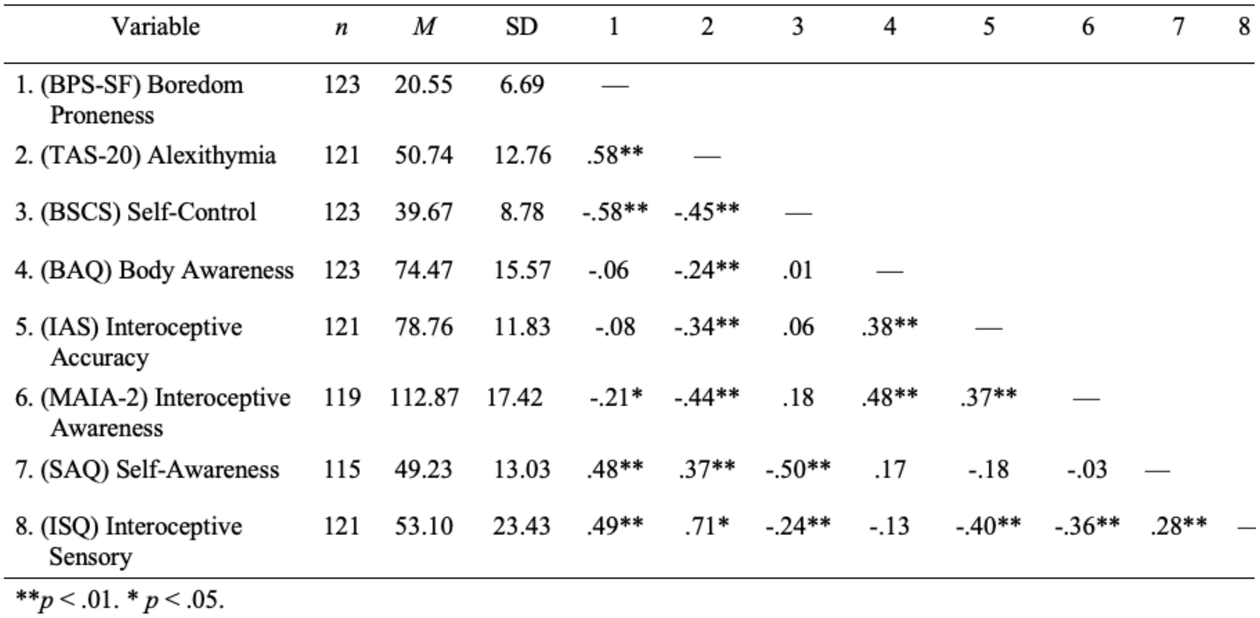
The same measures reported in the survey study above were used (see the section Measures on page 31 above for complete descriptions).

Results

The correlation matrix and descriptive statistics of all scales for the replication sample are presented in Table 4.

Table 4

Sample 2 Descriptive Statistics and Bivariate Correlations



Variable	*n*	*M*	SD	1	2	3	4	5	6	7	8
1. (BPS-SF) Boredom Proneness	123	20.55	6.69	—							
2. (TAS-20) Alexithymia	121	50.74	12.76	.58**	—						
3. (BSCS) Self-Control	123	39.67	8.78	-.58**	-.45**	—					
4. (BAQ) Body Awareness	123	74.47	15.57	-.06	-.24**	.01	—				
5. (IAS) Interoceptive Accuracy	121	78.76	11.83	-.08	-.34**	.06	.38**	—			
6. (MAIA-2) Interoceptive Awareness	119	112.87	17.42	-.21*	-.44**	.18	.48**	.37**	—		
7. (SAQ) Self-Awareness	115	49.23	13.03	.48**	.37**	-.50**	.17	-.18	-.03	—	
8. (ISQ) Interoceptive Sensory	121	53.10	23.43	.49**	.71*	-.24**	-.13	-.40**	-.36**	.28**	—

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

Sample 2 also replicated known relationships with boredom proneness such as a positive correlation between boredom proneness and alexithymia, *r*(121) = .58, *p* < .001, and a negative correlation between boredom proneness and self-control, *r*(123) = -.58, *p* < .001. The newly found correlations with boredom proneness observed in the first sample were also replicated. In the second sample, they were both moderate positive relations, first with self-awareness, *r(115)* = 0.48, *p* < .001, and second with interoceptive confusion as measured by the Interoceptive Sensory Questionnaire, *r(121)* =0.49, *p* < .001.

Interestingly, there was no significant correlation between boredom proneness and bodily awareness in the second sample. Similarly, the small positive association with interoceptive accuracy was not reproduced. This sample also yielded a modest negative correlation between boredom proneness and the Multidimensional Assessment of Interoceptive Awareness Scale (MAIA-2; *r(119)* = -0.21, *p* = .03).

Discussion

Replicating well-known relationships with boredom proneness such as a positive correlation with alexithymia and a negative correlation with self-control builds confidence in the reliability of the data collected. A smaller sample size (n=124 versus n=226) might explain the drop in magnitude of the correlations of interest with self-awareness and interoceptive confusion. Nonetheless, our replication sample still suggests that those high in boredom proneness focus intently on internal body states but may struggle to make sense of those states. The newly found negative correlation with the MAIA-2 supports its exclusion in our forward stepwise model (Table 2) while underlining the need to further test existing tools to probe interoception and its relationship with boredom proneness.

Together with the first sample described above, this replication constitutes a large adult sample that yielded two novel, moderate to strong correlations, both positive and significant ($p < .001$) that link trait boredom to an inordinate focus on internal states coupled with the struggle to make sense of those same states. Making sense of interoceptive signals likely represents a key capacity in maintaining cognitive (and affective; Barrett et al., 2016) homeostasis. That is, processing interoceptive signals is likely a critical component needed to anticipate the outcomes of intended actions. The next logical step would be to 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.

Chapter 5: Interoceptive attention and heartbeat detection

This research study aimed to investigate interoceptive accuracy as a function of trait boredom proneness. Specifically, it sought to better understand how interoceptive accuracy relates to boredom proneness as an empirical test of the hypothesis that emerged from the survey study reported above. That is, while boredom prone individuals may be acutely aware of their interoceptive cues, they struggle to make sense of those signals and as such may be less accurate in quantitative tasks such as heart rate counting. In addition, heart rate was collected as a psychophysiological measure during the heart rate counting task and two separate mood inductions (boredom and interest) to explore how these variables might inform the relation between boredom proneness and interoceptive accuracy.

Method

Participants

Healthy participants were recruited online among undergraduate students via a university-sponsored site for research. In return for their participation, they received 1 course credit. The study was approved by the University of Waterloo's Research Ethics Board and informed consent was obtained from all participants prior to the study.

A priori, we aimed at collecting the largest number of participants possible within a single term timeframe with a minimum of at least 50. Survey responses and physiological measures were collected for 105 participants (80 female, 19 male, 4 non-binary, 2 undisclosed). The mean age was 21.13, (*SD* = 4.6).

Screening the survey data for response time did not exclude any participant based on unreasonably fast response time. The fastest respondent in this sample averaged 7 seconds per question.

Materials

Skin conductance was collected using AD Instruments ML T116F finger electrodes and heart rate was measured using AD Instruments Finger Pulse Transducer TN1012/ST. Both finger transducers were connected to one AD Instruments PowerLab 4/30ML866 data acquisition device. Physiological data was collected and processed on an iMAC computer running LabChart 7. The participant was seated in front of a second computer running the experiment on PsychoPy (Peirce et al., 2019).

Measures

The **Short Boredom Proneness Scale** (BPS-SF; Struk et al., 2017) was used to measure boredom proneness (see page 32 above for a full description). Cronbach's alpha for the current study was good with a score of 0.85. Although normally distributed, the representation of boredom proneness in the current sample was low (*N* =103: *M* =21.93, *SD* = 6.5). The larger participant pool for the term from which it was drawn (Fall 2023) had a more typical distribution of responses (*N* = 2,315, *M* = 29.43, *SD* = 10.22).

For replication and hypothesis testing purposes, participants were asked to fill out the four following scales:

1. The 18-item **Body Awareness Questionnaire** (BAQ; Shields et al., 1989) as described above on page 33. Cronbach's alpha for the current study was good with a score of 0.83.
2. The 21-item **Interoceptive Accuracy Scale** (IAS; Murphy et al., 2019) as described above on page 33. Cronbach's alpha reliability for the current study was 0.80.
3. The 20-item **Interoceptive Sensory Questionnaire** (ISQ; Fiene et al., 2018) as described above on page 34. Cronbach's alpha for the current study was excellent with a score of 0.93.

4. The 28-item **Self-Awareness Questionnaire** (SAQ; Longarzo et al., 2015) as described above on page 34. Cronbach's alpha for the current study was excellent with a score of 0.90.

Procedure

This experiment consisted of two parts: a heartbeat counting task followed by two mood inductions (i.e., boredom and interest). Heart rate was measured throughout both parts. Participants were seated in front of a computer screen with one finger pulse transducer connected to the index finger of their non-dominant hand. Baseline measures of heart rate were obtained by instructing the participant to sit with their eyes closed for two minutes. They were then asked to report the number of heartbeats perceived in three distinct time intervals (25, 35 and 45 seconds). The actual number of heartbeats occurring during each trial was recorded to compare with the number reported as a measure of accuracy.

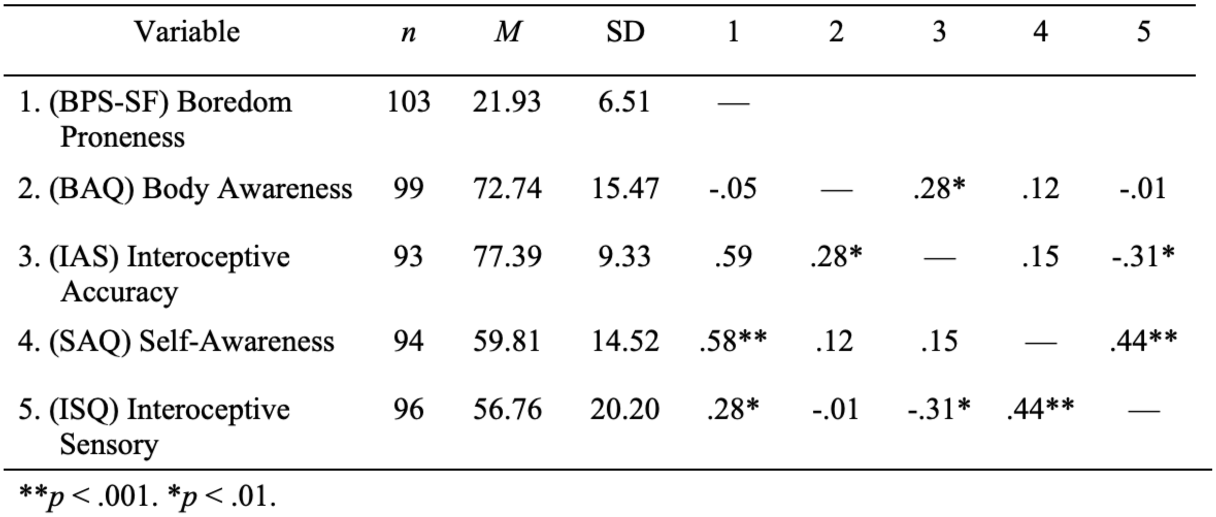
A second baseline epoch of two minutes with eyes closed was then collected prior to commencing the mood inductions. Prior to the inductions commencing, participants rated their level of state boredom on a Likert scale from 1 (not at all bored) to 7 (extremely bored). Participants also rated their level of interest on a scale from 1 to 7. Then, participants watched a boredom inducing movie for approximately 4 minutes after which their boredom and interest ratings were collected once more. This procedure was repeated for the interest inducing video. Every participant watched the boredom inducing video first and the interest video last.

Results

Scores on all scales were normally distributed with skewness ranging from -0.19 to 0.54 and kurtosis ranging from -0.18 to 1.16. Table 5 shows the correlation matrix for all scales.

Table 5

Experiment Sample Descriptive Statistics and Bivariate Correlations



Variable	*n*	*M*	SD	1	2	3	4	5
1. (BPS-SF) Boredom Proneness	103	21.93	6.51	—				
2. (BAQ) Body Awareness	99	72.74	15.47	-.05	—	.28*	.12	-.01
3. (IAS) Interoceptive Accuracy	93	77.39	9.33	.59	.28*	—	.15	-.31*
4. (SAQ) Self-Awareness	94	59.81	14.52	.58**	.12	.15	—	.44**
5. (ISQ) Interoceptive Sensory	96	56.76	20.20	.28*	-.01	-.31*	.44**	—

**$p < .001$. *$p < .01$.

In line with the results of both previous experiments (Chapters 3 and 4), boredom proneness was moderately, positively correlated with self-awareness, *r(94)* = 0.48, *p* < .001. Similarly, interoceptive confusion as measured by the Interoceptive Sensory Questionnaire yielded a modest but significant positive correlation with boredom proneness, *r(96)* = 0.28, *p* = .007.

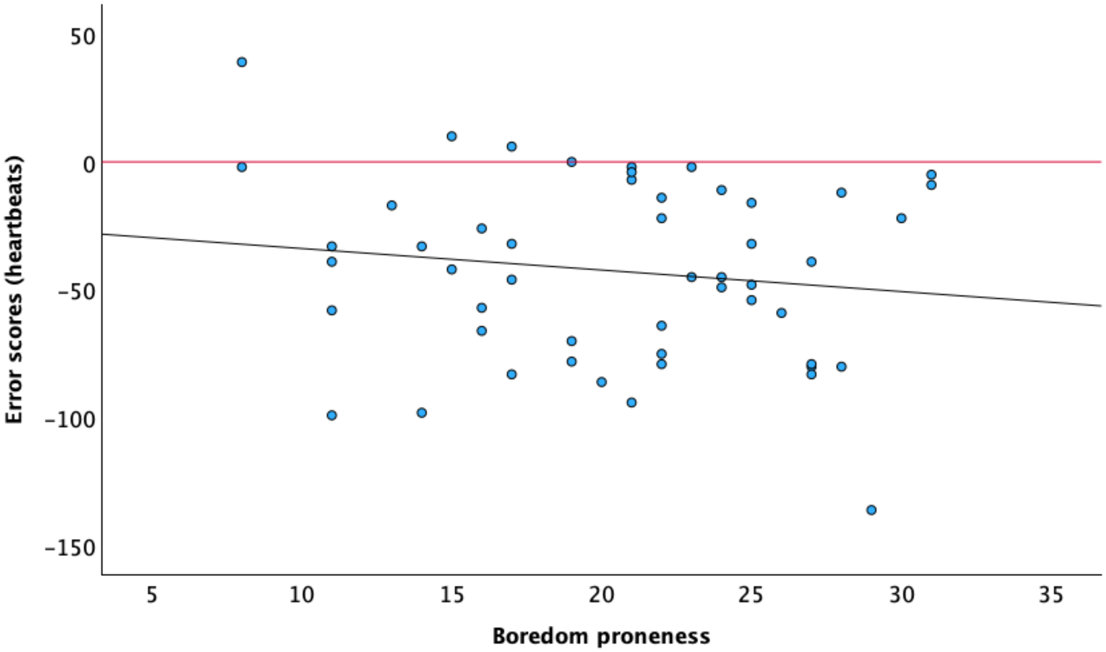
Physiological data curation is ongoing. Thus far, heart rate data was extracted to constitute a sample of 52 participants (33F, M_{age}= 20.49, *SD*=3.81) and allow for partial analysis of the data. The next sections will discuss these results.

Heartbeat Detection Task

The number of reported heartbeats was subtracted from the number of actual heartbeats for each of the three intervals and then averaged to create a mean error score for each participant. These scores did not significantly vary as a function of boredom proneness (*r*(51) = -.14, *p* = .32; Figure 1).

Figure 1

Scatterplot of error scores and boredom proneness

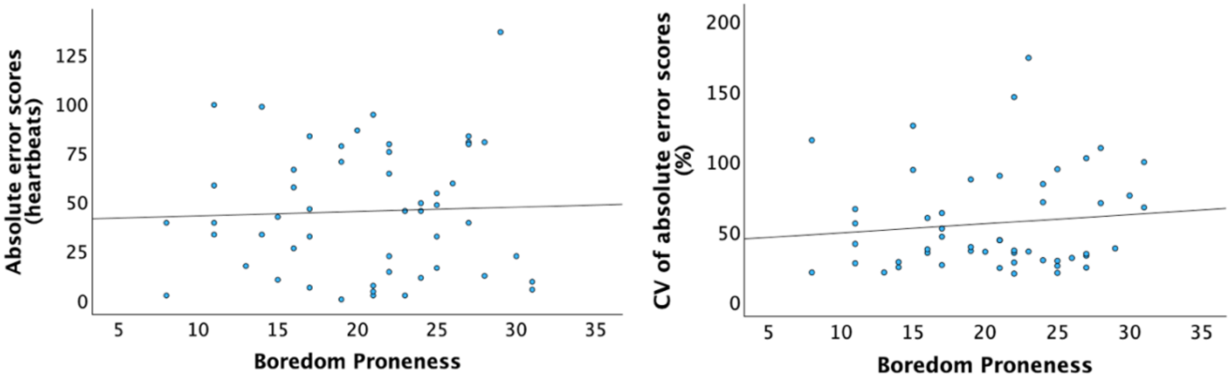


Note. N=51. Scatterplot of heartrate counting error and boredom proneness. Scores above the zero line (indicated in red) indicate overestimates, whereas scores below this line represent underestimates. The line of best fit for the data is indicated in a black, solid line.

Similarly, absolute error scores (an indication of the magnitude of error) were not significantly correlated with boredom proneness (*r*(51) = 0.04, *p* = .77). To examine variability in responding on this task the Coefficient of Variation (CV) was calculated for each participant by dividing the standard deviation of the participant's performance by the mean over all three trials. A high CV indicates a high variance and can be more than 100% if the standard deviation is greater than the mean. There was no significant correlation between participants' CV and boredom proneness (*r*(51) = 0.11, *p* = .44).

Figure 2

Scatterplots of absolute error and coefficient of variance scores as a function of boredom proneness



Note. N=51.

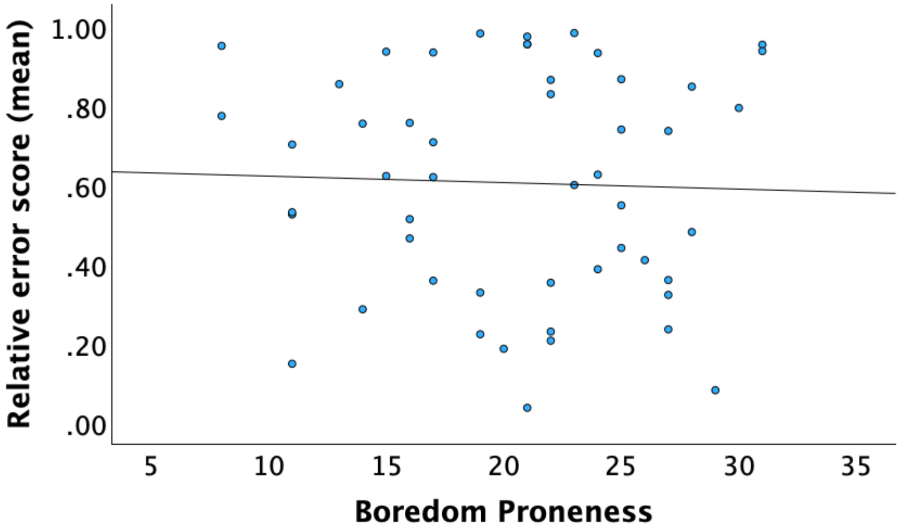
Previous studies probing interoceptive accuracy using heartbeat detection tasks have computed a relative error score that includes reported values in the denominator to prevent overestimating performance when variance is high (Garfinkel et al., 2015; Hart et al., 2013). Each trial was calculated as follows:

$$1 - \frac{(\left|n\text{beats}_{actual} - \; n\text{beats}_{reported}\right|)}{((n\text{beats}_{actual} + \; n\text{beats}_{reported})/2)}$$

Resulting scores were averaged over the three trials for each participant. These relative performance scores did not correlate significantly with boredom proneness (*r*(51) = -0.35, *p* = .81; Figure 3).

Figure 3

Scatterplot of relative error scores and boredom proneness



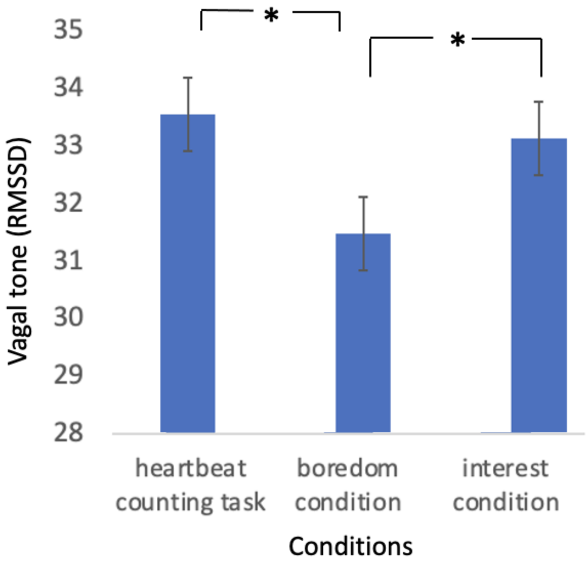
Note. This figure represents a dimensionless performance score for each participant. A value of 1.00 indicates perfect heartbeat detection: $n\text{beats}_{actual} = n\text{beats}_{reported}$.

Results from the first part of the experiment indicated that boredom prone individuals were not less accurate in counting their heartbeats than other participants. This smaller sample replicated the boredom proneness and self-awareness correlation ($r(51) = 0.55$, $p < .001$); however, the correlation between boredom proneness and interoceptive confusion was not replicated in this sample size.

Next, AD Instruments software LabChart 7 was used to extract the heartbeat data collected and Root Mean Square of Successive Differences (RMSSD) was obtained to calculate vagal tone — an objective measure of heart rate variability (HRV; Laborde et al., 2017).
The averaged RMSSD was obtained for all conditions by calculating each successive time difference between heartbeats in milliseconds. These values were squared and results were averaged. Then, the square root of the total was obtained. Figure 4 depicts the RMSSD results.

Figure 4

Vagal tone across all conditions



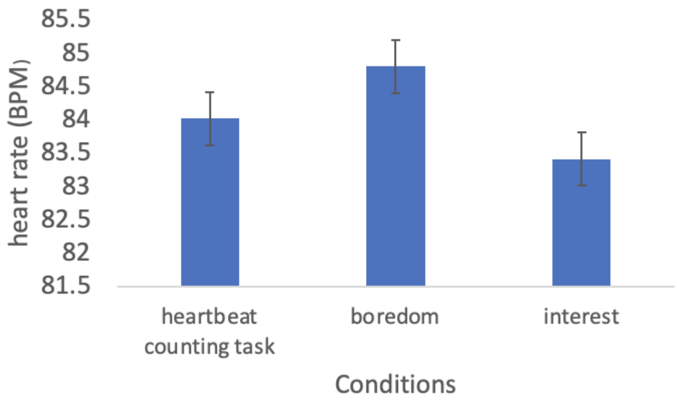
Note. N=47. Total outliers removed = 4 (heartbeat recording error = 2 and ± 2.5 *SD* from the mean = 2). **p* = .03. Error bars = Standard Error.

A paired-samples t-test comparing RMSSD in the boredom and heartbeat counting task conditions showed a significant difference (boredom *M*= 31.4, *SD* = 15.28); heartbeat counting task *M*= 33.4 (*SD*=15.39; *t*(46)= -1.90, *p* = .03).

A second paired-samples t-test comparing RMSSD in the boredom and interest conditions also showed a significant difference (interest *M*= 33.0, *SD*=15.10; *t*(46)= -1.99, *p* = .03). As depicted in Figure 4, boredom led to a stronger stress response (lower RMSSD) than either the heartbeat counting task or the interest condition. Figure 5 depicts the averaged heart rate across all conditions. Participants heart rate tracked with RMSSD results as expected with the highest Beats Per Minute (BPM) recorded during the boredom condition (84.81) as compared to either the heart rate counting task (84.02) or the interest induction (83.41).

Figure 5

Averaged heart rate across conditions

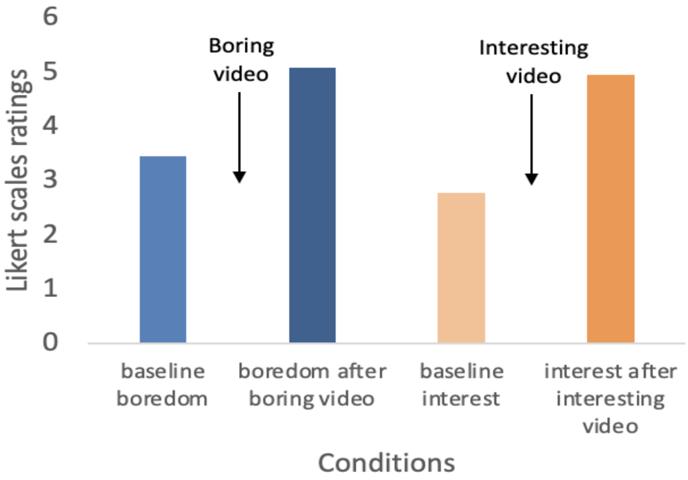


Note. N=47. Error bars = Standard Error.

Finally, subjective measures of boredom and interest before and after mood inductions were compiled. As expected, participants reported higher levels of boredom than interest after watching the boring video and higher interest than boredom after watching the interesting video (Figure 6).

Figure 6

Subjective measures of boredom and interest before and after mood inductions



Note. N=47. Baselines: Participants were instructed to close their eyes for 2 minutes.

Discussion

The data collected here does not suggest that those high in boredom proneness experience any challenges in accurately perceiving interoceptive signals, at least in the domain of heartbeat counting. Taken together with survey results from Chapters 3 and 4, results from the heartbeat counting task indicated that even though boredom prone individuals report struggling to make sense of their interoceptive cues, their objective estimates of their own heart beats were not significantly different than those low in boredom proneness. It is worth noting that the sample analyzed here exhibited a lower than typical level of boredom proneness (*M*=20.53) when compared to the larger sample it was drawn from (*M*=29.43; the large sample mean is typical of undergraduate samples tested in our lab (e.g., Mugon & Danckert, 2018). It is plausible that participants high in boredom proneness chose not to participate given that the task description used for recruitment clearly stated that boredom would be induced, which is a particularly unappealing prospect for the highly boredom prone (Tam et al., 2020). It is plausible that the inclusion of a sample more representative of the full spectrum of boredom proneness may highlight relations not seen in the current sample.

When contrasting the induction of boredom with interest, results indicated that boredom induced a stress response consistent with accounts of boredom as a negatively valenced experience (Van Tilburg & Igou, 2011). That is, the boredom mood induction led to lower RMSSD and higher BPM than was observed in either the interest mood induction or the heartbeat counting task. This also aligns with previous work showing that boredom led to higher BPM relative to a sadness induction (Merrifield & Danckert, 2014). In that study, results were interpreted to reflect a disengaged attentional state given the pattern of directional fractionation observed (elevate heart rate coupled with lower skin conductance levels). It is possible that both things are true of the bored state – that when bored we are disengaged *and* feel this to be a negative experience (Gorelik & Eastwood, 2019). This would fit well with the cognitive homeostasis model developed in this thesis. Underutilization of cognitive resources may first indicate a disengaged attentional state. Coding such disengagement as negatively valenced would work well to propel the organism to find alternate options for engagement.

Chapter 6: General Discussion

The first part of this thesis proposed a model of affective regulation with flexible and context-dependent values delimiting a desired cognitive set point. Analogous to homeostatic regulation, the model suggests that feelings of boredom operate as one of many possible self-regulatory signals that indicate departure from that set point. Excursions outside of one's cognitive homeostatic set point are necessarily felt as unpleasant. They are also disadvantageous to the agent in terms of performance and mental well-being. Additionally, it explores boredom proneness, the trait propensity to experience boredom, as signalling a dysfunctional regulation of the cognitive set point.

For a model to be useful, its metaphor should help illustrate, understand, and predict a complex concept. Representing boredom in the context of affective regulation with an analogy to a homeostatic system underlines the importance of a dynamic balance between internal and external milieus. With a better understanding of how internal and external signals are perceived and processed, more efficient prediction of outcomes becomes possible. For instance, the model predicts that when an environment is either over or understimulating/challenging/varied, the external milieu will be perceived as distressing. The felt nature of that distress will likely vary as a function of both external contingencies and internal goal states. Regardless, an adequate response to the distress must arise from the agent engaging actions that attempt to stabilize cognitive engagement with the environs. The feeling of boredom (i.e., a signal of cognitive underutilization) that surfaces at that moment should serve as a prompt to regulate behavior by moving to an activity that would reinstate cognitive engagement. This may represent a point of failure for those high in trait boredom proneness. Their failure to launch into action may stem from a difficulty in regulating responses to seek alternate activities to alleviate the discomfort.

Data from Chapter 3 aimed to explore boredom proneness as an indication of dysfunctional regulation of the cognitive set point. The objective was to measure the relations between trait boredom proneness and interoceptive processing given the latter is deemed important for maintaining a cognitive setpoint. That is, accurately representing interoceptive signals likely plays an important role in affective regulation and in the anticipation of what may or may not constitute an engaging activity (Barrett, 2017; Danckert & Elpidorou, 2023). Probing interoception was considered to be a sensible approach given the link between insular activation and state boredom uncovered in previous neuroimaging work (Danckert and Merrifield, 2018; Dal Mas & Wittman, 2017). Other neuroimaging work has linked the posterior insula to afferent interoceptive cues such as cardiac vagal tone, and the anterior insula to the integration of these interoceptive signals with exteroceptive sensory information (Nguyen et al., 2016). Paired with the notion that the anterior insula is involved in the subjective experience of emotions (Craig, 2009), it seemed plausible that trait boredom proneness would be linked to differences in interoceptive abilities.

In two samples, results showed that those high in boredom proneness tend to pay an inordinate amount of attention to interoceptive signals but struggle to make sense of them. Both samples tested here also replicated well-known relationships with boredom proneness, including a negative relation with self-control (e.g., Isacescu et al., 2017), and a positive correlation with alexithymia (Eastwood et al., 2007). This latter relation is interesting as it suggests that difficulties in making sense of interoceptive signals may be at the heart of alexithymic challenges for the highly boredom prone.

Despite the survey findings discussed briefly above, objective measures of interoceptive accuracy showed no relation with boredom proneness. While the sample tested were lower in boredom proneness than typical samples, it may also be the case that objective and subjective metrics do not coincide. Recent work exploring the ontology of self-control showed that there is no relation between self-report measures and task metrics in that domain (Eisenberg et al., 2019). Furthermore, when using either domain to predict real-world outcomes, it was only the self-report measures that did a moderate job of prediction (Eisenberg et al., 2019). There may be many reasons for this, sensitivity being a prominent one. Indeed, the tasks or measures used may lack the requisite sensitivity to detect differences that are well captured by self-report.

Nevertheless, it is possible that there are also compensatory mechanisms at play to remediate the perceived struggle a high boredom prone individual has in making sense of interoceptive cues. Further research would be needed to explore possible compensatory mechanisms. Another hypothesis derived from the work of Nguyen and colleagues (2016) mentioned above concerns the different roles of the anterior and posterior insular cortex. That is, the heartbeat counting exercise is more appropriately considered as a posterior-insula task given the role this region plays in primary interoceptive perception (Craig, 2009). In contrast, the subjective, conscious interpretation of interoceptive signals, and the integration of those signals with external contingencies, likely depends more on the anterior insula cortex (Craig, 2009). In other words, trait boredom proneness may stem from differences in how the brain integrates interoceptive signals to represent emotions such as boredom in order to predict the best way to alleviate the discomfort, rather than differences in how those interoceptive cues are perceived per se. An alternative explanation of these results could be linked back to previous research such as the work of Wiens (2000) suggesting that interoceptive accuracy plays a role in the experience of the intensity of emotions, namely that good heartbeat detectors reported feeling emotions more intensely. Since the direction of this relationship is not clear, feeling boredom more intensely than most coupled with accrued self-awareness may slightly boost heartbeat detection abilities for individuals experiencing chronic boredom despite their reporting of interoceptive confusion. Perhaps these enhancing particularities of chronic boredom are sufficient to mask possible differences with non-boredom prone individuals in a heartbeat detection task.

Despite finding no relation with interoceptive accuracy, heart rate measures did confirm past results that characterize state boredom as an aversive, disengaged state (Merrifield & Danckert, 2014; Van Tilburg & Igou, 2011; Eastwood et al., 2012). That is, the elevated heart rate and a stronger stress response (lower RMSSD) associated with the boredom mood induction accord well with accounts of boredom as a negatively valenced feeling (Danckert & Elpidorou, 2023). Moreover, subjective assessments of boredom and interest levels between inductions track perfectly with the emotions that were induced (i.e., boredom and interest) and the physiological measures collected (i.e., a lower stress response when on tasks or watching an interesting video). Together these results characterize state boredom as a physiological stressor that ultimately ought to guide the organism to find alternate ways to engage cognitive resources more optimally. The activation of the sympathetic nervous system in the boredom condition fits well as a push to restore cognitive homeostasis by switching to a more positively valenced activity.

To address the possibility that the task used here was simply not sensitive enough to detect differences associated with boredom proneness, future work may use a heart rate phase adjustment task. While silent counting of heartbeats perceived is a pragmatic test of objective interoceptive accuracy, artifacts can emerge from participants using previous knowledge of their heart rate to guide responses. The heart rate phase adjustment task is more robust to both physiological and strategic confounds (Plans et al., 2021). Instead of counting their heartbeats, participants are asked to adjust a dial to match their actual heartbeat to a tone that is slightly out of phase with their actual heartbeat. Also, the task could be expanded to directly assess the potential difference in predictive abilities by prompting participants to rate their interoceptive confidence after each trial (i.e., predict their accuracy performance). Any discrepancy between accuracy scores and confidence ratings could be construed as an interoceptive prediction error score. Analyses could then evaluate predictive abilities as a function of trait boredom proneness (see Garfinkel et al., 2015 for an example of this approach).

In conclusion, this thesis has demonstrated novel relations between boredom proneness and interoception that warrant further research to understand how interoception may guide the experience of boredom. The model developed here also lays out new avenues for investigation to further characterize the experience and its implications on cognitive-affective regulation, as well as motivation to attend to, and engage with, the environment.

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Appendices

Appendix A - Self-Awareness Questionnaire (SAQ)

Longarzo et al., 2015.

1. I feel my heartbeat in my ears.
2. I feel very hot in comparison to others.
3. I feel pain extremely.
4. I feel my stomach tightening.
5. I feel a sudden hunger pang.
6. I feel my back ache.
7. I feel pins and needles.
8. I feel that I can’t get enough air into my lungs.
9. I have an extra-strong heartbeat.
10. I feel full and bloated after eating.
11. I have the sudden urge to urinate.
12. I feel as if I am on fire.
13. I feel a burning sensation in my stomach.
14. I feel a pain in my stomach.
15. I feel very cold in comparison to others.
16. I feel like I have to throw up.
17. I feel chilled.
18. I feel my legs heavy.
19. I feel my throat dry.
20. I have a heavy feeling in my chest.
21. I feel my heart thudding.
22. I feel sudden thirst pangs.
23. I feel breathless without engaging in any type of exertion and effort.
24. I feel my ears burning.
25. I feel a lump in my throat.
26. I feel faint.
27. I feel my palms sweaty.
28. I have difficulty in swallowing.

Scoring:

5-point Likert scale

Appendix B - Multidimensional assessment of interoceptive awareness (MAIA-2)

Mehling et al., 2018.

Noticing

1. When I am tense, I notice where the tension is located in my body.
2. I notice when I am uncomfortable in my body.
3. I notice where in my body I am comfortable.
4. I notice changes in my breathing, such as whether it slows down or speeds up.

Non-Distracting

5. *I ignore physical tension or discomfort until they become more severe.
6. *I distract myself from sensations of discomfort.
7. *When I feel pain or discomfort, I try to power through it.
8. *I try to ignore pain.
9. *I push feelings of discomfort away by focusing on something.
10. *When I feel unpleasant body sensations, I occupy myself with something else so I don't have to feel them.

Not-Worrying

11. *When I feel physical pain, I become upset.
12. *I start to worry that something is wrong if I feel any discomfort.
13. I can notice an unpleasant body sensation without worrying about it.
14. I can stay calm and not worry when I have feelings of discomfort or pain.
15. *When I am in discomfort or pain I can't get it out of my mind.

Attention Regulation

16. I can pay attention to my breath without being distracted by things happening around me.
17. I can maintain awareness of my inner bodily sensations even when there is a lot going on around me.
18. When I am in conversation with someone, I can pay attention to my posture.
19. I can return awareness to my body if I am distracted.
20. I can refocus my attention from thinking to sensing my body.
21. I can maintain awareness of my whole body even when a part of me is in pain or discomfort.
22. I am able to consciously focus on my body as a whole.

Emotional Awareness

23. I notice how my body changes when I am angry.
24. When something is wrong in my life I can feel it in my body
25. I notice that my body feels different after a peaceful experience.
26. I notice that my breathing becomes free and easy, when I feel comfortable.
27. I notice how my body changes when I feel happy/joyful.

Self-Regulation

28. When I feel overwhelmed, I can find a calm place inside.
29. When I bring awareness to my body, I feel a sense of calm. (This q was skipped in S1/S2 in Qualtrics)
30. I can use my breath to reduce tension (This q was labeled as Q29)
31. When I am caught up in thoughts, I can calm my mind by focusing on my body/breathing. (Q30)

Body Listening

32. I listen for information from my body about my emotional state.
33. When I am upset, I take time to explore how my body feels.
34. I listen to my body to inform me about what to do.

Trusting

35. I am at home in my body.
36. I feel my body is a safe place
37. I trust my body sensations.

Scoring:

5-point Likert scale

* indicates a reversed scored item

Appendix C - Interoceptive Sensory Questionnaire (ISQ)

Fiene et al., 2018.

1. I have difficulty making sense of my body’s signals unless they are very strong.
2. I tend to rely on visual reminders (e.g. times on the clock) to help me know when to eat and drink.
3. I have difficulty feeling my bodily need for food.
4. I’m not sure how my body feels when it’s a hot day.
5. I find it difficult to describe feelings like hunger, thirst, hot or cold.
6. Sometimes I don’t know how to interpret sensations I feel within my body.
7. If I injure myself badly, even though I can feel it, I don’t feel the need to do much about it.
8. I only notice I need to eat when I’m in pain or feeling nauseous or weak.
9. There are times when I am only aware of changes in my body because of the reactions of other people.
10. I find it difficult to read the signs and signals within my own body (e.g. when I have hurt myself or I need to rest).
11. I have difficulty understanding when I am hungry or thirsty.
12. I find it difficult to identify some of the signals that my body is telling me (ex. if I’m about to faint or I’ve overexerted myself)
13. It is difficult for me to describe what it feels like to be hungry, thirsty, hot, cold or in pain.
14. I am confused about my bodily sensations.
15. I have difficulty locating injuries in my body.
16. Sometimes, when my body signals a problem, I have difficulty working out what the problem might be.
17. I don’t tend to notice feelings in my body until they’re very intense.
18. I find it difficult to put my internal bodily sensations into words.
19. Even when I know that I am hungry, thirsty, in pain, hot or cold, I don’t feel the need to do anything about it.
20. Even when I know that I am physically uncomfortable, I do not act to change my situation.

Scoring:

5-point Likert scale

Appendix D - Interoceptive Accuracy Scale (IAS)

Murphy et al., 2019.

1. I can always accurately perceive when my heart is beating fast.
2. I can always accurately perceive when I am hungry.
3. I can always accurately perceive when I am breathing fast.
4. I can always accurately perceive when I am thirsty.
5. I can always accurately perceive when I need to urinate.
6. I can always accurately perceive when I need to defecate.
7. I can always accurately perceive when I encounter different tastes.
8. I can always accurately perceive when I am going to vomit.
9. I can always accurately perceive when I am going to sneeze.
10. I can always accurately perceive when I am going to cough.
11. I can always accurately perceive when I am hot/cold.
12. I can always accurately perceive when I am sexually aroused.
13. I can always accurately perceive when I am going to pass wind.
14. I can always accurately perceive when I am going to burp.
15. I can always accurately perceive when my muscles are tired/sore.
16. I can always accurately perceive when I am going to get a bruise.
17. I can always accurately perceive when I am in pain.
18. I can always accurately perceive when my blood sugar is low.
19. I can always accurately perceive when someone is touching me affectionately rather than non-affectionately.
20. I can always accurately perceive when something is going to be ticklish.
21. I can always accurately perceive when something is going to be itchy.

Scoring:

5-point Likert scale

Appendix E - Body Awareness Questionnaire (BAQ)

Shields et al., 1989.

1. I notice differences in the way my body reacts to various foods.
2. I can always tell when I bump myself whether or not it will become a bruise.
3. I always know when I've exerted myself to the point where I'll be sore the next day.
4. I am always aware of changes in my energy level when I eat certain foods.
5. I know in advance when I'm getting the flu.
6. I know I'm running a fever without taking my temperature.
7. I can distinguish between tiredness because of hunger and tiredness because of lack of sleep.
8. I can accurately predict what time of day lack of sleep will catch up with me.
9. I am aware of a cycle in my activity level throughout the day.
10. * I don't notice seasonal rhythms and cycles in the way my body functions.
11. As soon as I wake up in the morning, I know how much energy I'll have during the day.
12. I can tell when I go to bed how well I will sleep that night.
13. I notice distinct body reactions when I am fatigued.
14. I notice specific body responses to changes in the weather.
15. I can predict how much sleep I will need at night in order to wake up refreshed.
16. When my exercise habits change, I can predict very accurately how that will affect my energy level.
17. There seems to be a "best" time for me to go to sleep at night.
18. I notice specific bodily reactions to being over-hungry.

Scoring:
7-point Likert scale
* indicates a reversed scored item

Appendix F - The Shortened Boredom Proneness Scale (BPS-SR)

Struk et al., 2017.

1. I often find myself at “loose ends,” not knowing what to do.
2. I find it hard to entertain myself.
3. Many things I have to do are repetitive and monotonous.
4. It takes more stimulation to get me going than most people.
5. I don’t feel motivated by most things that I do.
6. In most situations, it is hard for me to find something to do or see to keep me interested.
7. Much of the time, I just sit around doing nothing.
8. Unless I am doing something exciting, even dangerous, I feel half-dead and dull.

Scoring:
5-point Likert scale

Appendix G - The Brief Self-Control Scale (BSCS)

Tangney, Baumeister & Boone, 2004.

1. I am good at resisting temptation.
2. * I have a hard time breaking bad habits.
3. * I am lazy.
4. * I say inappropriate things.
5. * I do certain things that are bad for me, if they are fun.
6. I refuse things that are bad for me.
7. * I wish I had more self-discipline.
8. People would say I have iron self-discipline.
9. * Pleasure and fun keep me from getting work done.
10. * I have trouble concentrating.
11. I am able to work effectively toward long-term goals.
12. *Sometimes I can’t stop myself from doing something, even if I know it is wrong.
13. *I often act without thinking through all the alternatives.

Scoring:

5-point Likert scale

* indicates a reverse scored item

Appendix H - The Toronto Alexithymia Scale (TAS-20)

Bagby et al., 1994.

1. I am often confused about what emotion I am feeling.
2. It is difficult for me to find the right words for my feelings
3. I have physical sensations that even doctors don't understand.
4. *I am able to describe my feelings easily.
5. *I prefer to analyze problems rather than just describe them.
6. When I am upset, I don't know if I am sad, frightened, or angry.
7. I am often puzzled by sensations in my body.
8. I prefer to just let things happen rather than to understand why they turned out that way.
9. I have feelings that I can't quite identify.
10. *Being in touch with emotions is essential.
11. I find it hard to describe how I feel about people.
12. People tell me to describe my feelings more.
13. I don't know what's going on inside me.
14. I often don't know why I am angry.
15. I prefer talking to people about their daily activities rather than their feelings.
16. I prefer to watch "light" entertainment shows rather than psychological dramas.
17. It is difficult for me to reveal my innermost feelings, even to close friends.
18. *I can feel close to someone, even in moments of silence.
19. *I find examination of my feelings useful in solving personal problems.
20. I look for hidden meanings in movies or plays.

Scoring:

5-point Likert scale

* indicates a reverse scored item