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An Investigation into Interoception as a Transdiagnostic Mechanism Underpinning Anxiety-Related Disorders

by

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Abstract

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Emerging research implicates interoception, the sensing and interpretation of internal bodily signals, as a transdiagnostic mechanism in the development and maintenance of anxiety. Despite growing prominence in research, the mechanisms underlying this relationship remain largely unknown. The present thesis aims to address gaps in the field through the theoretical, systematic, and empirical exploration of the role of interoception across anxiety-related disorders.

Chapter 1 provides a theoretical foundation by exploring the conceptual and methodological issues surrounding the study of interoception in psychological research, setting the stage for the subsequent systematic review and empirical investigation. Chapter 2 presents a systematic review of the existing literature, synthesising evidence on the relationship between interoceptive dimensions and anxiety disorders in adult populations. Data was collected across 37 studies with a total of 3134 participants examining the relationship between interoception and anxiety, including generalised anxiety disorder (GAD), panic disorder, post-traumatic stress disorder (PTSD), obsessive-compulsive disorder (OCD), and social anxiety disorder (SAD). Studies employed self-report, behavioural, and neuroimaging measures across cardiac, respiratory, and gastrointestinal axes. A narrative synthesis of the findings revealed disorder-specific interoceptive profiles. Panic disorder and GAD were most consistently associated with heightened interoceptive attention and altered accuracy, particularly during threat-related tasks. PTSD and OCD were more strongly linked to maladaptive interoceptive beliefs, including low body trust and difficulties with bodily self-regulation. In chapter 3, an empirical study is presented that investigates the associations between interoceptive dimensions and anxiety-related traits and symptoms in a non-clinical adult sample. Drawing on a large sample (N = 305), including lab-based behavioural data and validated self-report measures, the study reveals associations between interoceptive dimensions, anxiety traits and symptoms, offering empirical support for theoretical models and identifying potential targets for clinical intervention.

Together, these findings offer a novel contribution to the literature by advancing a multidimensional understanding of interoceptive processes across anxiety spectrums, highlighting clinically relevant mechanisms that may inform targeted interventions and future translational research in anxiety. Clinical implications and future directions are discussed.

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Research Thesis: Declaration of Authorship

Print name: Lucy Snell

Title of thesis: An Examination of Interoception as a Transdiagnostic Mechanism Underpinning Anxiety-Related Disorders

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

Signature: .....Date: 30/09/2024

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Definitions and Abbreviations

ACT ..... Acceptance and Commitment Therapy

AS..... Anxiety Sensitivity

BPQ..... Body Perception Questionnaire

CBT..... Cognitive Behavioural Therapy

DBT ..... Dialectical Behaviour Therapy

DSM-5 ..... Diagnostic and Statistical Manual of Mental Disorders, 5th Edition

HCT ..... Heartbeat Counting Task

HDT..... Heartbeat Detection Task

GAD..... Generalised Anxiety Disorder

IAS..... Interoceptive Accuracy Scale

ICD-11 ..... International Classification of Diseases, 11th Edition

IU ..... Intolerance of Uncertainty

IUS ..... Intolerance of Uncertainty Scale

MAIA..... Multidimensional Assessment of Interoceptive Awareness

NICE ..... National Institute for Health and Care Excellence

OCD..... Obsessive-Compulsive Disorder

OCI ..... Obsessive-Compulsive Inventory

PCL..... Post-Traumatic Stress Disorder Checklist

PDSS..... Panic Disorder Severity Scale

PHQ..... Patient Health Questionnaire

PTSD..... Post-Traumatic Stress Disorder

SAD ..... Social Anxiety Disorder

SIPS ..... Social Interaction Phobia Scale

STAI-T..... State-Trait Anxiety Inventory – Trait Subscale

Chapter 1 Introduction

1.1 Interoception as a Transdiagnostic Mechanism

Despite decades of diagnostic refinement, identifying the core psychological and physiological mechanisms underlying mental health disorders remains a key challenge in clinical psychology research, with profound implications for how we assess and treat distress. Traditionally, mental health diagnoses have been categorised into discrete disorders using taxonomic classification systems such as the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed., text rev.; DSM-5-TR; American Psychiatric Association, 2022) and the *International Classification of Diseases, 11th Revision* (ICD-11; World Health Organisation, 2019). While these frameworks have significantly influenced the conceptualisation and management of mental health, particularly in Western contexts, they have faced growing criticism for issues related to reliability, validity, diagnostic instability, and heterogeneity within diagnoses (Kotov et al., 2017). Increasingly, many researchers argue that these traditional taxonomies based on symptomology may not capture the fundamental underlying mechanisms of mental health difficulties, potentially limiting the development of more targeted and effective treatments (Insel et., 2010). As a result, contemporary mental health research is shifting toward a 'transdiagnostic' perspective, which seeks to identify the underlying cognitive, emotional, and physiological mechanisms that transcend traditional diagnostic boundaries (Dalgleish et al., 2020). Building on this shift towards transdiagnostic frameworks, growing research has identified interoception as a key mechanism underlying various mental health conditions (Brewer et al., 2021).

1.2 Defining and Measuring Interoception

Interoception refers to the process by which the nervous system senses, interprets and integrates internal bodily signals, encompassing the ability to accurately perceive, attend to, and make sense of internal physiological states at both conscious and unconscious levels (Chen et al.,

2021; Khalsa et al., 2018). Early definitions of interoception primarily centred on visceral sensations and the regulation of internal bodily states via homeostatic pathways, playing a critical role in homeostasis (Craig, 2002; Critchley & Garfinkel, 2017). As interoception research grows, definitions and conceptualisations have evolved. Contemporary definitions of interoception have broadened to include cognitive, emotional, and attentional processes that influence how these signals are interpreted and integrated, as well as the brain's top-down regulatory influence on bodily systems (Murphy, 2024; Tsakiris & Critchley, 2016). Some recent definitions therefore emphasise the bi-directional nature of brain–body communication, highlighting the complex interplay between the brain and other organs (Chen et al., 2021). While there is ongoing debate regarding the exact boundaries of interoception (Murphy, 2024), core interoceptive processes are understood to involve signals arising from multiple bodily systems, such as the cardiovascular, respiratory, gastrointestinal, nociceptive, thermoregulatory, and immune systems, underscoring the broad physiological basis of interoceptive experience (Khalsa et al., 2018).

Interoception has also been found to underpin a range of higher-order cognitive functions such as emotion regulation (Füstös et al., 2013; Zamariola et al., 2019), decision-making (Herman & Tsakiris, 2021; Werner et al., 2009; Werner et al., 2013), and memory (Garfinkel et al., 2013; Messina et al., 2022). Given this role within core cognitive and physiological processes, interoception has attracted growing research interest as a transdiagnostic mechanism across mental health disorders (Saltafossi et al., 2024). However, consensus on the conceptualisation and measurement of interoception remains yet to be established. This has prompted some researchers to call for greater clarity and standardisation in both conceptual and methodological frameworks (Desmedt et al., 2025).

1.3 Dimensions of Interoception

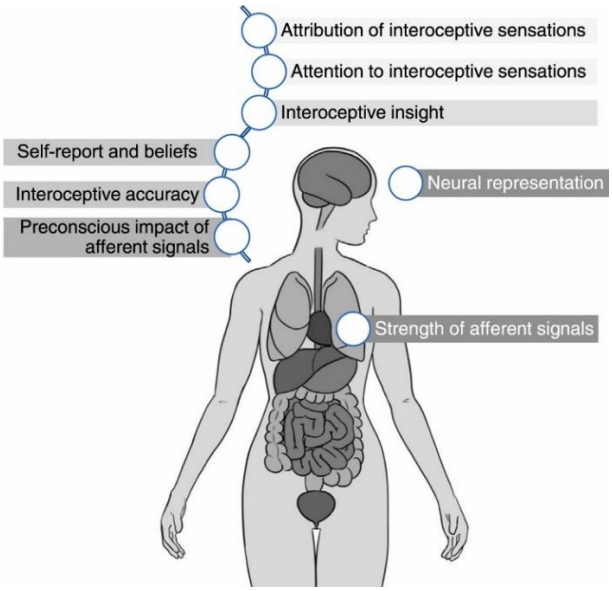
Interoception is inherently multifaceted, operating at multiple levels and across multiple bodily domains. Psychological research has largely focussed on the conscious perception of internal bodily signals, examining how individuals vary in their ability to detect, attend to and interpret signals.

These individual differences have led researchers to conceptualise interoception as comprising distinct ‘dimensions’ (e.g., interoceptive accuracy, attention and beliefs), each reflecting different aspects of how bodily sensations are processed and experienced. However, such constructs are inconsistently defined or used interchangeably across studies. Challenges therefore remain regarding how interoception is conceptualised and measured, leading to ongoing debates regarding the most effective way to capture the complexities of interoception and its role in psychological processes (Desmedt et al., 2025).

In efforts to standardise interoceptive terminology, researchers have attempted to clarify the distinct components involved in interoceptive processing (Garfinkel et al., 2015; Khalsa et al., 2018; Murphy et al., 2020; Suksasilp & Garfinkel, 2022). However, it has been argued that such frameworks do not always align empirically with existing interoception measures, and conceptualisation of interoception remains an ongoing process (Desmedt et al., 2025; Feldman et al., 2024).

The foundational and widely applied model in research is the three-dimensional model of interoception, which includes interoceptive accuracy, sensibility and awareness (Garfinkel et al., 2015). Most recently, Suksasilp and Garfinkel (2022) have built upon this framework to propose a multidimensional model of interoception. This extended the number of dimensions, recognising that individual differences can be assessed at multiple levels of processing, including visceral, neural, preconscious and higher-order dimensions, as outlined in Figure 1.1. The model suggests that these interoceptive dimensions may differentially map onto cognitive and emotional processes and that assessment of these dimensions can help isolate interoceptive disruptions that may be present in various clinical conditions (Suksasilp & Garfinkel, 2022).

Figure 1.1 Multidimensional Model of Interoception (Suksasilp & Garfinkel, 2022)



Note. Reproduced from Suksasilp & Garfinkel (2022), illustrating distinct levels of interoceptive processing. Ranging from afferent signalling and neural representation through to conscious interoceptive dimensions such as interoceptive accuracy, beliefs and insight.

This thesis adopts interoceptive terminology and key terms as outlined in the multidimensional model of interoception proposed by Suksasilp and Garfinkel (2022). By using this recent model, this thesis aligns with current advancements in interoception research, offering a nuanced and detailed framework for understanding individual differences in how bodily signals are processed. It is applied throughout both chapters to ensure consistency and conceptual clarity, which is particularly important given the varying definitions and conceptualisations in the literature. Key definitions are outlined in Table 2.2.

1.4 Interoception and Anxiety

Anxiety disorders are among the most prevalent mental health conditions globally (GBD 2019 Mental Disorders GBD Mental Disorders Collaborators, 2022). Their prevalence has shown a consistent upward trend over the past few decades, with significant increases reported in recent years (Chen et al., 2025). This trend reflects broader epidemiological patterns and is closely linked to

major global events such as the COVID-19 pandemic (da Silva et al., 2021; Seighali et al., 2024), socio-economic shifts (Wu et al., 2025), and growing awareness of mental health concerns (Foulkes & Andrews, 2023). Projections suggest that the number of individuals affected by anxiety disorders will continue to rise significantly, with adolescents, particularly those aged 15–19, expected to represent one of the most affected age groups by 2050 (Chen et al., 2025). Evidence also points to rising symptom severity across specific anxiety diagnoses, particularly in young adult women (e.g., Slee et al., 2021). Therefore, recent studies underscore the urgent need for targeted prevention and treatment strategies to address the escalating issue of anxiety disorder burden and mitigate long-term impact globally (Bie et al., 2024; Chen et al., 2025).

Interoceptive processes have been linked to various mental health disorders, and may be particularly relevant to the development and maintenance of anxiety psychopathology (Khalsa & Lapidus, 2016). Emerging research suggests that heightened attention to internal bodily signals, distorted interoceptive beliefs, and reduced interoceptive accuracy may all contribute to the onset and persistence of anxiety-related symptoms, although current evidence is mixed. Theoretical models suggest that imprecise self-referential interoceptive predictions due to noisy or uncertain bodily input amplify perceived threat and unpredictability, thereby reinforcing anxious states and contributing to the maintenance of symptoms (Paulus & Stein, 2010). As such, examining the specific ways in which interoceptive dimensions relate to anxiety is critical to deepening our understanding of the mechanisms underpinning these conditions. However, despite increasing interest, relatively few studies have systematically examined how distinct interoceptive dimensions interact with specific anxiety traits and symptoms across different populations.

1.5 Aims and Rationale of the Thesis

Given the growing interest in interoception as a transdiagnostic factor in anxiety, alongside the rising prevalence of anxiety conditions, it is imperative to advance theoretical understanding of interoceptive processes to inform targeted therapeutic interventions. Despite emerging evidence suggesting interoception plays a role in anxiety, research delineating how interoceptive processes are

implicated in the development and maintenance of specific symptom profiles remains limited. This thesis aims to address this gap through two complementary chapters. Chapter 2 presents a systematic review examining the current evidence on the relationship between interoception and anxiety disorders in adult clinical populations, with the aim of synthesising existing findings and identifying gaps in the literature. Chapter 3 builds on these findings through an empirical investigation exploring how distinct interoceptive dimensions are associated with transdiagnostic anxious traits and anxiety symptoms in a non-clinical sample. Both chapters explore the relationship between interoception and anxiety, yet they address distinct dimensions of this relationship: one through a synthesis of existing clinical evidence and the other through empirical investigation in a non-clinical sample. Together, these chapters aim to support a more refined understanding of the role of interoception in anxiety and inform future research and clinical practice.

1.6 Interoception and Anxiety Disorders in Adult Clinical Populations

Given the growing empirical evidence that alterations in interoceptive processes, such as heightened attention to bodily sensations, impaired accuracy, and maladaptive beliefs may be implicated in anxiety disorders, Chapter 2 presents a systematic review of existing studies exploring this relationship in clinical populations. A narrative synthesis of findings aims to address current gaps in the literature by examining the relationship between interoception and anxiety-related conditions, including generalised anxiety disorder (GAD), obsessive–compulsive disorder (OCD), panic disorder, post-traumatic stress disorder (PTSD), and social anxiety disorder (SAD). The review also explores whether there is a predominant focus on specific interoceptive dimensions within clinical populations (e.g., accuracy, attention, beliefs; Suksasilp & Garfinkel, 2022), and which bodily modalities (e.g., cardiac, gastrointestinal, respiratory) are frequently studied. This is important to examine because an overemphasis on certain dimensions or modalities may bias our understanding of interoception in anxiety disorders, potentially overlooking other relevant processes. The review also highlights trends in how different anxiety conditions are represented across interoception research. By mapping the scope, focus, and limitations of the existing evidence base, this review

offers a novel contribution to the literature and supports advancements in understanding the complex associations between distinct facets of interoception and anxiety in clinical populations.

1.7 Exploring the Role of Interoception in Anxious Traits and Symptoms

Chapter 3 builds on the findings of the systematic review by empirically examining how distinct interoceptive dimensions relate to transdiagnostic anxious traits and disorder-specific anxiety symptoms. While previous research has typically focused on comparisons between clinical and non-clinical groups, this study adopts a dimensional approach to examine how interoceptive processes relate to varying levels of anxiety symptomatology across a general sample. The study utilises a multimethod approach, incorporating both self-report questionnaires and behavioural heartbeat perception tasks. To our knowledge, this is one of the first studies to concurrently explore how multiple interoceptive dimensions are associated with both anxious traits (e.g., trait anxiety, intolerance of uncertainty, anxiety sensitivity) and disorder-specific symptomology (e.g., GAD, OCD, panic disorder, PTSD and SAD). This approach allows for a more refined understanding of how different facets of interoception may contribute to anxiety psychopathology along a continuum. From a research perspective, it offers novel insights into the mechanisms linking interoception and anxiety across diagnostic boundaries. Clinically, these findings may help inform more precise and interoceptively informed interventions for anxiety-related conditions, particularly for individuals who may not meet diagnostic thresholds but still experience significant distress.

1.8 Clinical Implications

In light of the transdiagnostic significance of interoception, there is growing interest in targeted therapeutic interventions aimed at modulating interoceptive processes (Heim et al., 2023; Khoury et al., 2018). For instance, Cognitive Behavioural Therapy (CBT) is widely regarded as the gold-standard treatment for panic disorder, with interoceptive exposure as a key component (National Institute for Health and Care Excellence [NICE], 2020). Interoceptive exposure involves deliberately eliciting physiological symptoms of panic (e.g., increased heart rate, shortness of breath)

to reduce catastrophic misappraisals and increase tolerance of internal bodily cues that often trigger anticipatory anxiety or panic attacks (Manfro et al., 2008). These exercises are believed to facilitate extinction learning by strengthening inhibitory neural pathways, which in turn help to regulate overactive subcortical threat-response systems (Milad & Quirk, 2012). Research has shown that interoceptive exposure significantly reduces anxiety sensitivity and panic symptoms, including panic attack frequency and severity (Boettcher & Barlow, 2019; Carter et al., 2003; Craske et al., 1995; Holtz et al., 2019).

Beyond panic disorder, interoceptive exposure has been explored as a treatment for somatic sensations in PTSD (Andersen et al., 2017; Wald & Taylor, 2008), social anxiety (Collimore & Asmundson, 2014; Dixon et al., 2015) and OCD (Blakey & Abramowitz, 2018). Efficacy of interoceptive exposure appears strongest when delivered as part of a multicomponent CBT intervention, combined with strategies such as in vivo exposure, cognitive restructuring, or mindfulness (Farris et al., 2025). As such, interoceptive exposure is increasingly recognised as a transdiagnostic treatment strategy across anxiety disorders (Boswell et al., 2013).

Interoceptive research also supports the therapeutic potential of mindfulness-based interventions for improving interoception (Molteni et al., 2024). This includes practices such as yoga (Neukirch et al., 2019; Shen et al., 2023), meditation (Lima-Araujo et al., 2022), and mindfulness-based stress reduction (Ardi et al., 2021; Kang et al., 2022). These interventions are thought to enhance interoceptive functioning by encouraging individuals to direct attention towards internal sensations in a non-judgemental and accepting manner (Mehling et al., 2011)**,** unlike other strategies that may involve avoiding or actively distracting oneself from bodily sensations. Research also has clinical implications for mindfulness-informed therapies such as Dialectical Behaviour Therapy (DBT) (Linehan, 1993) and Acceptance and Commitment Therapy (ACT) (Hayes & Pierson, 2005), which integrate mindfulness practices as a part of broader transdiagnostic interventions (Shapero et al., 2018). However, Khoury et al. (2018) note that evidence regarding interoceptive regulation mechanisms after mindfulness-based interventions is unclear, primarily due to the lack of validated interoceptive measures in randomised-controlled trials with clinical populations.

Other clinical implications involve interventions targeting respiratory regulation (e.g., diaphragmatic breathing, heartrate variability biofeedback; He et al., 2024; Wareing et al., 2024) and neuromodulation (e.g., vagus nerve stimulation; Villani et al., 2019) which are increasingly recognised for their role in improving interoceptive abilities (Weng et al., 2021). Improving interoceptive ability may allow individuals to more accurately perceive and interpret bodily signals, reducing the tendency to misinterpret normal physiological changes as threatening, and thereby alleviate anxiety (Clark & Ehlers, 1993). These developments highlight the growing potential of interoceptive-based intervention in clinical practice, offering promising avenues for enhancing treatment outcomes in anxiety-related disorders.

1.9 Reflections and Limitations

Given the constraints of conducting a piece of research while also managing clinical and academic demands of Clinical Psychology training, I had to make several pragmatic decisions to ensure feasibility. These included refining my research questions to align with what was realistically achievable within the available time and resources. I chose to administer an online survey to maximise reach and supplemented this with a smaller laboratory-based component to capture behavioural interoceptive measures. This mixed-method approach allowed me to balance breadth and depth, though it also required careful consideration of what could be meaningfully interpreted within a limited sample. Through this process, I learned the value of flexibility, methodological adaptability, and balancing scientific rigour with practicality in applied research settings.

Balancing clinical responsibilities with research demands was challenging at times; however, holding both perspectives enriched the research process. My clinical work deepened my awareness of how interoceptive difficulties may manifest in clients (e.g., bodily hypervigilance, alexithymia) while the research highlighted gaps in how such experiences are understood and addressed in therapy. These insights will inform my future practice, encouraging more holistic, body-aware approaches to my clinical assessment, formulation and intervention.

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Chapter 2 The Relationship Between Interoception and Anxiety Disorders in Adult Clinical Populations – A Systematic Review and Narrative Synthesis

Journal choice: *'The Neuroscience & Biobehavioral Reviews'* has been used as a guide to prepare this review. The named journal publishes review articles that bring new insights into brain-behaviour relationships, where the relationship between psychological processes and behaviour is clearly established, or has relevance to one or more aspects of neuroscience. There are no stipulations on word count, with an abstract of maximum 250 words. Tables, figures, captions, and references are excluded from the word count.

Abstract: 248 words

Word count: 9019 (excluding abstract, tables, figures, and references)

2.1 Abstract

Interoception, defined as the perception of internal bodily states, has emerged as a key mechanism implicated in the development and maintenance of anxiety disorders. This systematic review synthesises evidence on the relationship between interoception and anxiety in adult clinical populations, with a specific focus on how distinct interoceptive dimensions (i.e., accuracy, attention, and beliefs) relate to different anxiety presentations. A systematic search was conducted across PsycINFO, PubMed, and Web of Science (last updated April 2025). Thirty-seven studies met inclusion criteria, across multiple anxiety disorders including generalised anxiety disorder (GAD), panic disorder, post-traumatic stress disorder (PTSD), obsessive-compulsive disorder (OCD), and social anxiety disorder. Included studies employed self-report, behavioural, and neuroimaging measures across cardiac, respiratory, and gastrointestinal axes. Evidence supports disorder-specific interoceptive profiles. Panic disorder and GAD were most consistently associated with heightened interoceptive attention and altered accuracy, particularly during threat-related tasks. PTSD and OCD were more strongly linked to maladaptive interoceptive beliefs, including low body trust and diminished belief in one's capacity to regulate attention to internal sensations. Neuroimaging findings indicated altered functional connectivity within interoceptive brain networks. Notably, over half the included studies (n = 18) were published within the past five years, reflecting accelerating interest in this area. While interoception appears as a transdiagnostic dimension relevant across anxiety disorders, the current evidence base is mixed and shaped by methodological variability. Nonetheless, emerging interoceptive patterns support the potential clinical utility of targeting interoceptive processes. Greater standardisation and cross-cultural considerations are needed to guide future research and clinical translation.

Keywords: Interoception; Anxiety; Panic Disorder; Generalised Anxiety Disorder; Post-Traumatic Stress Disorder; Social Anxiety Disorder, Obsessive-Compulsive Disorder; Systematic Review; Interoceptive Accuracy; Interoceptive Attention; Interoceptive Awareness

2.2 Introduction

Contemporary models of anxiety increasingly highlight the role of bodily signal processing in shaping emotional experience and threat perception. Interoception refers to the sensing, interpretation, and regulation of internal bodily signals arising from various physiological systems, including cardiovascular, respiratory, gastrointestinal, and thermoregulatory processes (Craig, 2002; Khalsa et al., 2018). The conscious awareness and interpretation of these internal bodily cues are thought to play a fundamental role in maintaining homeostasis, shaping emotional experience, and contributing to the sense of self (Critchley & Harrison, 2013; Tsakiris & Critchley, 2016). Current theoretical frameworks conceptualise interoception as a multidimensional construct ranging from neural representation to higher order processing of interoceptive signals, encompassing interoceptive accuracy (objective accuracy), interoceptive beliefs (self-reported attention to internal signals), and interoceptive insight (the correspondence between subjective and objective measures) (Suksasilp & Garfinkel, 2022). These interoceptive dimensions are thought to contribute differentially to the development and maintenance of psychopathology and may play distinct roles across anxiety disorders.

In light of this, a growing body of research implicates interoception as a transdiagnostic mechanism in mental health (Brewer et al., 2021; Khalsa & Verdonk, 2024). Emerging perspectives highlight the relevance of interoception across anxiety disorders, with individual differences in interoceptive processing increasingly recognised as contributing to the underlying mechanisms of anxiety and related conditions (Khalsa & Lapidus, 2016; Paulus & Stein, 2010). Understanding the relationship between distinct facets of interoception and specific anxiety disorders is important for clarifying the mechanisms through which interoceptive processes may contribute to symptom expression and maintenance (Saltafossi et al., 2024). However, these relationships remain unclear and understudied, with existing findings often yielding inconsistent results.

Generalised anxiety disorder (GAD) is characterised by excessive and uncontrollable worry, often accompanied by somatic symptoms such as palpitations and muscle tension (American

Psychological Association, 2022). Increasingly, GAD has been linked to interoceptive dysfunction, with evidence suggesting altered brain–body integration and cortical processing of interoceptive signals compared to healthy individuals (Pang et al., 2019; Teed et al., 2022). These alterations may contribute to the maintenance of generalised anxiety by amplifying perceived internal threat cues and disrupting the ability to accurately interpret bodily states (Paulus & Stein, 2010).

Panic disorder is characterised by recurrent, unexpected panic attacks and persistent concern about their recurrence, and has been described as a prototypical interoceptive disorder (Murphy, 2024). Cognitive-behavioural models of panic propose that panic arises when internal bodily signals (i.e., racing heart, shortness of breath) are catastrophically misinterpreted as threatening, perpetuating panic attacks (Clark & Ehlers, 1993). Some theories suggest that individuals with panic disorder may have heightened interoceptive accuracy, particularly for cardiac signals, which can exacerbate anxiety when these sensations are perceived as threatening (Ehlers et al., 1995). However, empirical findings on this relationship remain mixed, and meta-analytic evidence has not consistently linked interoceptive accuracy with panic symptoms (Adams et al., 2022).

Similarly, research exploring obsessive-compulsive disorder (OCD) and interoception has been mixed. Theoretical frameworks of OCD highlight how individuals misinterpret intrusive thoughts as threatening, leading to compulsive behaviours aimed at preventing anticipated harm (Salkovskis et al., 1998). Findings on improved interoceptive accuracy in OCD are mixed (Demartini et al., 2021; Yoris et al., 2017). Individuals with OCD have reported heightened subjective sensitivity to bodily sensations, reflected in greater noticing, greater worrying, and lower bodily trust relative to controls (Eng et al., 2020; Eng et al., 2024). Emerging evidence suggests an overall reduction in interoceptive insight in OCD (Wilson et al., 2025), and a tendency to distrust one's memory, perception, and other cognitive functions (Chiang & Purdon, 2023; Dar et al., 2022).

Social anxiety disorder (SAD), also known as social phobia, is characterised as a fear of social situations and exposure to scrutiny from others (Stein & Stein, 2008). Cognitive models posit that socially anxious individuals engage in heightened self-focused attention towards internal body signals

and use this information to build a negatively biased self-perception during social interactions (Rapee & Heimberg, 1997). In line with this model, research has demonstrated that socially anxious participants exhibit an attentional bias towards internal cues of potential threat (Choi et al., 2016; Pineles & Mineka, 2005). Stevens et al. (2011) found evidence of increased interoceptive accuracy in social anxiety in university students, suggesting greater accuracy of interoceptive cues (e.g., racing heart), may be misinterpreted as signs of visible arousal, thereby intensifying fears of negative evaluation by others. Experimental studies have also shown that manipulated feedback about physiological arousal (e.g., perceived heart rate) can heighten social anxiety, self-focused attention, and negative self-appraisals during social encounters (Shahidi & Baluch, 1991; Wells & Papageorgiou, 2001), highlighting the role of interoceptive beliefs in maintaining SAD.

Post-traumatic stress disorder (PTSD) is characterised by intrusive memories, hyperarousal, avoidance, and mood disturbances following trauma (Yehuda et al., 2015). Emerging evidence highlights interoceptive disruptions in PTSD, including difficulties in perceiving and interpreting bodily signals (Joshi et al., 2023; Nicholson et al., 2016; Putica & Agathos, 2024). Neuroimaging studies further support this, showing structural and functional alterations in brain regions involved in interoception (Lanius et al., 2015). Empirical findings show lower interoceptive accuracy after acute stress in individuals with childhood trauma (Schaan et al., 2019), and higher accuracy has been associated with fewer PTSD symptoms in sexual trauma survivors (Reinhardt et al., 2020). However, research on this area is limited, underscoring the need for further investigation into interoception in PTSD, as well as a broader investigation across other anxiety-related disorders.

Given the complexity of interoception as a multidimensional construct, existing research varies in focus across specific dimensions (i.e., accuracy, beliefs, attention, insight) and bodily systems. Interoceptive accuracy has received the most empirical attention to date (Desmedt et al., 2023), with the cardiac domain emerging as the most frequently studied bodily axis. Such disparities in research focus highlight the importance of examining interoceptive processes across multiple dimensions and bodily systems to better understand their relevance to anxiety and related psychopathology.

Notably, variation in research emphasis may reflect variability in the salience of interoceptive differences across anxiety disorders (Murphy, 2024). For instance, panic disorder is frequently characterised by prominent somatic symptoms such as palpitations and chest pain, whereas conditions like OCD may involve more cognitive symptomatology, where interoceptive disruptions may be less overt or differently expressed.

Despite a growing body of research on interoception, significant gaps remain in understanding its role across anxiety-related conditions. To the best of our knowledge, no registered systematic reviews have comprehensively explored how specific facets of interoception relate to these disorders in clinical populations. The proposed systematic review aims to address this gap by synthesising the evidence on the relationship between interoception and anxiety-related disorders, including GAD, OCD, panic disorder, PTSD, and SAD.

Secondary aims are to (1) assess whether there is a predominant focus on specific interoceptive processes within clinical populations (e.g., accuracy, attention, beliefs and insight; (Suksasilp & Garfinkel, 2022), (2) identify which bodily modalities (e.g., cardiac, gastrointestinal, respiratory) are frequently studied, and (3) explore which specific disorders are disproportionately represented in the interoception literature. This systematic review will offer a novel contribution to the literature by offering insights into the patterns, scope, and gaps in interoception research, as well as the complex associations between facets of interoception and anxiety disorders in clinical populations.

2.3 Methods

2.3.1 Protocol and Registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines, (see Appendix A; Page et al., 2021). The review protocol was registered on PROSPERO (registration number: CRD42024615637) on the 21st

November 2024, prior to the commencement of data extraction. This can be accessed via: https://www.crd.york.ac.uk/PROSPERO/view/CRD42024615637

2.3.2 Information Sources

Initial scoping searches were carried out prior to finalising the review question and protocol. These scoping searches were conducted using Google Scholar, PROSPERO, and the University of Southampton's online library portal to explore the current literature, identify any existing reviews or protocols, and to inform the search terms for the final search strategy.

A systematic literature search was conducted across three bibliographic databases: PsycINFO, Web of Science, and PubMed. This search took place between 24th and 29th November 2024. A second search was performed on 16th April 2025 to capture any newly published studies since the initial search. This yielded an additional 33 records; however, after removing 4 duplicates, none of the remaining 29 studies met the inclusion criteria.

2.3.3 Search Strategy

The final search strategy was informed by the key terms within the research question. The search combined terms related to interoception (e.g., 'interocept*') with terms for specific clinical populations (e.g., 'social anxiety disorder', 'SAD', and 'social phobia'). Separate searches were conducted for each anxiety disorder to maximise retrieval sensitivity. This approach is consistent with recommendations for systematic reviews that emphasise replicability and sensitivity in search strategies (Rethlefsen et al., 2021). Searches were tailored to the syntax and indexing of each database. The full search strategies for each database are included in Appendix B. Reference lists of included articles were manually screened to identify additional studies.

2.3.4 Eligibility Criteria

All studies were screened against predetermined inclusion and exclusion criteria informed by the Population, Exposure, Comparator, and Outcome (PECO) framework, as appropriate for non-intervention systematic reviews (see Appendix C; Morgan et al., 2018), and in accordance with PRISMA guidelines (Page et al., 2021). To be eligible, studies were required to include adult participants (≥18 years) with a formal diagnosis or validated measure of an anxiety-related condition, specifically GAD, OCD, panic disorder, PTSD or SAD.

Only studies including adults were eligible to ensure developmental comparability in interoceptive processing and anxiety presentation. Interoceptive abilities and related neural systems continue to develop through childhood and adolescence, influenced by changes in sensory integration, emotional regulation, and attentional control (Carr et al., 2024; Murphy et al., 2017). Moreover, many interoceptive tasks validated in adults are not suitable for use with younger populations due to differing cognitive and sensory capacities (Carr et al., 2024). Restricting inclusion to adults therefore minimised developmental and methodological heterogeneity, enabling clearer synthesis of interoception-anxiety associations within a developmentally stable population.

The outlined anxiety types were selected as they are conceptually and clinically central anxiety-related disorders that together span a broad range of anxious presentations. Phenomenologically, they encompass diverse pathways through which interoceptive processes are theorised to contribute to anxiety, including somatic hyperarousal, worry-related bodily symptoms, self-focused monitoring of arousal, and intrusive thoughts with altered bodily trust. Other disorders, such as illness anxiety disorder (formerly hypochondriasis) and specific phobias, are also relevant to interoceptive theories of psychopathology; however, initial scoping searches indicated that the available literature for these areas is relatively limited, methodologically heterogeneous, and conceptually narrower in scope. For pragmatic reasons, these conditions were therefore excluded, though their omission highlights an important avenue for future research and synthesis.

Comparisons were either made with healthy control groups or based on variations in anxiety symptom severity within the clinical sample. Studies were required to include a validated measure of interoception, assessed through either self-report questionnaires, such as the Multidimensional Assessment of Interoceptive Awareness (MAIA), Body Perception Questionnaire (BPQ), or Interoceptive Accuracy Scale (IAS) or through experimental tasks (e.g., heartbeat perception, respiratory or signal detection tasks). Eligible studies used a quantitative design and reported on an outcome related to interoceptive processes. Only peer-reviewed articles published in English were included. There were no restrictions on the year of publication. Studies were excluded if they focused exclusively on subclinical samples, involved participants with primary diagnoses outside the anxiety spectrum (e.g., psychotic disorders, neurodevelopmental conditions, or intellectual disabilities), or used animal models. A detailed summary of inclusion and exclusion criteria is provided in Table 2.1.

Table 2.1 Systematic Review Inclusion and Exclusion Criteria

	Inclusion Criteria	Exclusion Criteria
Population	Adult (≥18 years) population with a formal diagnosis or validated measure of anxiety-related disorder	Children and adolescents (<18 years); non-clinical samples or sub-clinical anxiety; Individuals with other primary diagnoses; Animal studies
Exposure	Assessment of interoception using validated self-report measures or experimental tasks	No measure of interoception or use non-validated tools
Comparison	Non-anxious control participants (between-group) or with varying levels of anxiety symptoms (within-group)	No comparison group
Outcome	Reported outcomes related to interoceptive performance	No interoceptive outcomes or insufficient data for extraction
Other	Human studies; English language full text available	Animal studies; non-English language full text; Abstract available only

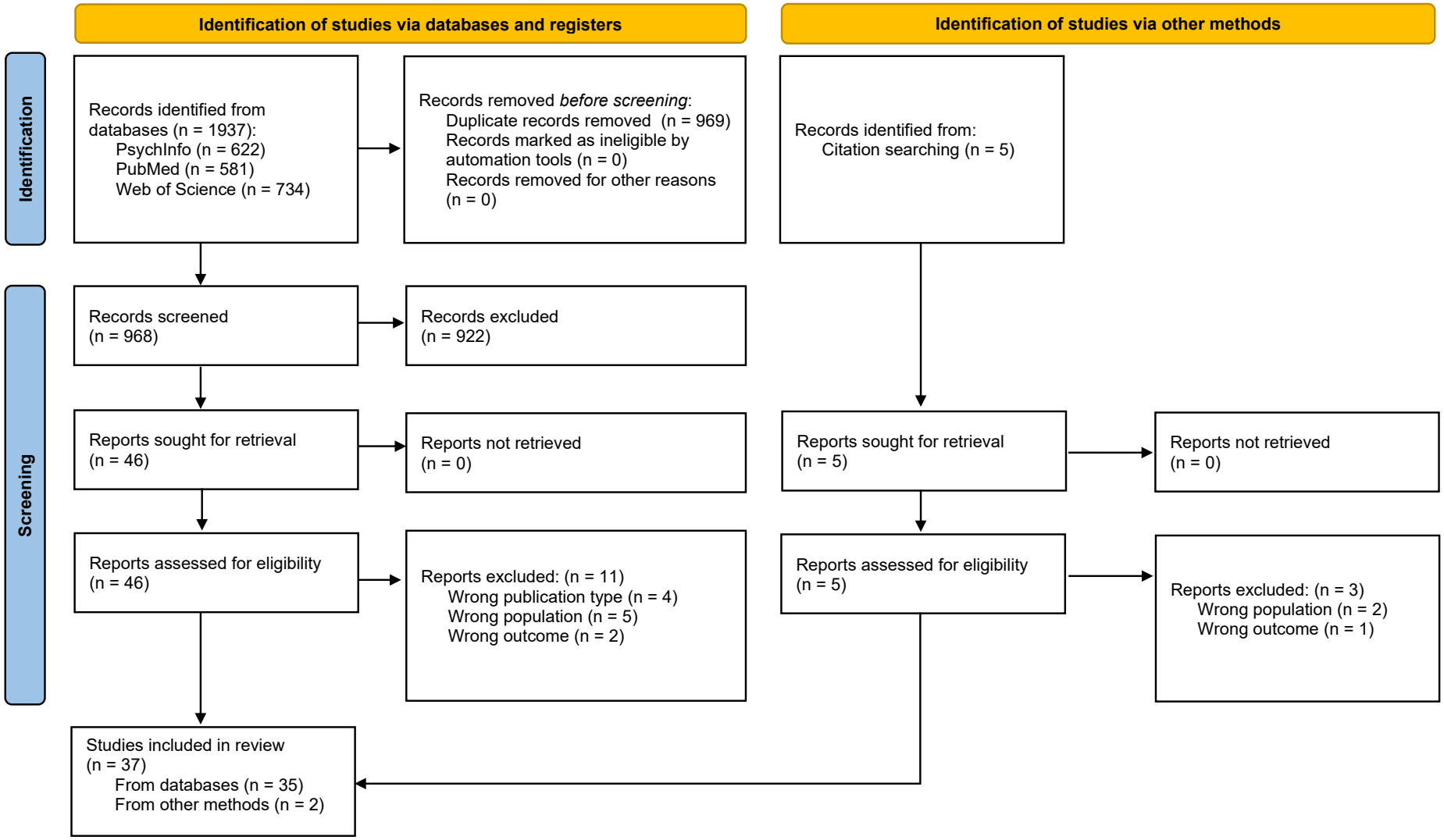
2.3.5 Screening Process

The screening and selection process was conducted in line with PRISMA guidelines (Page et al., 2021). All studies identified through the systematic search were imported into Rayyan (Ouzzani et al., 2016), an online screening platform used to facilitate title and abstract screening. Duplicates were automatically detected and removed manually. Four reviewers independently screened all titles and abstracts against the pre-specified eligibility criteria using Rayyan. For studies that met eligibility criteria or where it was unclear based on the title / abstract, full texts were retrieved and assessed. Reviewers would mark each article as 'include' or 'exclude with reasons' (i.e., wrong population type, wrong study design) using the Rayyan software. Any conflicts (e.g., disagreement between inclusion vs. exclusion decisions) were automatically flagged by Rayyan. These were then resolved through team discussion to reach consensus. There were no disagreements. Reviewer independence was maintained throughout the screening process to minimise potential bias.

2.3.6 Study Selection

In total, 1937 studies were identified through the systematic search. After removing 969 duplicates, 968 records remained title and abstract screening. The full texts of 46 studies were assessed for eligibility, with 35 eligible for inclusion. An additional two studies were identified by screening the reference lists of included studies. These studies were older and may not have been retrieved during the database search as the term 'interoception' was not commonly used at the time of their publication. A final total of 37 studies were included in the review, as outlined in the PRISMA flow diagram (Figure 2.1).

Figure 2.1 PRISMA Flow Diagram



2.3.7 Data Extraction

Data was extracted systematically to collate relevant information from each included study. Key variables included author, year, study title, and the anxiety-related condition under investigation. Study context was captured through details on country of origin, sample type, and sample size, along with demographic information and distribution of clinical subgroups. Methodological characteristics were documented, including study design, interoceptive bodily axis assessed (e.g., cardiac, respiratory), and interoceptive dimension measured (e.g., accuracy, attention, beliefs). The specific interoceptive measurement tools and analytic approaches (e.g., correlations, *t*-tests, ANOVA) were recorded, alongside reported effect sizes where available. Finally, key findings regarding the relationship between interoception and the assessed anxiety-related condition were extracted. Where summary information is missing or unclear, the data will be described qualitatively or excluded from specific analyses.

2.3.8 Quality Assessment for Risk of Bias

Quality and risk assessment of studies were carried out using a modified version of the Effective Public Health Practice Project Quality Assessment Tool for Quantitative Studies (EPHPP; Thomas et al., 2003), outlined in Appendix D. The quality of the study was not an inclusion criterion; however, a study quality check was carried out to determine the strength of the evidence.

The EPHPP tool was adjusted to include domains relevant to the method of the studies; methodological quality was evaluated based on five of the original eight components: (1) selection bias, assessing the representativeness of the sample; (2) study design, distinguishing between cross-sectional and longitudinal approaches; (3) data collection methods, ensuring validity and reliability; (4) participant withdrawals and dropouts, based on the proportion of complete data; and (5) the suitability / appropriateness of the analyses for the study design. Three components were not included in the quality assessment as they were not applicable to observational studies: (1) the blinding component, (2) confounders, and (3) intervention integrity.

Following EPHPP guidelines, each study was assigned a rating of either ‘strong’, ‘moderate’ or ‘weak’ for each of the five assessed components, as well as an overall rating of study quality. Studies were globally rated as ‘weak’ if two or more components were rated as weak; ‘moderate’ if one component was rated as ‘weak’; or ‘strong’ if a study had no ‘weak’ ratings. In line with systematic review guidelines (Boland et al., 2017), selected studies were independently quality assessed by the first author (LS). To ensure consistency and reliability in the assessment process, 20% of the studies were randomly selected for spot-checking by the last author (JM). No discrepancies between the first author and last author arose.

2.3.9 Data Synthesis and Analysis

The data synthesis was conducted using a narrative synthesis approach, following the guidelines for a systematic review without meta-analysis (SWiM), as outlined by Campbell et al. (2020). Due to the anticipated heterogeneity of the included studies outlined in the review protocol, statistical pooling via meta-analysis was not feasible (Lubowitz & Cote, 2025). Reported results were narratively synthesised based on study-level findings, which commonly included correlation coefficients, mean differences, or regression estimates. Where available, authors’ interpretations of effect size magnitude were considered.

The narrative synthesis was structured around the research question and organised into two levels. To address the primary outcome, studies were first grouped by clinical population (i.e., GAD, OCD, panic disorder, PTSD and SAD) to explore how interoception relates to each specific anxiety-related condition. Given that several studies did not focus on a single diagnostic category, a further category of ‘Mixed Anxiety’ was included to capture studies examining transdiagnostic or undifferentiated anxiety samples.

For secondary analysis, within each clinical population, studies were further stratified according to the specific interoceptive processes assessed, including interoceptive accuracy, interoceptive beliefs, and interoceptive attention, as conceptualised by Suksasilp and Garfinkel

(2022). Although both interoceptive beliefs and attention are commonly measured via self-report, they represent conceptually distinct constructs within the multidimensional interoception framework (Suksasilp & Garfinkel, 2022). Therefore, findings related to 'beliefs' and 'attention' are synthesised separately. Table 2.2 provides an overview of the key interoceptive dimensions included in the framework, which guided the thematic synthesis of results.

The results will be presented as a narrative synthesis, describing the relationships observed between interoception and anxiety disorders in the included studies. Findings will also be tabulated and presented alphabetically in the summary table. Key findings related to the number of studies per anxiety-related condition, the proportion of studies examining each interoceptive dimension, and the methods employed will be graphically displayed to supplement the narrative synthesis.

Table 2.2 Definitions of Key Interoceptive Dimensions

Dimension	Definition
Interoceptive accuracy	The ability to correctly perceive internal bodily signals, assessed through behavioural tasks comparing objective physiological events to self-reported experiences.
Interoceptive beliefs	Beliefs about internal bodily sensations, including both conscious and unconscious aspects, typically measured using self-report questionnaires and confidence ratings.
Interoceptive attention	The tendency or ability to focus on internal bodily sensations, either habitually or when instructed, often assessed via self-report relative to attention to external stimuli.
Interoceptive insight	Metacognitive awareness of one's interoceptive abilities, reflected in the correspondence between objective interoceptive task performance and subjective confidence or perceived accuracy.

Note. Adapted from (Suksasilp & Garfinkel, 2022), this table summarises the key interoceptive processes guiding the synthesis of findings, including interoceptive accuracy, beliefs, insight, and attention.

2.4 Results

2.4.1 Study Characteristics

Study characteristics are displayed in full in Appendix E. A total of 37 studies were included in this review, comprising a combined total of 3143 participants. This included 1774 individuals in the clinical condition groups (GAD = 203; OCD = 468; panic disorder = 597; PTSD = 62; SAD = 41; mixed anxiety = 403). The studies also included 1369 control participants: 1074 healthy controls, 165 substance-dependent controls, 27 phobic controls, 51 eating disorder controls and 52 depressed controls. Sample sizes for the clinical groups on average were 42.6 (median: 25.5) and ranged from 14 (Poppa et al., 2019) to 221 participants (Smith et al., 2021).

The most researched anxiety condition was panic disorder (46% of included studies), whereas the least frequently studied was SAD (5%), as shown in Figure 2.2. Across the studies, a range of interoceptive dimensions were assessed. Interoceptive accuracy was the most frequently assessed, evaluated in 22 out of the 37 studies (59%) reviewed. Interoceptive beliefs were assessed in 18 studies (49%) and attention in 15 studies (41%). Interoceptive insight was the least explored, assessed as the relationship between objective accuracy and subjective confidence or perceived accuracy, in two studies (5%), see Figure 2.3 for further details.

Figure 2.2 Frequency of Included Studies by Clinical Group

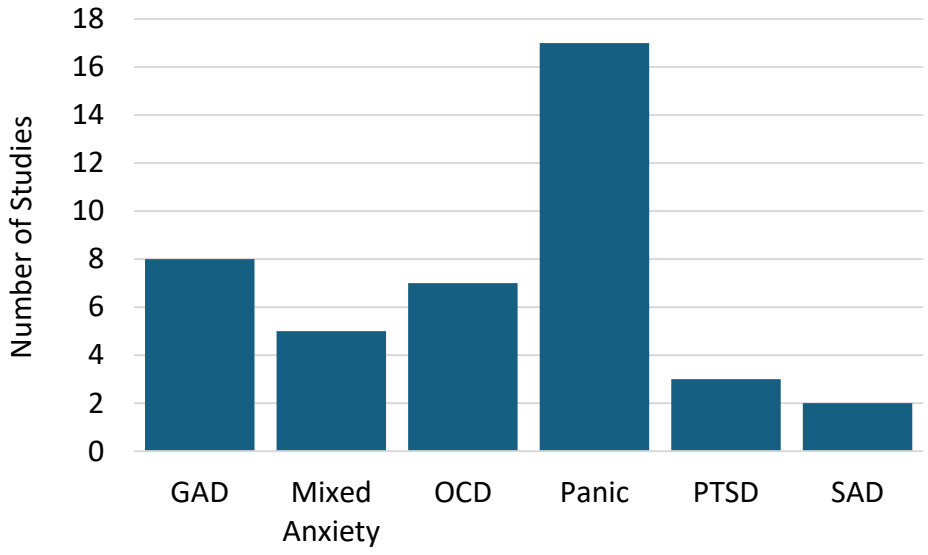
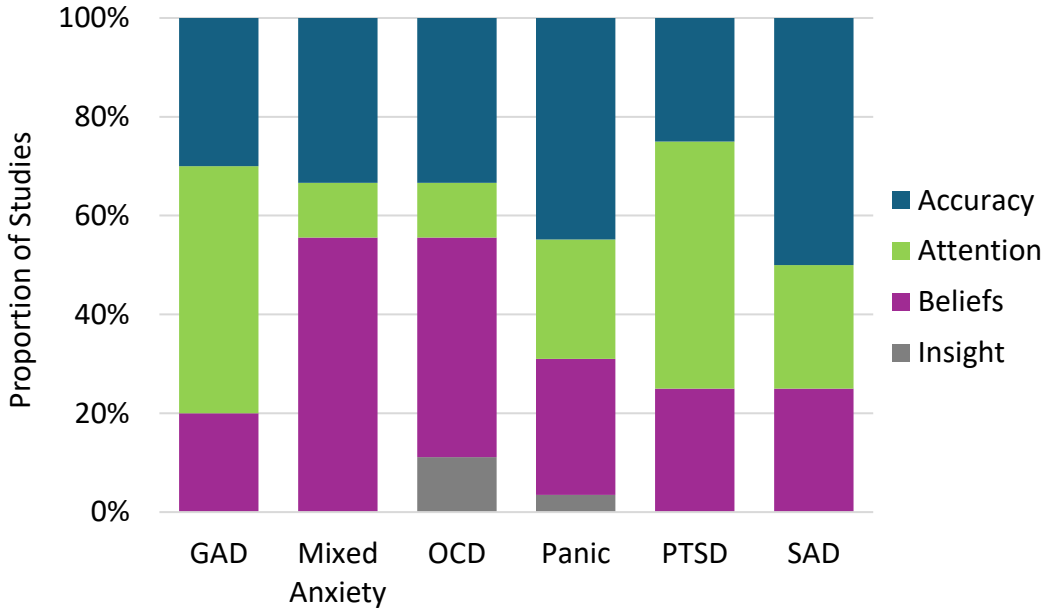
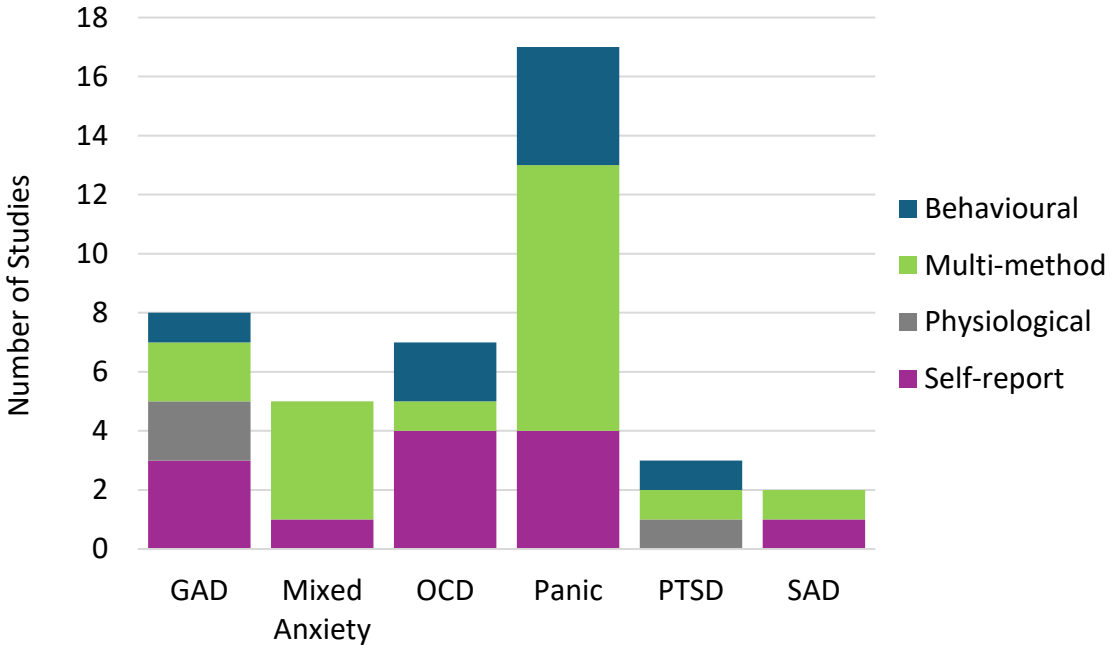


Figure 2.3 Proportion of Interoceptive Dimension Assessment by Clinical Group



A variety of measurement tools were employed, including self-report, physiological and behavioural tasks (see Figure 2.4). Many studies used multi-methods (49%), typically combining self-report measures with behavioural tasks; the most common self-report tool was the MAIA, whilst the most frequently administered task was the Heartbeat Counting Task (HCT). The studies examined a variety of interoceptive modalities, such as cardiac, respiratory, nociceptive, and gastrointestinal domains. Notably, the cardiac axis was the most extensively researched, with 24 out of 37 studies (65%) focusing on this bodily axis. The included studies mostly adopted cross-sectional or case-control methodologies. Publication dates ranged from 1992 to 2024, with half of the studies (*n* = 18) being published within the past five years, underscoring the growing interest of this area of research. Geographically, the studies were conducted across a range of countries, with the highest number originating from the United States (n = 14), followed by Germany (n = 8) and China (n = 6) (see Appendix E for detailed characteristics).

Figure 2.4 Frequency of Measurement Tools by Clinical Group



Risk of bias was assessed using the EPHPP Quality Assessment Tool for Quantitative Studies (Thomas et al., 2003). Across the included studies, methodological quality was variable. Of the 37 studies assessed, 9 (24%) were rated as strong, 17 (46%) as moderate, and 11 (30%) as weak in overall quality. Common methodological strengths included the use of valid and reliable interoceptive and anxiety-related measures, as well as appropriate statistical analyses. However, several studies demonstrated limitations. Specifically, the most frequent areas of weakness were selection bias, where study samples were not clearly representative of the target population, and participant withdrawal / dropouts, with many studies not explicitly reporting the number of dropouts or the reasons for attrition. These findings highlight the need for cautious interpretation of results, particularly in studies rated as 'weak'. A detailed breakdown of component and global ratings for each study is provided in Appendix F.

Table 2.3 Summary of Key Findings of Included Studies

Author(s) & Year	Anxiety Condition	Sample Size	Interoceptive Channel	Interoceptive Dimension	Interoceptive Measure	Key Findings
Andor et al. (2008)	GAD	GAD = 33 HC = 34	Electrodermal	Accuracy Beliefs	Signal detection task Confidence ratings	↑ accuracy in GAD than controls ($p < .001$, $\eta p^2 = .25$). No difference in assumed ability to perceive bodily sensations between groups ($p = .18$, $\eta p^2 = .03$)
Antony et al. (1995)	Panic SAD	PD = 20 SAD = 20 HC = 20	Cardiac	Accuracy Beliefs	Heartbeat counting Confidence ratings	No difference in accuracy between panic, social anxiety and control groups ($p > .05$)
Asmundson et al. (1993)	Panic	PD = 20 HC = 20	Cardiac	Accuracy Beliefs	HDT Self-report questions	No difference in accuracy between panic and control groups ($p > .05$). No difference in beliefs between panic and control groups ($p > .05$)
Belanger et al. (2023)	OCD	OCD = 145	Cross-modal	Beliefs	MAIA	No relationship between interoceptive beliefs and OCD except for 'Not Worrying' MAIA subscale ($r = .17$)

Bogaerts et al. (2022)	Panic	PD = 60 HC = 144	Cross-modal	Beliefs Attention	Interoceptive Sensitivity and Attention Questionnaire	No difference in beliefs between panic and control group. ↑ self-reported attention to unpleasant sensations in panic group
Craske et al. (2001)	Panic	PD = 90 HC = 16	Cardiac Respiratory	Accuracy Beliefs Attention (arousal)	HCT Hyperventilation task BSQ	No difference in accuracy between panic and control group. ↑ beliefs (fear, distress) than controls. ↑ attention / arousal than controls
Cui et al. (2016)	GAD Panic	GAD = 21 PD = 18 HC = 22	Cardiac Respiratory	Attention	BPQ (Awareness)	↑ interoceptive attention to palpitations and breathlessness in panic compared to controls (p < .001). ↑ interoceptive attention to fear generalisation in GAD than controls (p < .001). No difference between GAD and PD patients (p = .197)
Cui et al. (2020)	GAD	GAD = 32 HC = 30	Cardiac	Accuracy Attention	HCT BPQ (Awareness)	↑ accuracy in GAD than controls (p = .030, d = 0.51). ↑ attention in GAD than controls (p < .001, d = 1.60)
Demartini et al. (2021)	OCD	OCD = 18 HC = 18	Cardiac	Accuracy	HCT	↓ accuracy in OCD than controls (p = .016; d = 0.85)

Ehlers & Breuer (1992)	Panic	PD = 65 P. Attacks = 50 Phobias = 27 HC = 46	Cardiac	Accuracy	HCT	↑ accuracy in panic disorder than phobia, infrequent panickers and controls ($p < .001$)
Eng et al. (2020)	OCD	OCD = 81 Controls = 76	Cross-modal	Beliefs	MAIA	↑ 'maladaptive' interoceptive beliefs in OCD than control group
Eng et al. (2022)	OCD	OCD = 77 HC = 53	Cross-modal	Beliefs	MAIA	↑ 'maladaptive' interoceptive beliefs in OCD than control group, including 'Noticing' ($d = 0.96$), 'Emotional Awareness' ($d = 0.88$), 'Not Distracting' ($d = 0.85$), 'Not Worrying' ($d = 0.87$)
Eng et al. (2024)	OCD	OCD = 82 HC = 38	Bodily Urge Sensitivity & Regulation	Attention	MAIA - 'Noticing' subscale Eye-blink suppression task	↑ interoceptive attention towards bodily sensations in high OCD symptom severity than moderate ($\Delta MAD = 1.50$) & low symptom severity groups ($\Delta MAD = 1.94$)

Gaebler et al. (2013)	SAD	SAD = 21 HC= 21	Cardiac	Accuracy Attention	HCT Functional & Dysfunctional Self-focused Attention Questionnaire (FDSAQ)	↓ accuracy in SAD than controls (*d* = 0.78). ↑ self-focussed attention in SAD (*d* = 0.92)
Giardino et al. (2010)	Panic	COPD-PD = 10 COPD-NP = 9 HC = 9	Respiratory	Accuracy Beliefs	Respiratory Load Detection Task Dyspnoea Intensity Rating	No difference in accuracy between panic and controls. ↑ negative interoceptive beliefs (greater breathlessness) in panic than COPD-NP (*p* = .041) and control groups (*p* = .012)
Ironside et al. (2023)	Mixed Anxiety	Anx. / dep. = 104 Depression = 52	Respiratory Pain / Nociception	Accuracy Beliefs Attention	Breath-hold Challenge Cold-pressor Challenge Heartbeat Tapping Task Visceral Attention Task Confidence ratings	No difference in accuracy in between groups. No difference in attention to interoceptive signals between groups. ↑ negative beliefs in anxiety & depression group than depression only
Jin et al (2020)	Panic	PD = 18 HC = 21	Cardiac	Accuracy Attention	HCT fMRI	No sig. difference in accuracy in panic than control group but moderate effect size (*p* = .07; *d* = 0.63). ↑ interoceptive attention in panic group

Kroeze et al. (1996)	Panic	PD = 16 HC = 17	Cross-modal	Attention	14-item Symptom Checklist (intensity of sensations & no. of panic symptoms)	↑ attention to bodily sensations in panic than controls ($p < .05$)
Lapidus et al. (2020)	Mixed Anxiety	Anx. / mood = 51 ED = 51 HC = 51	Respiratory Pain / Nociception	Beliefs	Ratings of pain intensity during behavioural tasks	↑ negative beliefs (fear, stress) in response to interoceptive cues than controls
Lee et al. (2024)	Mixed Anxiety	Anxiety = 67 Depression = 36	Cross-modal	Beliefs	K-MAIA (Korean version)	↑ maladaptive interoceptive beliefs (e.g., mistrust of bodily sensations) in mixed anxiety than control group (r = -.47 to -.54, $p < .001$)
Li et al. (2023)	Panic GAD	GAD = 21 Panic = 18 HC = 22	Cross-modal	Attention	BPQ (Awareness)	↑ interoceptive attention in panic and GAD groups than controls
Li et al. (2020)	GAD	GAD = 18 HC = 18	Cardiac	Accuracy	HCT	No difference in interoceptive accuracy between GAD and controls ($p = .33$)

Limmer et al. (2015)	Panic	PD = 40 HC = 53	Respiratory	Accuracy Attention	Physiological data (e.g., HR, EMG, SCL) Rating scale of sensations BPQ	Accuracy varies by signal type: ↑ accuracy in panic group for cardiac-related signals (HR, EMG) but not others (SCL, breathing). No differences in interoceptive attention between groups ($p < .001$)
Machorrinho et al. (2022)	PTSD Mixed Anxiety	<u>38 DV victims:</u> PTSD = 24 Anxiety = 27 No PTSD = 12 No anxiety = 10	Cardiac	Accuracy Beliefs	HCT MAIA	No difference in accuracy between PTSD ($rs = .10$), or anxiety symptoms ($rs = .10$) compared to controls. ↑ negative interoceptive beliefs in PTSD related to MAIA subscales 'Trusting' ($r = .56$), 'Self-regulation' ($r = .36$). ↑negative interoceptive beliefs in mixed anxiety related to 'Trusting' ($r = .49$).
Mussgay et al. (1999)	Panic	Panic = 53 HC = 48	Cardiac	Accuracy	HCT	No difference in accuracy between panic and controls
Pang et al. (2019)	GAD	GAD = 25 HC = 15	Cardiac	Attention (Neural)	Heartbeat evoked potential (HEP)	Altered interoceptive attention in individuals with GAD (i.e., disrupted neural modulation between internal and external focus). ↑ sensitivity to cardiac signals, which correlated with anxiety symptom severity

Poppa et al. (2019)	PTSD	PTSD & SUD = 14 SUD = 29	Respiratory	Attention	The Interoceptive-Exteroceptive Attention task	↓ interoceptive attention in PTSD at a neural level (β = –.92, *p* = .004)
Richards et al. (1996)	Panic	PD = 26 HC = 14	Cardiac	Accuracy	HCT	↑ accuracy in panic than controls in a restricted breathing task only
Schmitz et al. (2021)	PTSD	PTSD = 24 HC = 32	Cardiac	Attention	Heartbeat evoked potential (HEP)	No difference in cardiac interoceptive attention at the neural level between PTSD and control group (*p* = .462, *d* = 0.20)
Schultchen et al. (2019)	OCD	OCD = 26 HC = 26	Cardiac	Accuracy	HCT	↓ accuracy in OCD than controls (*r* = -.45; *p* < .001)
Smith et al. (2021)	Mixed Anxiety	Anx. / dep.= 221 Substance use = 136 HC = 53	Cardiac Respiratory	Accuracy Beliefs	Heartbeat Tapping Task Confidence rating	↓ adaptive interoceptive processing in anxiety & depression groups compared to controls (i.e., during a breath-hold condition)

Teed et al. (2022)	GAD	GAD = 29 HC = 29	Cardiac Respiratory	Beliefs	Heartbeat & respiratory intensity ratings	↑ interoceptive beliefs in GAD than controls (i.e., higher cardiorespiratory intensity, p = .01)
Verdonk et al. (2024)	GAD	GAD = 24 HC = 24	Cardiac	Attention (Neural)	Heartbeat-evoked potential (HEP)	↑ neural sensitivity in GAD than controls (increased interoceptive attention at a neural level) (d = 0.46)
Wölk et al. (2014)	Panic	PD = 17 HC = 17	Cardiac	Accuracy	HCT	No difference in accuracy between panic and controls (p = .20, d = 0.31)
Yoris et al. (2017)	OCD Panic	OCD = 15 PD = 15 HC = 25	Cardiac	Accuracy Beliefs Insight	Heartbeat Tapping Task Confidence ratings Relationship between accuracy and confidence	↑ accuracy in OCD compared with control and panic groups. ↓ confidence of performance in OCD than controls (p = .03) and panic groups (p = .04) No difference in confidence between panic and control groups (p = .10). ↓ insight in OCD groups (i.e., no correlation between objective accuracy and confidence of accuracy (r = .11; p = .67)

Yoris et al. (2015)	Panic	Panic attack = 21 HC = 13	Cardiac	Accuracy Beliefs	HDT BSQ	No difference in accuracy between panic and controls (p = 0.19, ηp^2 = .06). ↑ negative interoceptive beliefs in panic than control group (i.e., threatening interpretations of bodily sensations) (p < .001, ηp^2 = .58)
Zoellner & Craske (1999)	Panic	Infrequent panic attacks = 31 HC = 27	Cardiac	Accuracy Beliefs	HCT Confidence ratings	↑ accuracy in infrequent panickers than control group (p < .05). No difference in interoceptive beliefs (confidence) across groups

*No*te. Arrows (↑/↓) denote higher / lower levels of effect relative to control or comparison group; BPQ = Body Perception Questionnaire; BSQ = Body Sensations Questionnaire; DV = Domestic Violence; ED = Eating Disorder; fMRI = Functional Magnetic Resonance Imaging; GAD = Generalized Anxiety Disorder; HC = Healthy Control; HCT = Heartbeat Counting Task; HDT = Heartbeat Detection Task; OCD = Obsessive-Compulsive Disorder; SAD = Social Anxiety Disorder; SUD = Substance Use Disorder; PD = Panic Disorder; PTSD = Post-Traumatic Stress Disorder; HC = Healthy Controls. p values and effect sizes (e.g., d, ηp^2) are reported where available.

2.4.2 The Relationship Between Interoception and GAD

A total of eight studies examined the relationship between interoception and GAD, with a mix of study designs including cross-sectional, case-control and randomised clinical trials. The included studies focussed on cardiac and respiratory domains

2.4.2.1 Interoceptive Accuracy and GAD

Three studies investigated interoceptive accuracy using behavioural tasks. Two used the HCT (i.e., (Cui et al., 2020; Li et al., 2020), while one study employed a signal detection paradigm using skin conduction responses to assess perception of subtle autonomic arousal (non-specific skin conductance fluctuations) (Andor et al., 2008).

Findings between the heartbeat counting based studies were inconsistent. Cui et al. (2020) reported significantly higher interoceptive accuracy in the GAD group compared to controls (d = 0.51). Whereas Li et al. (2020) found no significant difference between groups, though exploratory analyses linked reduced grey matter volume in interoception-related brain regions (e.g., left medial prefrontal cortex) to higher heartbeat perception sensitivity in patients in GAD, suggesting heartbeat perception is associated with brain structure in GAD. In the signal detection task, Andor et al. (2008) found that GAD participants demonstrated superior detection of physiological arousal cues relative to controls (ηp^2 = .25) when asked to report whether they perceived any physiological arousal before an auditory tone. These mixed findings may suggest that interoceptive accuracy in GAD may be task-dependant, and that accuracy may not be uniformly impaired or enhanced across bodily dimensions (i.e., cardiac or electrodermal). Notably, improved performance did not always coincide with heightened confidence, raising questions about the integration of sensory evidence and interoceptive beliefs in GAD (i.e., interoceptive insight), although this was not formally assessed in the included studies.

2.4.2.2 Interoceptive Attention And GAD

Five studies assessed interoceptive attention in individuals with GAD using self-report questionnaires and behavioural tasks. Of these, three studies assessed interoceptive attention using the BPQ (Cui et al., 2020; Cui et al., 2016; Li et al., 2023). Across all three, individuals with GAD reportedly significantly greater interoceptive attention on the BPQ-Awareness subscale compared to healthy controls. For example, Cui et al. (2020) reported a large effect size (d = 1.6), indicating a marked tendency for individuals with GAD in the sample to attend closely to internal bodily signals. In studies that also included panic disorder groups, no significant differences were found between GAD and panic participants in BPQ-Awareness scores (a measure of habitual interoceptive attention). However, Cui et al. (2016) proposed that the nature of this attentional focus may differ between conditions; while individuals with panic disorder may be more acutely attuned to specific bodily sensations associated with fear and physiological arousal (e.g., palpitations, breathlessness), those with GAD may exhibit a broader and more diffuse attentional focus on the body. This may reflect the pervasive and sustained nature of worry characteristic of GAD, in contrast to the acute, episodic physiological reactivity observed in panic disorder.

Two studies investigated the neural underpinnings of interoceptive attention in GAD using heartbeat-evoked potentials (HEPs), an EEG-based measure reflecting cortical an electrophysiological marker of cardiac interoception (Pang et al., 2019; Verdonk et al., 2024). In both studies, GAD participants exhibited larger HEP amplitudes compared to healthy controls, suggesting altered interoceptive attention at the neural level. For instance, Verdonk et al. (2024) found significantly larger HEP amplitudes over right frontocentral and parietal regions during saline infusion (i.e., in the absence of physiological arousal), with a moderate effect size (d = 0.46). These findings indicate that some fundamental electrophysiological differences exist between individuals with GAD and controls.

2.4.2.3 Interoceptive Beliefs in GAD

Two studies included the measurement of interoceptive beliefs in their research. Teed et al. (2022) primarily investigated neural and autonomic responses to peripheral adrenergic stimulation in individuals with GAD using functional magnetic resonance imaging (fMRI). The study also assessed self-reported interoceptive beliefs (referred to as 'awareness' in the paper) through subjective ratings of heartbeat and breathing sensations. The results showed that GAD patients reported significantly more intense cardiorespiratory sensations during a lower dose of isoproterenol compared to controls, but no such differences during placebo conditions or with the higher dose of isoproterenol. Such findings suggest that individuals with GAD exhibit heightened interoceptive beliefs, particularly under low autonomic arousal.

In contrast, Andor et al. (2008) found that GAD participants did not differ from controls in their general beliefs about interoceptive ability, or in the certainty of their bodily sensation judgments during a signal detection task. However, despite demonstrating greater interoceptive accuracy than controls, their confidence ratings did not reflect this enhanced performance. This pattern may indicate reduced interoceptive insight in GAD, described by Suksasilp and Garfinkel (2022) as the metacognitive correspondence between objective task performance and subjective self-report.

2.4.3 The Relationship Between Interoception and OCD

Seven studies were identified that examined interoception in individuals with OCD. Many of these studies employed cross-sectional designs, typically comparing clinical OCD samples with healthy controls or exploring associations between interoceptive processes and symptom severity within OCD populations. Across studies, interoception was primarily assessed through self-report measures (see Figure 2.4), with the most common bodily axis of focus being associated with cardiac and visceral domains. One study combined behavioural tasks (heartbeat tapping) to complement

self-report findings (Yoris et al., 2017). Research to date has predominantly focused on interoceptive beliefs, such as trust and worry about bodily sensations in OCD clinical populations, while comparatively fewer studies have investigated interoceptive accuracy or attention.

2.4.3.1 Interoceptive Accuracy in OCD

Three studies assessed interoceptive accuracy in OCD samples. Demartini et al. (2021) found that OCD patients demonstrated significantly lower heartbeat counting accuracy than controls (d = 0.85), and this deficit was not explained by comorbid anxiety, depression, or alexithymia. Similarly, Schultchen et al. (2019) reported OCD participants showed lower interoceptive accuracy on the HCT compared to controls; reduced interoceptive accuracy was also found to be related to more OCD symptoms. Notably, interoceptive accuracy did not significantly improve following cognitive-behavioural therapy, suggesting that these deficits may represent a stable feature in OCD (Schultchen et al., 2019).

In contrast, Yoris et al. (2017) reported that OCD patients exhibited higher interoceptive accuracy during a heartbeat tapping task compared to both panic disorder patients and healthy controls. This discrepancy in findings may be attributable to methodological differences between studies. While both Demartini et al. (2021) and Schultchen et al. (2019) employed the heartbeat counting task (Schandry, 1981), Yoris et al. (2017) utilised a heartbeat tapping task (Canales-Johnson et al., 2015). Specifically, the tapping task requires integration of both interoceptive (heartbeat) and exteroceptive (motor tapping) signals, whereas the counting tasks focusses exclusively on interoceptive signals. As such, it has been argued that these tasks measure distinct aspects of interoceptive accuracy (Schultchen et al., 2019).

2.4.3.2 Interoceptive Beliefs in OCD

Four studies assessed interoceptive beliefs in individuals with OCD, predominately using the MAIA, with one study instead assessing confidence ratings during a heartbeat tapping task (Yoris et al., 2017). Studies using the MAIA demonstrated less adaptive interoceptive beliefs in OCD (Belanger

et al., 2023; Eng et al., 2020, 2022). For instance, Eng et al. (2022) found that OCD patients reported greater noticing of bodily sensations than controls (*d* = 0.96), but also greater distraction (*d* = −0.85), worry (*d* = −0.87), and lower trust in these sensations (*d* = −0.65). They concluded that "adaptive" interoceptive beliefs (e.g., trusting bodily sensations) were linked to lower OCD and anxiety symptom severity, while "maladaptive" beliefs (e.g., excessive noticing without regulation) were associated with greater dysfunction, a pattern also supported by accompanying neuroimaging analysis. Similarly, Eng et al. (2020) reported that specific interoceptive beliefs were differentially associated with OCD symptom dimensions: for example, noticing was positively associated with “symmetry” and "not-just-right" experiences, while worrying was associated with contamination concerns. Together, these findings suggest that altered interoceptive beliefs may be tied to specific OCD symptom clusters.

2.4.3.3 Interoceptive Attention and OCD

One study explicitly investigated interoceptive attention in OCD populations. Eng et al. (2024) focused specifically on the MAIA Noticing subscale. This subscale captures the degree of attention to bodily sensations rather than beliefs about them (Mehling et al., 2018), therefore this study is included under the ‘interoceptive attention’ section of this synthesis, rather than ‘interoceptive beliefs’. Group comparisons revealed that that individuals with high OCD severity reported significantly greater noticing of bodily sensations compared to those with moderate and low OCD symptom severity. These findings suggest that greater attention to bodily sensations is positively associated with OCD symptom severity. Overall, while preliminary evidence suggests that altered interoceptive attention, characterised by increased noticing of bodily sensations, may play a role in the phenomenology of OCD, it is important to note that research in this area remains limited in comparison to other anxiety disorders included within this review.

2.4.4 The Relationship Between Interoception and Panic Disorder

A total of 17 studies examined the relationship between interoception and panic disorder. Most employed cross-sectional, case-control designs, comparing individuals with a current or past diagnosis of panic disorder to healthy controls. A smaller subset of studies included additional comparison groups, such as individuals with GAD (Cui et al., 2016), OCD (Yoris et al., 2017) and SAD (Antony et al., 1995) providing opportunities for transdiagnostic comparisons. The most consistently examined interoceptive dimension across studies examining panic disorder was interoceptive accuracy, primarily operationalised using heartbeat perception tasks.

2.4.4.1 Interoceptive Accuracy and Panic Disorder

Of the 18 included studies, 13 assessed interoceptive accuracy. Of these, cardiac accuracy was most frequently examined (n =10); specifically, seven used heartbeat counting tasks, two used heartbeat discrimination tasks, and one employed a tapping paradigm. Eight studies reported no statistically significant differences in interoceptive accuracy between individuals with panic disorder and healthy controls (Antony et al., 1995; Asmundson et al., 1993; Craske et al., 2001; Jin et al., 2020; Mussgay et al., 1999; Wölk et al., 2014; Yoris et al., 2015; Yoris et al., 2017). However, three of these studies noted numerically higher accuracy scores in panic disorder (Antony et al., 1995; Jin et al., 2020; Mussgay et al., 1999; Wölk et al., 2014). In contrast, three studies reported significantly greater interoceptive accuracy in individuals with panic disorder compared to comparison to controls (Ehlers & Breuer, 1992; Richards et al., 1996; Zoellner & Craske, 1999). Richards et al. (1996) found that individuals with panic disorder only demonstrated greater cardiac accuracy than controls during a restricted breathing task (i.e., breathing through a narrow straw). No differences were observed during relaxation or exercise conditions, suggesting heightened interoceptive accuracy in in panic disorder may be specific to panicogenic situations.

Two studies assessed interoceptive accuracy within the respiratory bodily axis in panic disorder, using tasks such as the hyperventilation challenge (e.g., measuring respiratory rate and end-tidal CO_2) to evaluate reactivity to induced respiratory cues (Craske et al., 2001), and the respiratory load detection task to assess perceptual thresholds for inspiratory resistance (Giardino et al., 2010). Both studies reported no significant differences in respiratory interoceptive accuracy between panic disorder and control groups. Notably, Giardino et al. (2010) found that PD-COPD comorbid individuals did not exhibit heightened interoceptive accuracy to respiratory loads; however, they reported experiencing greater dyspnoea in response to inspiratory resistance. This finding suggests a potential dissociation between physiological and subjective interoceptive experiences.

Limmer et al. (2015) adopted a multi-system approach to assess interoceptive accuracy in panic disorder, asking participants to rate perceived changes in six physiological signals: heart rate, the intensity of their heartbeat, palm humidity (as a proxy for skin conductance), shoulder muscle tension (EMG), breathing rate, and breathing depth. Panic disorder participants showed greater accuracy for cardiac and muscular-related signals (e.g., heart rate, muscle tension), but not for others (e.g., skin conductance or respiratory cues), indicating domain-specific enhancement for fear relevant signals, rather than a generalised interoceptive advantage (Limmer et al., 2015).

2.4.4.2 Interoceptive Beliefs and Panic Disorder

Seven studies explored interoceptive beliefs using self-report questionnaires (e.g., Body Sensations Questionnaire) and confidence ratings. Three studies found differences in interoceptive beliefs between panic disorder patients and healthy controls, including reporting greater breathlessness and intense perception of bodily discomfort (Giardino et al., 2010), heightened fear of bodily symptoms (Craske et al., 2001), and more threatening interpretations (Yoris et al., 2015). For example, Yoris et al. (2015) found that despite no increase in objective interoceptive accuracy, panic disorder patients interpreted these sensations as threatening (i.e., believing they signal harm or

catastrophe) (ηp2 = 0.58). Conversely, four studies reported no group differences in self-reported beliefs about perceptual acuity and confidence in performance (Antony et al., 1995; Asmundson et al., 1993; Bogaerts et al., 2022; Zoellner & Craske, 1999), possibly reflecting methodological variations or differences in sample characteristics.

2.4.4.3 Interoceptive Attention and Panic Disorder

Six studies examined interoceptive attention using a range of modalities of interoceptive measurement, including self-report questionnaires (i.e., BPQ) and neuroimaging. Results consistently reported heightened attention to bodily sensations among individuals with panic disorder. For instance, Kroeze et al. (1996) observed that individuals with panic disorder reported more intense and varied bodily sensations compared to control groups. Similar findings were reported in other studies reporting higher attention to unpleasant sensations (Bogaerts et al., 2022).

Cui et al. (2016) and Li et al. (2023), which appear to draw from the same dataset, reported significantly higher BPQ-awareness scores in the panic condition compared to controls, suggesting panic disorder is associated with heightened attention to bodily sensations and internal states. In contrast, Limmer et al. (2015) found no group differences on the BPQ-Awareness subscale but observed greater autonomic reactivity (BPQ-ANSR; $p < .001$) in panic disorder participants, indicating that panic disorder may be more strongly associated with physiological reactivity than with awareness itself.

Functional neuroimaging studies revealed enhanced interoceptive processing in panic disorder (Cui et al., 2016; Jin et al., 2020; Li et al., 2023). These studies report increased functional connectivity between interoceptive brain regions, such as the somatosensory cortex and thalamus (Cui et al., 2016), as well as atypical functional connectivity in the anterior default mode network which is linked to anxiety sensitivity and avoidance (Li et al., 2023). Jin et al. (2020) found increased activation of the bilateral superior parietal lobe in panic disorder patients compared to controls

during interoceptive tasks and concluded panic patients may be more attuned to processing information associated with their internal states.

2.4.5 The Relationship Between Interoception and PTSD

Three studies assessed the relationship between interoception and PTSD. These varied in methodology (e.g., neuroimaging, heartbeat perception tasks, self-report) and participant characteristics (e.g., substance use comorbidity, intimate partner violence). Two studies assessed interoception in the cardiac domain (Machorrinho et al., 2022; Schmitz et al., 2021), whilst one assessed respiratory (Poppa et al., 2019).

2.4.5.1 Interoceptive Accuracy in PTSD

One study investigated interoceptive accuracy in a clinical sample of women with PTSD following exposure to intimate partner violence, using the Heartbeat Counting Task. The findings revealed no significant association between PTSD symptom severity and heartbeat counting performance (Machorrinho et al., 2022).

2.4.5.2 Interoceptive Beliefs in PTSD

Machorrinho et al. (2022) investigated interoceptive beliefs in clinical PTSD samples, measured via the MAIA. Results showed that women with PTSD symptoms exhibited significantly lower levels of both interoceptive trusting and interoceptive self-regulation compared to women without PTSD. These findings indicate PTSD may be associated with negative beliefs and attitudes toward bodily signals, despite objective interoceptive accuracy being unaffected.

2.4.5.3 Interoceptive Attention in PTSD

Two studies investigated the relationship between PTSD and interoceptive attention, with mixed findings depending on the interoceptive modality and measurement approach (Poppa et al., 2019; Schmitz et al., 2021). Poppa et al. (2019) examined interoceptive attention during a

respiratory-focused task (the IN-OUT task) using fMRI in women with substance use disorders, with and without comorbid PTSD. Individuals with PTSD exhibited reduced functional connectivity within an orbitofrontal network during interoceptive attention compared to controls with substance use disorders alone. These findings suggest that PTSD may be associated with impaired neural network engagement during interoceptive attention, particularly within regions supporting bodily signal integration.

In contrast, Schmitz et al. (2021) used heartbeat-evoked potentials (HEPS) to assess cardiac interoceptive attention in individuals with PTSD and healthy controls. Patients with PTSD showed descriptively higher HEP amplitudes than controls, although this difference was not statistically significant. This suggests that, at rest, individuals with PTSD may not demonstrate altered cortical processing of cardiac signals compared to healthy controls. Together, these studies suggest that PTSD may be associated with disrupted interoceptive attention at the neural systems level during active interoceptive engagement (i.e., focused attention to breathing), but not necessarily with baseline cortical representation of cardiac signals at rest. Differences in the type of interoceptive signal (respiratory vs. cardiac) and the nature of the task (active attention vs. passive resting state) may contribute to the divergent findings.

2.4.6 The Relationship Between Interoception and Social Anxiety Disorder

Two studies investigated interoception in clinical social anxiety (Antony et al., 1995; Gaebler et al., 2013). Both studies considered interoception across multiple dimensions, including accuracy, attention, and beliefs, using a combination of behavioural and self-report measures.

2.4.6.1 Interoceptive Accuracy in Social Anxiety Disorder

Both studies assessed cardiac interoceptive accuracy through heartbeat counting tasks, yielding contrasting findings. Gaebler et al. (2013) reported significantly lower accuracy in individuals with SAD compared to healthy controls size (d = 0.78). In contrast, Antony et al. (1995) found no significant differences in cardiac accuracy between social anxiety, panic disorder and control groups;

individuals with social phobia were equally as accurate as those with panic disorder, with both groups demonstrating slightly higher accuracy than healthy controls.

2.4.6.2 Interoceptive Beliefs in Social Anxiety Disorder

No group differences in confidence during the heartbeat counting tasks was reported (Antony et al., 1995; Gaebler et al., 2013). Although limited to two studies, these findings suggest that while social anxiety may involve reduced interoceptive accuracy and heightened self-focus, confidence in bodily signal detection appears relatively preserved.

2.4.6.3 Interoceptive Attention in Social Anxiety Disorder

Gaebler et al. (2013) found individuals with SAD self-reported significantly higher self-focused attention than controls (d = 0.92), while being less accurate in estimating their heartbeats.

2.4.7 The Relationship Between Interoception and Mixed Anxiety

In addition to disorder-specific investigations, a smaller body of research explored interoceptive processes in samples characterised by mixed or unspecified clinical anxiety presentations (n = 5). These studies included individuals with varying anxiety symptoms or comorbidities, rather than focussing on a single diagnostic category. Studies examined interoception across heterogeneous anxiety samples, often including participants with comorbid depression or other mood disorders (Ironside et al., 2023; Lapidus et al., 2020; Lee et al., 2024; Machorrinho et al., 2022; Smith et al., 2021).

2.4.7.1 Interoceptive Accuracy in Mixed Anxiety

Across three studies, objective measures of interoceptive accuracy, such as heartbeat counting tasks and tapping tasks, did not consistently distinguish individuals with anxiety from control or comparison groups (Ironside et al., 2023; Machorrinho et al., 2022; Smith et al., 2021) For instance, Smith et al. (2021) found that healthy controls demonstrated improved heartbeat tapping

accuracy when bodily signals were intensified through physiological perturbation (i.e., a breath-hold condition). However, individuals with comorbid depression and anxiety disorders did not show this improvement, with their accuracy remaining unchanged despite stronger bodily signals. This pattern suggests a blunted enhancement of interoceptive accuracy in anxiety and depression, indicating reduced flexibility in adapting to heightened bodily signals in the context of anxiety and depression.

2.4.7.2 Interoceptive Beliefs in Mixed Anxiety

All five studies investigating interoception in mixed anxiety samples assessed interoceptive beliefs using either self-report questionnaires or confidence ratings on behavioural tasks. Results generally indicated maladaptive interoceptive beliefs in anxiety groups, particularly characterised by fear, mistrust or heightened concerns regarding bodily sensations. Two studies employed the MAIA to assess interoceptive beliefs. Lee et al. (2024) found that specific MAIA subscales significantly predicted anxiety scores: higher 'noticing' scores predicted greater anxiety, whereas higher 'attention regulation' and 'trusting' in bodily signals predicted lower anxiety levels. Similarly, Machorrinho et al. (2022) reported that women experiencing anxiety symptoms exhibited significantly lower interoceptive trust compared to controls (p =.027).

Ironside et al. (2023) employed several interoceptive tasks, including a breath-hold challenge, a cold-pressor task, heartbeat tapping task, and visceral interoceptive attention task, to examine interoceptive processes in individuals with comorbid anxious depression compared to individuals with depression alone. The anxious depression group reported significantly greater fear of suffocation during the breath-hold challenge and withdrew from the cold-pressor task more quickly, despite similar self-reported pain ratings across groups. Although, no group differences were reported in self-reported ratings of confidence, difficulty or intensity in the heartbeat detection task. These findings suggest that anxious depression is characterised by heightened negative beliefs and reactivity toward bodily sensations. Notably, no group differences were found in objective interoceptive accuracy on the heartbeat tapping task, indicating that the observed differences reflect

increased perceived threat or aversiveness to bodily signals, rather than alterations in interoceptive accuracy or attention.

Similarly, Lapidus et al. (2020) found that individuals with mood and anxiety disorders reported significantly greater stress and suffocation fear during a breath-hold task compared to healthy controls, despite no group differences in physiological measures (e.g., heart rate, oxygen levels). Consistent with Ironside et al. (2023), these findings highlight that heightened negative beliefs and affective responses to bodily signals, rather than objective accuracy interoceptive deficits, may characterise interoceptive dysfunction in anxiety.

2.4.7.3 Interoceptive Attention in Mixed Anxiety

One study probed interoceptive attention in comorbid anxiety and depression groups in comparison to controls. Ironside et al. (2023) used the Visceral Interoceptive Attention task, which requires participants to focus either on internal bodily sensations (i.e., heart or gastrointestinal sensations) or external stimuli (i.e., word colour changes). The study found no significant group differences in attention to interoceptive signals, as measured by performance on the visceral attention task.

2.5 Discussion

The aim of the present systematic review was to examine the available studies that quantify the associations between interoception and anxiety conditions, including GAD, OCD, panic disorder, PTSD, and SAD. Secondary aims of the review were to explore whether there is greater focus on specific interoceptive process (e.g., accuracy, attention, beliefs) and interoceptive modalities (e.g., cardiac, gastrointestinal, respiratory) within clinical population research in anxiety. Additionally, the review sought to identify which specific anxiety disorders are disproportionately represented in the interoception literature.

The findings highlight the complex and multifaceted relationship between interoception and anxiety-related psychopathology. Interoceptive processes appear to play a transdiagnostic role across a range of anxiety disorders, with evidence implicating their involvement in GAD, OCD, panic disorder, PTSD, and to a lesser extent, SAD. Despite this shared relevance, the specific nature of interoceptive differences varies across conditions, which may suggest the role of interoception is not entirely uniform, but rather embedded within a broader network of interacting cognitive, emotional, and physiological processes.

In GAD, findings suggest a consistent pattern of heightened interoceptive attention, observed at a self-reported and neurophysiological level, as evidenced by increased heartbeat-evoked potentials (Pang et al., 2019; Verdonk et al., 2024). Interoceptive beliefs also appear elevated in certain contexts, particularly under low autonomic arousal (Teed et al., 2022). However, evidence for enhanced interoceptive accuracy is mixed and appears task-dependent, with improvements in accuracy not always accompanied by greater confidence (Andor et al., 2008) Such findings align with theoretical accounts suggesting that individuals with GAD exhibit heightened vigilance towards internal bodily states alongside maladaptive beliefs about these sensations, contributing to the maintenance of worry and anxiety, even in the absence of objectively increased physiological arousal (Wells, 1995).

In OCD, research indicates heightened attention to bodily sensations, yet individuals often demonstrate reduced trust in these sensations and doubt their feelings and internal states. This aligns with theoretical accounts of OCD, which suggest that pathological doubt and a lack of trust in internal bodily signals contribute to obsessive-compulsive symptoms (Chiang & Purdon, 2023; Dar et al., 2022). Evidence regarding interoceptive accuracy is mixed, potentially due to methodological variation between studies. Research in this area is therefore limited with notable gaps in the breadth of interoceptive dimensions assessed and a need for more diverse methodological approaches (Wilson et al., 2025).

In panic disorder, findings demonstrate a consistent pattern of heightened interoceptive attention and increased physiological reactivity to internal bodily signals, particularly within the cardiac domain. Interoceptive beliefs tend to be negative, reflecting fear and catastrophic misinterpretation of bodily sensations (Yoris et al., 2015). Disruptions in interoceptive signals associated with arousal are likely to provoke exaggerated bodily sensations and an increase in fear responses (Paulus & Stein, 2010), consistent with the cognitive model of panic, which suggests that amplified interoceptive attention and misinterpretation of bodily signals as threatening perpetuates fear and physiological arousal (Clark, 1986). Evidence regarding differences in interoceptive accuracy in panic remains mixed (Adams et al., 2022), likely due to methodological variability.

Research exploring interoception in PTSD clinical populations is also limited and methodologically varied. For instance, one study examined interoceptive accuracy in PTSD and found no significant associations between accuracy and symptom severity (Machorrinho et al., 2022). However, other studies not included in this review have found contrasting results. Reinhardt et al. (2020) found interoceptive accuracy predicts variance in PTSD symptoms, with decreased accuracy associated with PTSD symptoms. Neuroimaging studies suggest interoceptive attention may be disrupted in PTSD at the neural level during active interoceptive engagement (i.e., focused attention to breathing) (Poppa et al., 2019), but this disruption does not appear to extend to baseline cortical representation of cardiac signals at rest (Schmitz et al., 2021). Further research using consistent methodologies and within-participant comparisons across bodily axes is needed. Furthermore, negative interoceptive beliefs, including lower self-regulation and trust in bodily signals, were observed in women with PTSD (Machorrinho et al., 2022). These findings align with PTSD models that emphasise hypervigilance to threat-related cues, avoidance of bodily states, pointing to interoceptive disruption as a potential transdiagnostic mechanism underlying PTSD symptomatology.

The present review highlights a gap in the literature regarding interoception in clinically diagnosed SAD populations. Whilst some studies in sub-clinical populations report increased interoceptive accuracy (Stevens et al., 2011) evidence from clinical samples suggest the opposite,

with reduced cardiac accuracy observed in individuals with SAD (Gaebler et al., 2013). Elevated self-focussed attention, however, has been more consistently reported across clinical and sub-clinical samples (Deiters et al., 2013; Gaebler et al., 2013; Heitmann et al., 2014), aligning with cognitive models of SAD that emphasise internal focus and physiological hypervigilance (Clark & Wells, 1995). The limited evidence base underscores the need for robust research to clarify interoception's role in SAD and its viability as an intervention target.

The findings of this review highlight the substantial variability in the extent and focus of interoceptive research across different anxiety disorders. Panic disorder received the most empirical attention, followed by GAD and then OCD, whereas SAD remains markedly underexplored in relation to interoceptive mechanisms. As acknowledged in previous literature, the evidence base is heavily weighted towards investigations of cardiac and respiratory interoception (Desmedt et al., 2023; Murphy, 2024). The current review reflects this trend, with 78% of the included studies focusing exclusively on these domains, while significantly less attention has been given to other interoceptive domains such as gastrointestinal, thermoregulatory, nociceptive or autonomic systems. Most studies (61%) focused on a single interoceptive bodily axis, typically assessed through heartbeat perception tasks or respiratory-focused paradigms. Furthermore, many studies used a single measurement of interoception (62%), with interoceptive accuracy emerging as the most frequently assessed dimension. A subset of studies employed self-report measures which capture interoceptive experiences across multiple bodily axes. This can be particularly useful when examining heterogeneous clinical presentations, where individuals may exhibit heightened sensitivity to different types of internal signals. For example, in GAD, individuals may differ in the bodily signals they are most sensitive to, such as heart rate, breathing or gastrointestinal discomfort, suggesting that anxiety may arise from dysregulation across different interoceptive channels.

The uneven distribution of research highlights important gaps in the evidence base, limiting our understanding of how interoceptive processes may differentially contribute to the onset and maintenance of specific anxiety disorders. An systemic approach is therefore needed in future

research to assess multiple levels of interoceptive systems, combining top-down assessments of interoceptive attention and beliefs with bottom-up perturbation methods (Khalsa et al., 2018; Quadt et al., 2018).

The methodological limitations of the studies included in this review raise important considerations for the interpretation of findings. Sample sizes were often small and disproportionately composed of women, potentially limiting generalisability. Moreover, although the HCT remains one of the most widely used methods in interoceptive research, its validity has been increasingly questioned (Desmedt et al., 2023). Evidence suggests that the HCT may be influenced by non-interoceptive factors such as guessing strategies (Ring & Brener, 2018; Windmann et al., 1999) and response biases (Corneille et al., 2020; Zamariola et al., 2018). As such, outcomes on the HCT may not reliably reflect interoceptive accuracy. Desmedt and Van den Bergh (2024) argue that it may more accurately reflect interoceptive '*estimation*' rather than objective accuracy and emphasise the need for formal validation of the task.

Another limitation in the reviewed literature is the inconsistencies observed in the conceptualisation of conscious dimensions of interoception, and how these are measured. Interoception is inherently multifaceted and encompasses a range of dimensions which are inconsistently or interchangeably across studies. Efforts to standardise interoceptive terminology have led to the development of conceptual frameworks, with Garfinkel et al.'s (2015) tripartite model being among the most widely adopted. This has improved consistency in the field; however, the conceptualisation of interoception remains an evolving process (Desmedt et al., 2025). Terms such as 'awareness', 'sensitivity,' and 'sensibility' are often used interchangeably across the included studies, complicating comparison. This definitional ambiguity hinders meaningful synthesis and limits the precision with which interoception's role in anxiety-related psychopathology can be interpreted. This underscores the need for conceptual clarity and consistent measurement of interoception in future research (Desmedt et al., 2025).

It is prudent to acknowledge the limitations of the present review. Firstly, the inclusion of studies employing heterogeneous methodologies (e.g., self-report questionnaires, behavioural tasks, neural imaging) may have introduced variability in findings, complicating efforts to draw consistent conclusions across studies. Secondly, there is a limited number of studies available for certain anxiety disorder subtypes (e.g., SAD and PTSD), which restricts the extent to which conclusions can be drawn about disorder-specific patterns of interoceptive functioning. Consequently, findings should be interpreted with caution, as they may reflect gaps or imbalances in the existing literature rather than genuine differences in interoceptive dimensions across disorders.

This review also drew on cross-sectional data, limiting the ability to draw causal inferences regarding whether atypical interoception precedes the onset of anxiety disorders or emerges because of them. Variability in participant characteristics (e.g., comorbid conditions, medication use, demographic differences) could also influence outcomes, limiting the generalisability of conclusions.

The methodological quality of included studies was variable; conclusions from weaker studies should be treated with caution, as common limitations (e.g., selection bias) may affect the reliability of observed associations. While patterns in higher-quality studies may offer useful insights, the overall variability in study quality limits the robustness of conclusions. Lastly, grey literature, dissertations and non-English studies were excluded from study selection which may have introduced publication bias.

2.5.1 Clinical Implications and Future Directions

Interoceptive interventions could have diagnostic and therapeutic utility in anxiety disorders (Schoeller et al., 2024). The findings of this review offer important clinical implications, particularly given the rapidly increasing rate of anxiety disorders globally (Chen et al., 2025). First, the transdiagnostic significance of interoception, evidenced by disruptions across a range of anxiety-related disorders, highlights the potential value of incorporating interoceptive processes into psychological assessment, formulation and intervention. While interoception appears to function as

a transdiagnostic mechanism across these conditions, certain interoceptive dimensions may hold greater clinical relevance within specific diagnostic presentations. Tailoring interventions to the salient interoceptive disruptions within each presentation may enhance therapeutic precision, while still acknowledging the shared underlying mechanisms. For example, interoceptive exposure may be relevant for reducing fear responses to internal sensations in panic disorder (Boettcher & Barlow, 2019). Whereas mindfulness-based approaches that cultivate non-judgemental awareness of bodily sensations may be more effective in PTSD (Molteni et al., 2024). These findings also underscore a broader need for increased awareness and training among clinicians regarding the relevance of interoception in anxiety-related psychopathology.

Future research should extend the scope of interoception beyond well-studied disorders to include underrepresented conditions such as PTSD and SAD, and by examining bodily domains beyond the cardiac and respiratory axes, such as gastrointestinal or thermoregulatory signals. An integrated approach is needed to assess interoceptive predictors of specific symptoms across multiple levels combining top-down measures (e.g., beliefs and attention) and bottom-up methods (e.g., measurement of neural signalling). Crucially, future work must adopt longitudinal, multimodal designs to clarify the causal pathways linking interoceptive difficulties to anxiety. While conceptual frameworks have laid important groundwork (Garfinkel et al., 2015; Khalsa et al., 2018; Murphy et al., 2019; Suksasilp & Garfinkel, 2022), progress in this field requires harmonising frameworks into a unified model that can be consistently used across studies to support conceptual clarity and methodological coherence (Khalsa & Lapidus, 2016). Finally, future work must consider cultural influences on interoceptive processing, which may shape both symptom expression and treatment responsiveness. A more inclusive, methodologically robust approach will be critical to advancing the translational potential of interoception research in anxiety-related disorders and informing the evolution of evidence-based therapeutic approaches.

2.5.2 Conclusion

To conclude, this review underscores the emerging role of interoception as a transdiagnostic mechanism implicated in the onset and maintenance of anxiety-related disorders. Despite promising insights, findings across the interoceptive dimensions remain complex and, at times, inconsistent, reflecting the challenges posed by varying definitions, methodological heterogeneity and diversity of anxiety conditions. Some emerging patterns suggest that disruptions in interoceptive processes, such as heightened self-focussed attention or difficulties interpreting bodily signals, may be linked to increased symptom severity. These findings highlight the diverse and potentially condition-specific ways interoception may interact across anxiety populations.

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Chapter 3 Exploring The Role of Interoception in Anxious Traits and Symptoms

Journal choice: The *'Psychophysiology Journal'* has been used as a guide to prepare this paper. The named journal publishes articles that bring new insights into brain-behaviour relationships, where the relationship between psychological processes and behaviour is clearly established. There are no stipulations on word count, with an abstract of maximum 300 words. Tables, figures, captions, and references are excluded from the word count.

Abstract: 290 words

Word count: 8696 (excluding abstract, tables, figures, and references)

3.1 Abstract

Interoception, the ability to sense internal bodily signals, has been increasingly linked to anxiety, yet the mechanisms underlying this relationship remain largely unknown. This study explored the associations between multiple dimensions of interoception and anxiety-related traits and symptoms in a non-clinical adult sample. A total of 305 participants completed self-report measures assessing interoceptive beliefs (Multidimensional Assessment of Interoceptive Awareness), attention (Body Perception Questionnaire), and perceived interoceptive accuracy (Interoceptive Accuracy Scale), alongside measures of anxiety-related traits (trait anxiety, anxiety sensitivity, intolerance of uncertainty) and symptoms (generalised anxiety disorder, obsessive-compulsive disorder, panic disorder, post-traumatic stress disorder, and social anxiety disorder). A subsample (n = 103) additionally completed laboratory-based heartbeat perception tasks to assess objective interoceptive accuracy, confidence, and insight via heartbeat counting and detection tasks. Correlational analyses revealed that anxiety-related traits were significantly associated with self-reported interoceptive difficulties, particularly lower trust in bodily sensations and greater distress when noticing them. Novel associations between intolerance of uncertainty and interoception were observed., including negative correlations with interoceptive insight, bodily trust, and reduced tendency not to worry about discomforting internal sensations. Anxiety symptom severity was linked to self-reported increased attention to bodily signals, reduced bodily trust, and lower perceived accuracy. However, results from the heartbeat perception tasks found no relationship between cardiac interoceptive accuracy and anxiety-related traits, symptoms, or self-reported interoceptive abilities.

Findings support the conceptualisation of interoception as a multidimensional construct, demonstrating objective interoceptive accuracy and interoceptive beliefs as distinct constructs. Results align with emerging evidence that anxious traits are more closely related to subjective beliefs and interpretations of bodily signal than to objective interoceptive accuracy. Moreover, findings suggest distinct interoceptive profiles across anxiety presentations, with important implications for

theoretical models of anxiety and for interventions targeting interoceptive beliefs and attention in clinical populations.

Keywords: Interoception, Anxiety, Trait Anxiety, Intolerance of Uncertainty, Anxiety Sensitivity, Heartbeat Perception

3.2 Introduction

Interoception refers to the nervous system's ability to sense, interpret, and regulate signals from within the body (Chen et al., 2021; Khalsa et al., 2018). It plays a critical role in maintaining homeostasis (Craig, 2002; Critchley & Garfinkel, 2017) and has been found to underpin a range of higher-order cognitive functions, including attention, perception, decision-making, memory, and emotion regulation (Quigley et al., 2021; Tsakiris & Critchley, 2016). Given its role within these core cognitive and physiological processes, interoception has been increasingly studied as a transdiagnostic mechanism underlying the pathophysiology of various mental health conditions (Brewer et al., 2021).

Suksasilp and Garfinkel (2022) proposed a multidimensional framework of interoception that expands on previous dimensional models (Garfinkel et al., 2015), by incorporating a broader range of dimensions and distinguishing them based on levels of processing (outlined in Figure 1.1). At the lowest level, the framework considers the fundamental strength and nature of afferent bodily signals, followed by their preconscious impact and neural representation. Higher-order conscious dimensions of interoception include interoceptive accuracy, beliefs, insight, attention, and the attribution of interoceptive sensations (Suksasilp & Garfinkel, 2022). Interoceptive accuracy is defined as the ability to correctly identify internal body signals, measured by objective tests of interoceptive accuracy such as heartbeat perception and detection tasks (Schandry, 1981; Whitehead et al., 1977). Interoceptive beliefs refers to one's own perceptions and expectations regarding bodily sensations, measured through self-report measures such as questionnaires and confidence ratings. Interoceptive insight is a metacognitive measure which reflects how accurate individuals are at detecting their internal body signals, measured by the relationship between behavioural task performance (e.g., objective accuracy) and self-report performance (e.g. confidence). Interoceptive attention refers to the degree of focus to interoceptive sensations, typically assessed using self-report questionnaire measures, such as the Body Perception Questionnaire (BPQ; Porges,

1993). Lastly, the attribution of interoceptive sensations refers to how individuals interpret bodily signals, such as perceiving them as threatening or ambiguous, which can influence emotional and behavioural responses (Suksasilp & Garfinkel, 2022).

Interoceptive processes have been linked to various mental health disorders and may be particularly relevant to clinical anxiety (Khalsa & Lapidus, 2016). This can be examined through individual differences in anxious traits, and how individuals experience symptoms across different anxiety disorders. Research has recently begun to explore aspects of interoception in relation to individual differences in transdiagnostic anxious traits (Boswell et al., 2013; Carleton, 2016; McEvoy & Mahoney, 2012). Hierarchical models of anxious traits position trait anxiety as a central higher order dimension which is underpinned by several lower-order dimensions, such as intolerance of uncertainty and anxiety sensitivity (Paulus et al., 2015).

The relationship between trait anxiety and facets of interoception is highly heterogeneous within the literature. Some studies report positive correlations between trait anxiety and cardiac interoceptive accuracy (Domschke et al., 2010; Pollatos, Herbert, et al., 2007; Pollatos, Traut-Mattausch, et al., 2007) whilst others have found a negative relationship (De Pascalis et al., 1984; Kutscheidt et al., 2019), or no relationship (Duschek et al., 2015; Garfinkel et al., 2016; Slotta et al., 2021; Werner et al., 2013). Meta-analyses have similarly found no consistent association between cardiac interoceptive accuracy and trait anxiety (Adams et al., 2022; Desmedt et al., 2020).

On the other hand, the relationship between self-reported interoception (i.e., interoceptive beliefs) and trait anxiety has been more consistently reported. Studies using the Multidimensional Assessment of Interoceptive Awareness (MAIA) as a measure of interoceptive beliefs report most subscales correlate negatively with trait anxiety (Bornemann et al., 2015; Ferentzi et al., 2021; Mehling et al., 2012; Slotta et al., 2021), however some studies have shown no significant relationships (Borg et al., 2018). Specifically, Mehling (2016) identified that subscales related to regulating attention, not-worrying about, and trusting bodily sensations consistently show the

strongest negative associations. Other studies have explored the relationship between trait anxiety and interoceptive attention using the BPQ (Porges, 1993). However, findings in this area are inconsistent. Some studies suggest that heightened bodily awareness is a significant predictor of higher trait anxiety (Palser et al., 2018), while others report no relationship (Tünte et al., 2024). Additionally, with regard to interoceptive insight, Harrison et al. (2025) identified a negative association, where elevated trait anxiety was linked to decreased interoceptive insight in women, but not in men, indicating a potential gender-specific association.

Anxiety sensitivity (AS) refers to the fear of anxiety-related bodily sensations and the belief that these sensations are harmful (Reiss et al., 1986). Research examining the relationship between AS and interoception has yielded inconsistent findings, likely due to methodological differences in assessing interoception (Domschke et al., 2010). Some studies suggest that individuals with high AS demonstrate poorer interoceptive accuracy (e.g., lower heartbeat perception task scores), possibly because heightened arousal interferes with the precise detection of bodily signals (Paulus & Stein, 2010). Conversely, other studies have reported a positive association between AS and cardiac interoceptive accuracy, observed across adult and child populations (Domschke et al., 2010; Eley et al., 2007; Eley et al., 2004; Stewart et al., 2001; Sturges & Goetsch, 1996). Contemporary research, however, has found no significant associations (Körmendi et al., 2023). Studies examining self-reported interoception (i.e., beliefs about interoceptive performance; Suksasilp & Garfinkel, 2022) is also mixed (Gualtieri et al., 2025; Melhi et al., 2023). Mehling et al. (2012) reported AS was negatively correlated with the ‘Not Worrying’, ‘Attention Regulation’ and ‘Trusting’ subscales of the MAIA, with similar findings of negative correlations across all MAIA subscales in other research (Tünte et al., 2024).

Intolerance of uncertainty (IU) reflects an aversive response to uncertainty and has been identified as a transdiagnostic factor underpinning anxiety (Carleton, 2016). Despite recent advances in understanding interoception, the relationship between IU and interoception has not been well defined in literature (Morriss, 2025). However, a recent correlation analysis by Bijsterbosch et al.

(2023) identified a weak positive association between IU and the 'Emotional Awareness' subscale on the MAIA, suggesting lower levels of IU were associated with higher levels of Emotional Awareness. Additionally, IU showed negative associations with 'Not Distracting', 'Not Worrying', and 'Trusting' subscales (Bijsterbosch et al., 2023). Beyond these findings, empirical research directly linking IU and interoception is limited, although there is emerging research linking them theoretically; Freeston and Komes (2023) provide a theoretical account of how IU may be conceptualised from the standpoint as a "felt sense" or embodied experience of unsafety.

Understanding whether trait anxiety, anxiety sensitivity and IU interact with different aspects of interoception (as outlined in the Multidimensional Framework; Suksasilp & Garfinkel, 2022) could clarify transdiagnostic mechanisms through which interoceptive processes contribute to symptom expression and maintenance. Emerging perspectives highlight the transdiagnostic role of interoception across anxiety disorders, including generalised anxiety disorder (GAD) (Pang et al., 2019), obsessive-compulsive disorder (OCD) (Wilson et al., 2025), panic disorder (Zoellner & Craske, 1999), social anxiety disorder (SAD) (Stevens et al., 2011), post-traumatic stress disorder (PTSD) (Reinhardt et al., 2020; Schmitz et al., 2023), as well as depression (Eggart et al., 2019). However, these relationships remain unclear and understudied, with existing findings often yielding inconsistent results across anxiety-related disorders.

Given this transdiagnostic relevance, improving our understanding of the role of interoception may offer novel insights into the early identification and treatment of emotional disorders (Khalsa et al., 2018; Saltafossi et al., 2024). However, much of the existing research has focused on comparing clinical groups with control groups, rather than adopting a dimensional approach that examines symptom severity across populations. This limits our understanding of how interoceptive processes contribute to anxiety-related psychopathology along a continuum. Therefore, further research is needed to address these gaps and characterise the relationships between anxiety disorders and interoception. This is particularly important in the context of rising global rates of anxiety disorder (Chen et al., 2025).

The present study aimed to explore the relationship between interoceptive dimensions (accuracy, attention, beliefs and insight) and transdiagnostic anxious traits, including trait anxiety, anxiety sensitivity and intolerance of uncertainty. To further address the gap within the literature, the present study also explored the relationship between interoceptive dimensions and symptoms related to GAD, OCD, panic disorder, PTSD, and SAD.

To address gaps in the literature and build on prior findings, the present study examined associations between anxiety-related traits and symptoms with both self-reported and task-based interoceptive measures. This was guided by the following research questions:

1. **How did anxiety-related traits relate to self-reported interoception?**

   Based on prior research, trait anxiety and anxiety sensitivity were expected to be positively associated with interoceptive attention (BPQ). Both were also predicted to show negative associations with interoceptive beliefs, particularly the *Not Worrying*, *Not Distracting*, *Self-Regulation*, and *Trusting* subscales of the MAIA.

2. **How did anxiety-related symptoms relate to self-reported interoception?**

   Given mixed findings in the literature, associations between anxiety symptoms (GAD, OCD, panic, PTSD, social anxiety, depression) and self-reported interoceptive attention and beliefs were examined exploratorily, without directional predictions.

3. **How did anxiety-related traits relate to task-based interoception?**

   Due to inconsistent evidence regarding the relationship between anxiety-related traits (trait anxiety, anxiety sensitivity, intolerance of uncertainty) and interoceptive accuracy, confidence, or awareness, these analyses were considered exploratory.

4. **How did anxiety-related symptoms relate to task-based interoception?**

   Given limited and inconsistent findings regarding symptomatology and task-based interoceptive performance, these associations were also examined without directional predictions.

3.3 Methods

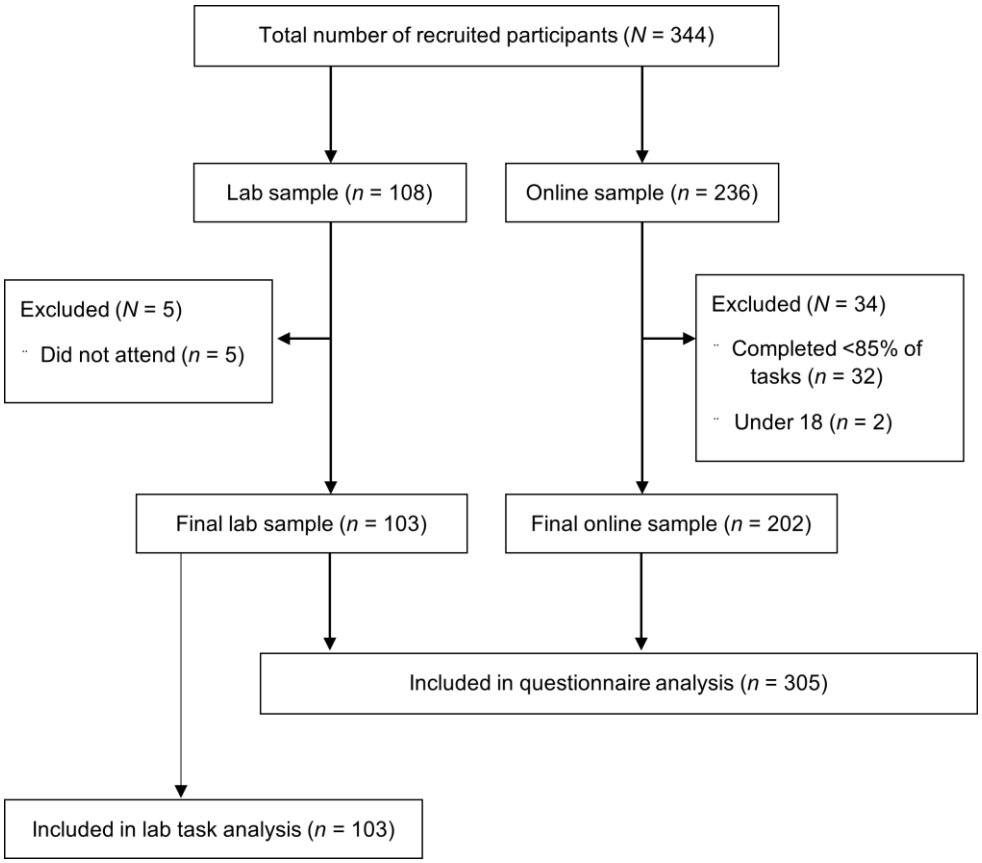
The present study comprised of two independent groups: an online sample and a lab-based sample. The online group competed a series of questionnaires remotely, while the lab-based group completed the same questionnaires in the lab and completed two heartbeat perception tasks. Full details of the recruitment procedures, participants, and measures are outlined in the sections that follow. Ethical approval was granted by the ethics committee of the University of Southampton (ERGO number 89229; see Appendix G).

3.3.1 Participants

3.3.1.1 Recruitment

Participants were recruited using a combination of convenience and voluntary response sampling. Online participants were recruited via social media platforms (e.g., LinkedIn) where study advertisements included a brief study description, eligibility criteria, and a link to the online survey. Lab-based participants were recruited through social media platforms and the University of Southampton's research participation system (SONA). SONA participants received course credit as compensation for their time and effort. External participants did not receive financial or academic incentives. The online and lab-based samples were independent from each other, as outlined in Figure 3.1.

Figure 3.1 Participant Flow Diagram



3.3.1.2 Participant Inclusion & Exclusion Criteria

This study was aimed at a non-clinical population. Inclusion criteria required participants to be 18 years of age or older, and to have sufficient fluency in English to complete the questionnaires and tasks, which was self-assessed by the participants. Exclusion criteria included being under 18 years of age, lacking sufficient English fluency, completing less than 85% of the questionnaires and tasks, having a history of traumatic head injury, or currently taking psychotropic medication, as such medications may alter subjective and psychophysiological responses. Participants recruited through the student research panel (SONA) confirmed their eligibility via an initial screening, while those recruited externally confirmed their eligibility through email before participating in the study.

3.3.1.3 Participant Characteristics

Power analysis was conducted using G*Power V3.1.9.2 (Faul et al., 2009). A-priori power analysis estimated a minimum sample size of approximately *N* = 84 adult participants for completing heartbeat perception tasks and questionnaires in the lab. The sample size was calculated using a bivariate normal model for correlation analyses (effect size = 0.30, α error probability = 0.05, power (1 - β) = 0.80). For the online questionnaire group, a larger sample size of *N* = 193 was estimated using a smaller effect size (*r* = 0.20) to ensure sufficient power for detecting more subtle relationships. This larger sample size also accounts for potential incomplete questionnaire data. The effect sizes were based on prior studies examining intolerance of uncertainty processes and interoceptive measures (e.g., Morriss et al., 2021; Pfeifer et al., 2017).

A total of 344 participants were recruited to take part across the online and lab-based components of the study. Of these, 39 participants did not meet the inclusion and exclusion criteria and were therefore excluded. The final sample consisted of 305 participants, including 202 online participants and 103 lab-based participants (see Figure 3.1). The mean age of the overall sample was 28 years old (*SD* = 13.32; ranging from 18 to 81) and 74.8% were female. For further demographic characteristics of each group, see Table 3.1.

3.3.1.3.1 Online Participant Characteristics

A total of 236 participants completed the online questionnaires using a data collection platform, Qualtrics. Thirty-two cases were excluded due to partial completion of the questionnaire, and a further two were excluded due to not reaching the minimum age requirement. Within the final online sample of 202 participants, 96% completed all questionnaires, while 4% of participants completed at least 87% of the 12 questionnaires (i.e., at least 9 questionnaires). The final online sample had a mean age of 31.97 years (SD = 14.87), with 71.3% identifying as female.

3.3.1.3.2 Lab Participant Characteristics

A total of 108 participants were recruited to complete questionnaires and heartbeat perception tasks in the laboratory. Five participants did not attend their scheduled timeslot, resulting in a final lab sample of 103 participants. The final lab sample had a mean age of 21.25 (*SD* = 5.28), with 81.6% identifying as female.

Table 3.1 Participant Demographic Information by Group

	Lab Group (*n* = 103)	Online Group (*n* = 202)
Mean age (*SD*)	21.25 (5.28)	31.97 (14.87)
Gender		
Female	84 (81.6%)	144 (71.3%)
Male	19 (18.4%)	47 (23.3%)
Transgender	0 (0%)	1 (0.5%)
Prefer not to say	0 (0%)	10 (5%)
Ethnicity		
Asian	9 (8.7%)	11 (5.4%)
Black	5 (4.9%)	4 (2%)
Multiethnic	3 (2.9%)	4 (2%)
White	83 (80.6%)	155 (76.7%)
Other	3 (2.9%)	13 (6.5%)
Prefer not to say	0 (0%)	15 (7.4%)
Sexual Orientation		
Asexual	0 (0%)	2 (1%)
Bisexual	16 (15.5%)	21 (10.4%)
Heterosexual	78 (75.7%)	146 (72.3)
Homosexual	7 (6.8%)	9 (4.5%)
Prefer not to say	2 (1.9%)	24 11.9%)

3.3.2 Measures

Participants completed a series of validated self-report measures to assess anxiety-related traits, anxiety-related symptoms, and interoceptive beliefs and attention. Demographic data related

to age, sex, ethnicity, nationality, English language fluency and sexual orientation was also collected. The questionnaires outlined below were administered with both online and lab-based participants. No modifications were made to the original scales.

3.3.2.1 Anxiety Trait Measures

Intolerance of Uncertainty Scale - 12 (IUS-12; Carleton et al., 2007). The IUS-12 is a 12 item self-report questionnaire intended to measure intolerance of uncertainty. Items include questions such as *"Unforeseen events upset me greatly"* and "*The smallest doubt can stop me from acting*" which are rated on a 5-point Likert scale ranging from 1 *(not at all characteristic of me)* to 5 (*entirely characteristic of me)*. Scores range from 12 to 60, with higher scores indicating greater intolerance of uncertainty. The scale has demonstrated excellent internal consistency in prior research (α = .85–.91; Carleton et al., 2007).

State-Trait Anxiety Inventory – Trait Subscale (STAIT-5; Zsido et al., 2020). The STAIT-5 is self-report questionnaire used to assess an individual's general tendency to experience anxiety. It has five items derived from the trait-anxiety subscale of the original 20-item *Spielberger State-Trait Anxiety Inventory* – Trait Subscale (STAI-T) (Spielberger, 1970). Participants rate the frequency of anxiety-related feelings (e.g., *"I feel nervous and restless"*) on a 4-point Likert scale ranging from 1 (*Almost never*) to 4 (*Almost always*). Total scores range from 6 to 24, with higher scores indicating greater trait anxiety. The STAI-T shortened version has demonstrated excellent internal consistency (α = .91; Zsido et al., 2020).

Anxiety Sensitivity Index (ASI; Reiss et al., 1986). The ASI is a 16-item self-report questionnaire used to assess the fear of anxiety-related bodily sensations, such as a racing heart or difficulty breathing. Items are rated on a 5-point Likert-type scale ranging from 0 (*very little)* to 4 (*very much*). Total scores range from 0 to 64, where higher scores indicate greater anxiety sensitivity. Sample items include *"When I feel tense, I worry that I might be seriously ill"* and *"It*

scares me when my heart beats rapidly". The ASI has demonstrated strong psychometric properties, including good internal consistency and construct validity (Vujanovic et al., 2007).

3.3.2.2 Anxiety Symptom Measures

Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001). The PHQ-9 is a nine-item self-report measure for assessing depressive symptoms. Participants rate how often they have been bothered by symptoms such as *"Feeling down, depressed, or hopeless"* over the past two weeks on a 4-point Likert scale ranging from 0 (*Not at all*) to 3 (*Nearly every day*). Total scores range from 0 to 27, with higher scores indicating greater depressive symptom severity. It was included in this study to screen for depressive symptoms, including suicidal ideation, and to ensure participants could access appropriate support if needed. Although PHQ-9 scores were not analysed, the measure provided important context on participant wellbeing and allowed consideration of depressive symptoms as a potential factor influencing interoceptive processing, The PHQ-9 has demonstrated excellent internal consistency ($\alpha = .89$; Kroenke et al., 2001) and strong construct validity (Kroenke et al., 2010).

Generalised Anxiety Disorder Questionnaire (GAD-7; Spitzer et al., 2006). The GAD-7 was used to measure symptoms of generalised anxiety. The GAD-7 is a widely used 7-item self-report questionnaire that assesses the frequency of anxiety symptoms over the past two weeks. Participants rate how often they have been bothered by difficulties such as *"Feeling nervous, anxious, or on edge"* on a 4-point Likert scale ranging from 0 (*Not at all*) to 3 (*Nearly every day*). Total scores range from 0 to 21, with higher scores indicating greater severity of anxiety. The GAD-7 has demonstrated excellent internal consistency (Cronbach's $\alpha = .92$) and strong construct validity (Spitzer et al., 2006).

Obsessive Compulsive Inventory – Revised (OCI-R; Foa et al., 2002). The OCI-R is an 18-item self-report questionnaire designed to assess distress associated with obsessive-compulsive symptoms. Participants rate how much they have been bothered or distressed by each symptom (e.g., *"I repeatedly check doors, windows, drawers, etc."*) over the past month on a 5-point Likert

scale ranging from 0 *(Not at all)* to 4 *(Extremely)*. Total scores range from 0 to 72, with higher scores indicating greater OCD symptom severity. The OCI-R has demonstrated excellent internal consistency (Cronbach's α = .90) and strong test-retest reliability (*r* = 0.84; Foa et al., 2002). Research supports the validity of the OCI-R in both clinical and non-clinical samples (Abramowitz & Deacon, 2006; Hajcak et al., 2004).

Panic Disorder Severity Scale – Self Report (PDSS-SR; Houck et al., 2002). The PDDS-SR is a 7-item self-report measure intended to measure the severity of panic disorder. Adapted from the original clinician-administered Panic Disorder Severity Scale (Shear et al., 1997), it assesses various dimensions of panic disorder, including the frequency of panic attacks, anticipatory anxiety, agoraphobic avoidance, and functional impairment. Participants rate the severity of each symptom over the past week using a 5-point Likert scale ranging from 0 *(None)* to 4 *(Extreme*), for example *"If you had any panic attacks during the past week, how distressing were they while they were happening?"*. Total scores range from 0 to 28, with higher scores indicating greater severity of panic symptoms. A cut-off score of 8 is suggested for diagnosis-level symptomology. The PDSS has shown good internal consistency (α = 0.92 (Houck et al., 2002).

Post-traumatic Stress Disorder Checklist for DSM-5 (PCL-5; Weathers et al., 2013). The PCL-5 is a 20 item self-report questionnaire intended to measure the frequency of PTSD symptoms in the past month. Participants rate statements such as *"In the past month, how much were you bothered by having Repeated, disturbing, and unwanted memories of the stressful experience*?" using a 5-point Likert scale ranging grom 0 (*Not at all*) to 4 (*Extremely)*. The total score ranges from 0 to 80, with higher scores indicating more severe PTSD symptoms. The PCL-5 is widely used in clinical and research settings for both screening purposes and assessing symptom severity; it has demonstrated high internal consistency (α = .94), and test-retest reliability (*r* = .82) (Blevins et al., 2015).

Social Interaction Phobia Scale (SIPS; Carleton et al., 2009). The SIPS is a 14-item self-report questionnaire intended to measure symptoms of social anxiety symptoms. Participants rate how

much they agree with statements such as *"I am nervous mixing with people I don't know well"* on a 5-point Likert scale ranging from 0 (*Not at all*) to 4 (*Extremely*). Total scores range from 0 to 56, with higher scores indicating greater severity of social anxiety symptoms. The SIPS has demonstrated good internal consistency (Carleton et al., 2009), robust convergent and discriminant validity across samples (Menatti et al., 2015).

3.3.2.3 Self-Report Measures of Interoception

Multidimensional Assessment of Interoceptive Awareness – Version 2 (MAIA-v2; Mehling et al., 2018). The MAIA-2 is a 37-item self-report scale intended to assess multiple facets of self-reported interoceptive beliefs. Participants rate statements such as "*I can pay attention to my breath without being distracted by things happening around me"* on a 6-point Likert scale ranging from 0 *(Never*) to 5 (*Always)*, with nine reverse-scored items. The MAIA-2 consists of eight subscales (outlined in Table 2), with mean scores calculated separately for each. Subscale scores range from 0 – 5. Higher scores indicate greater interoceptive awareness. The eight-factor structure has been validated across cultures in clinical (Eggart et al., 2021), and non-clinical samples (Fekih-Romdhane et al., 2023; Fiskum et al., 2023; Scheffers et al., 2024).

The MAIA-2 has demonstrated good internal consistency, with Cronbach's α ranging from .64 (Noticing) to .83 (Attention Regulation and Trusting) (Mehling et al., 2018). Test-retest reliability studies have shown moderate to good stability, with intraclass correlation coefficients ranging from .67 to .79 (Scheffers et al., 2024).

Table 3.2 MAIA-2 Subscales (Mehling et al., 2018)

MAIA Subscale	Definition
Noticing	Awareness of bodily sensations
Not Distracting	Tendency not to ignore or distract from sensations of discomfort
Not Worrying	Tendency not to worry about discomforting sensations
Attention Regulation	Ability to sustain and control attention to bodily sensations

Emotional Awareness	Awareness of the connection between bodily sensations and emotions
Self-Regulation	Ability to regulate distress by attending to bodily sensations
Body Listening	Active listening to bodily signals for insight
Trusting	Experience of one's body as safe and trustworthy

Note. MAIA = Multidimensional Assessment of Interoceptive Awareness.

Body Awareness Subscale of the Body Perception Questionnaire-Short Form (BPQ-SF; Cabrera et al., 2018). The BPQ-SF is a shorter version of the original full scale BPQ developed by Porges (1993). The shorter form focusses primarily on the Body Awareness and Autonomic Reactivity subscales. In line with previous research, only the Body Awareness subscale was used in the present study given the focus on subjective awareness of bodily sensations (Betka et al., 2018; Garfinkel et al., 2015). The Body Awareness subscale of the BPQ-SF is a 26 item self-report measure intended to assess an individual's sensitivity to internal bodily sensations (Cabrera et al., 2018), relating specifically to the measure of interoceptive attention (Suksasilp & Garfinkel, 2022). Participants respond to statements such as *"During most situations, I am aware of how fast I am breathing"* on a 5-point Likert scale, ranging from 1 *(Never)* to 5 (*Always)*. Scores range from 26 – 130, with higher scores representing higher levels of body awareness. The psychometric properties of the BPQ Body Awareness scale demonstrated high internal consistency (α = .92) and high test-retest reliability (Cabrera et al., 2018), as well as across diverse samples (Najari et al., 2024; Poli et al., 2021; Wang et al., 2020).

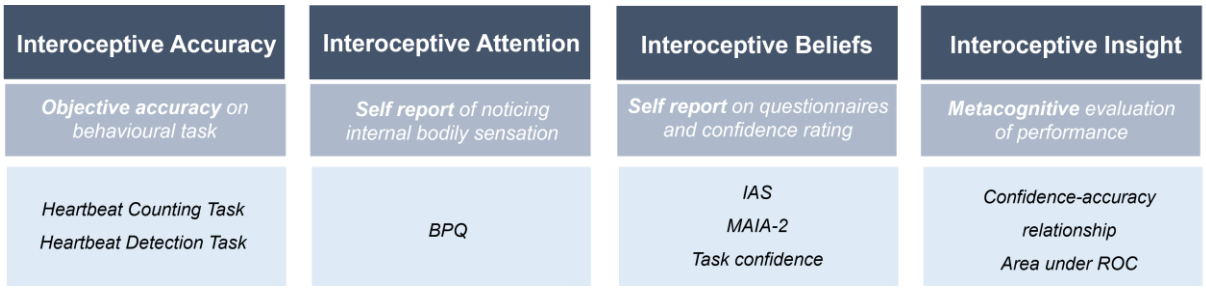
Interoceptive Accuracy Scale (IAS; Murphy et al., 2020). The IAS is a 21-item self-report questionnaire designed to assess an individual's perceived ability to accurately detect internal bodily signals. Participants rate statements such as *"I can accurately perceive when my heart rate changes"* on a 5-point Likert scale, ranging from 1 *(Strongly Disagree)* to 5 *(Strongly Agree*). Scores range from 21 to 105, with higher scores indicating greater self-reported interoceptive accuracy. Internal

consistency has been found to be good, with Cronbach's α ranging from .84 to .91 across studies (Murphy et al., 2020).

3.3.2.4 Behavioural Measures of Interoception

Self-report questionnaires assessing interoception measure an individual's perceived sensitivity to internal bodily signals; however, they do not determine whether this interoceptive belief corresponds to objective accuracy (Garfinkel et al., 2015; Suksasilp & Garfinkel, 2022). Therefore, a smaller sample of participants (*n* = 103) completed heartbeat perception tasks to assess objective interceptive accuracy. These tasks were combined with a measure of subjective confidence in performing the task to produce an index of interoceptive insight. The relationship between mean task accuracy (interoceptive accuracy) and mean confidence scores (interoceptive beliefs) was analysed to quantify interoceptive insight scores. An overview of the interoceptive dimensions explored and methods of measurement is outlined in Figure 3.2.

Figure 3.2 Overview of Interoception Dimensions and Methods of Measurement



Note. Interoceptive terminology and methods of measurement, as outlined in Suksasilp & Garfinkel's (2022) Multidimensional Model of Interoception. BPQ = Body Perception Questionnaire; IAS = Interoceptive Accuracy Scale; MAIA = Multidimensional Assessment of Interoceptive Awareness; ROC = Receiver Operating Characteristics.

Heartbeat Counting Task. In the Heartbeat Counting Task (HCT), participants were instructed to estimate their own heartbeats without external verification. At the start of each trial, an auditory cue *("Start")* was played through headphones, prompting participants to silently count their

heartbeats without physically checking their pulse. At the end of the trial, a second cue *("Stop")* signalled them to stop counting and report their estimated heartbeat count. There were six trials, with intervals of 25, 30, 35, 40, 45, and 50 seconds, presented in a randomised order. Full instructions can be found in Appendix H.

At the end of each trial, participants rated their confidence of their perceived accuracy. This confidence judgement was made by marking on a continuous visual analogue scale (VAS) that was 10 centimetres long. One end was marked "*Total guess / No heartbeat awareness*" while the other end was labelled "*Complete confidence / Full perception of heartbeat"* (see Appendix I). Confidence ratings on the VAS were measured manually in millimetres using a ruler for each of the six trials and then averaged to produce a single participant confidence score of their heartbeat counting performance accuracy.

To measure interoceptive accuracy, a probability accuracy score, 0 to 1, was calculated for each trial, where higher scores indicated greater heartbeat counting accuracy. To provide a symmetric accuracy response between actual number of beats ($n\text{beats}_{\text{real}}$) and reported number of beats ($n\text{beats}_{\text{reported}}$), the absolute difference between these values was calculated using the formula outlined in Figure 3.3.

Figure 3.3 Interoceptive Accuracy Formula

$$\text{Accuracy} = 1 - \frac{|\ n\text{beats}_{\text{real}} - n\text{beats}_{\text{reported}}\ |}{n\text{beats}_{\text{real}}}$$

When the difference between $n\text{beats}_{\text{real}}$ and $n\text{beats}_{\text{reported}}$ is larger than $n\text{beats}_{\text{real}}$, equation one can produce negative accuracy scores. Not only do these have no interpretable meaning but will cause erroneous mean accuracy values for the whole trial. To prevent this, the absolute difference in values was restricted to a maximum of $n\text{beats}_{\text{real}}$, as given by the formula outlined in Figure 3.4. After

six trials were completed the mean accuracy value was determined for each participant. Interoceptive insight was indexed by calculating within-participant correlations (*r*) between each participant's accuracy score and their corresponding VAS confidence score (Garfinkel et al., 2015).

Figure 3.4 Amended Interoceptive Accuracy Formula

$$\begin{array}{ll} |\,n\text{beats}_{\text{real}} - n\text{beats}_{\text{reported}}\,| & < n\text{beats}_{\text{real}} \quad \text{Accuracy} = 1 - \dfrac{|\,n\text{beats}_{\text{real}} - n\text{beats}_{\text{reported}}\,|}{n\text{beats}_{\text{real}}} \\ & >= n\text{beats}_{\text{real}} \quad \text{Accuracy} = 0 \end{array}$$

Heartbeat Detection Task. In the Heartbeat Detection Task (HDT), participants were presented with auditory tones through headphones that were either synchronous or asynchronous with their own heartbeat. In the synchronous condition, auditory tones were delayed by 300 milliseconds to account for the average 250 milliseconds delay between the R-wave and the arrival of the pulse pressure wave at the finger (Payne et al., 2006). In the asynchronous condition, tones were delayed by an additional 300 milliseconds (i.e., approximately 550 milliseconds after the R-wave), making them perceptually out of sync with the heartbeat (Wiens & Palmer, 2001). The task comprised of 20 trials, each lasting 20 seconds. This number of trials was selected to balance statistical power and participant fatigue.

After each trial, participants were asked to decide whether the auditory tones were synchronous or asynchronous with their own heart. They rated their confidence of their judgement on a 10-centimetre VAS ranging from 0 cm *("Total guess / No heartbeat awareness")* to 10 cm *("Complete confidence / Full perception of heartbeat").*

Confidence ratings on the VAS were measured manually in millimetres for each of the 20 trials and then averaged to produce a single confidence score. Interoceptive accuracy was determined by dividing the number of correct trials divided by the total number of trials, yielding the proportion of correct responses. As data from the HDT was binary, interoceptive insight (metacognitive awareness)

was assessed using receiver operating characteristic (ROC) curve analysis (Green & Swets, 1966). The area under the ROC curve quantified the extent to which confidence ratings reflected accuracy across trials (Garfinkel et al., 2015).

3.3.3 Procedure

3.3.3.1 Online Group Procedure

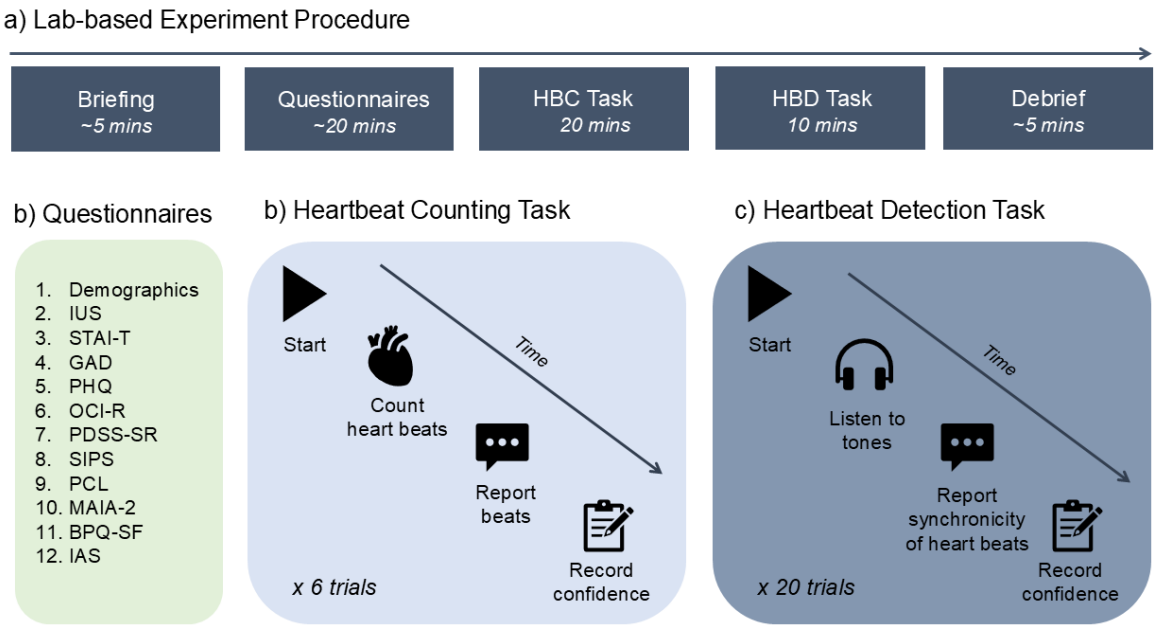
Questionnaire data was collected remotely using the survey platform Qualtrics (Qualtrics, 2024). Participants accessed the survey via an online link distributed through the study advertisement. Within Qualtrics, participants were presented with the Participant Information Sheet (see Appendix J.1), provided informed consent, and completed demographic questions before proceeding to the study measures. The estimated completion time for all questionnaires was approximately 20 minutes. Upon completion, participants were automatically presented with the full debrief form at the end of the Qualtrics survey (see Appendix L.1). This included relevant signposting information for both UK-based and international participants to ensure that all individuals, regardless of location, had access to appropriate sources of support should they experience any distress.

3.3.3.2 Lab Group Procedure

Upon arrival at the laboratory, participants were provided with information regarding the experimental procedure (see Appendix J.2). Participants were asked to review and sign an informed consent form to confirm their agreement to participate in the study (see Appendix K). Participants were taken to the testing booth where they were asked to complete a series of questionnaires presented on a computer. Next, participants completed the heartbeat counting and heartbeat detection tasks. For these tasks, they were asked to wear headphones, and a reusable soft-sensor pulse oximeter (Nonin Medical XPOD® 3012 LP with USB Connector) was placed on the index finger of their non-dominant hand to measure heartbeats. Tactile sensations from the pulse oximeter were minimised by using a soft, low-pressure sensor designed to minimise pulse-wave feedback (Murphy

et al., 2019). The pulse oximeter was connected to a PC and tracked heartbeats in real time during the counting task, allowing for an accurate comparison between actual and perceived counts. The lab-based study took approximately 50 minutes to complete. The procedure is illustrated in Figure 3.5 and upon completion, participants were debriefed and provided with a written debrief form (see Appendix L.2).

Figure 3.5 Laboratory-based Experiment Procedure



Note. ASI = Anxiety Sensitivity Index; BPQ = Body Perception Questionnaire; GAD = Generalised Anxiety Disorder; HBC = Heartbeat Counting Task; HBD = Heartbeat Detection Task; IAS = Interoceptive Accuracy Scale; IUS = Intolerance of Uncertainty Scale; MAIA = Multidimensional Assessment of Interoceptive Awareness; OCI = Obsessive-Compulsive Inventory; PCL = PTSD Checklist; PDSS-SR = Panic Disorder Severity Scale – Short Version; PHQ = Patient Health Questionnaire; SIPS = Social Interaction Phobia Scale; STAI-T = State-Trait Anxiety Inventory – Trait.

3.3.4 Data Management

Online data was collected using Qualtrics (Qualtrics, 2024) and stored on its encrypted servers before being exported as CSV files for analysis. Demographic data was collected, but no personally identifiable information was recorded. Data were assigned anonymous participant IDs and securely

stored on a password-protected, institution-approved drive. For lab-based tasks, participants were assigned anonymous participant IDs and participant data were stored on a password-protected University of Southampton computer, accessible only to authorised researchers.

3.3.5 Data Analysis

All experimental data were inputted and analysed using IBM SPSS version 29.0.2.0 (IBM Corp., 2023). Prior to analysis, the data set was examined for missing values, outliers, and normality. Descriptive statistics and reliability analysis was carried out. Parametric Pearson's correlational analyses were conducted to examine associations between anxiety trait measures, anxiety symptom measures, self-report interoceptive measures, and heartbeat perception task performance.

Online and lab questionnaire data were combined (N = 305) to explore how subjective interoceptive measures correlate with transdiagnostic anxiety traits (i.e., trait anxiety, AS and IU) and clinical symptom questionnaires (i.e., GAD, OCD, panic disorder, PTSD, and SAD). In a smaller sub-group of participants who completed the heartbeat perception tasks (n = 103), task performance was correlated with the corresponding participant's questionnaires to explore whether objective interoception is associated with self-reported anxiety traits and symptoms.

3.3.6 Exclusions and Missing Data

Data were screened for missing responses before analysis. All lab participants completed 100% of the questionnaires and heartbeat perception tasks. However, one participant's data was missing for six trials due to a data recording issue in the Heartbeat Detection Task; their score was therefore averaged across the completed 14 trials instead of 20.

In the online sample, 236 participants initiated the questionnaire battery, but 32 (13.6%) were excluded for not meeting the 87% completion threshold (i.e., at least 9 out of the 12 questionnaires). A further two participants were excluded for reporting an age below the eligibility criterion of 18 years. Among the final online sample, all individual questionnaires had 100% item-level completion.

However, eight online participants had partial missing data across the full battery: two completed 87%, four completed 92%, and two completed 96% of the total questionnaires. All individual measures were fully completed.

3.4 Results

3.4.1 Group Comparisons Between Lab-based and Online Groups

Independent-samples *t*-tests revealed a significant difference in age between the lab-based (*n* = 103) and online (*n* = 181)[1] groups, with lab participants younger (*M* = 21.25, *SD* = 5.28) than online participants (*M* = 31.97, *SD* = 14.87), *t*(247.08) = −8.77, *p* < .001. A chi-square test of independence indicated no significant association between group and gender, $\chi^2(1, N = 295) = 1.64$, *p* = .20.

Across most questionnaire measures, independent-samples *t*-tests showed no significant differences between groups. The exception was the Social Interaction Phobia Scale (SIPS), where online participants scored higher (*M* = 17.53, *SD* = 13.57) than lab participants (*M* = 21.52, *SD* = 14.84), *t(*303) = 2.36, *p* = .019.

3.4.2 Self-Report Measure Descriptive Statistics

Table 3.3 presents the descriptive statistics for the self-report measures in the online group (*n* = 202), including means, standard deviations, range, measures of normal distribution, and reliability analysis. Overall, these measures demonstrated robust psychometric properties, with Cronbach's α values ranging from .75 (*MAIA Not Worrying*) to .96 *(PCL)* for the online group. Most of the data

[1] *n* = 181 is reduced for online group age analyses, as 21 participants did not provide age information.

approximated a normal distribution, although some measures exhibited positive skew. For instance, the PDSS-SR (skewness = 1.66) indicated a floor effect, consistent with the expectation that most participants in a non-clinical sample report low panic symptoms. Similarly, the OCI (skewness = 0.88) reflects lower levels of obsessive-compulsive symptoms within this sample.

Table 3.3 Descriptive Statistics of Online Group Questionnaires and Subscales

Questionnaires / Subscales	*N*	*M*	*SD*	Observed Range	Skewness	Kurtosis	α
Trait Measures							
ASI	194*	26.81	13.06	0 – 59	0.28	-0.52	.91
IUS	202	33.20	9.56	13 – 57	0.18	-0.56	.91
STAIT-5	202	12.70	3.98	5 – 20	0.06	-0.99	.86
Interoceptive Measures							
BPQ	202	71.62	23.46	26 – 128	0.20	-0.52	.95
IAS	196*	44.85	13.10	21 – 92	0.46	0.42	.92
MAIA Noticing	202	2.57	1.28	0 – 5	-0.10	-0.67	.84
MAIA Not Distracting	202	2.25	1.13	0 – 5	0.21	-0.57	.87
MAIA Not Worrying	202	2.52	1.00	0 – 4.8	-0.08	-0.19	.75
MAIA Attention Regulation	202	2.36	1.14	0 – 5	0.05	-0.46	.91
MAIA Emotional Awareness	202	3.02	1.31	0 – 5	-0.49	-0.53	.90
MAIA Self-Regulation	202	2.22	1.27	0 – 5	0.19	-0.59	.89
MAIA Body Listening	202	1.91	1.27	0 – 5	0.33	-0.57	.88
MAIA Trusting	202	2.56	1.37	0 – 5	-0.15	-0.80	.88
Symptom Measures							
GAD-7	202	8.46	5.26	0 – 20	0.31	-0.75	.88
OCI	202	18.08	13.62	0 – 56	0.88	0.11	.92
PCL	202	23.14	18.73	0 – 75	0.69	-0.47	.96
PDSS-SR	202	3.96	5.23	0 – 28	1.66	3.01	.94
PHQ-9	202	8.57	6.33	0 – 26	0.62	-0.37	.89
SIPS	202	17.53	13.57	0 – 54	0.63	-0.46	.95

Note. *N is reduced for ASI and IAS measures due to incomplete questionnaire responses. IUS = Intolerance of Uncertainty Scale; STAI-T = State-Trait Anxiety Inventory – Trait; ASI = Anxiety Sensitivity Index; MAIA = Multidimensional Assessment of Interoceptive Awareness; BPQ = Body

Perception Questionnaire; IAS = Interoceptive Accuracy Scale; PHQ = Patient Health Questionnaire; GAD = Generalized Anxiety Disorder scale; PCL = PTSD Checklist; PDSS = Panic Disorder Severity Scale; SIPS = Social Interaction Phobia Scale; OCI = Obsessive-Compulsive Inventory. Cronbach's α values represent internal consistency reliability for each group separately.

Table 3.4 presents the descriptive statistics for the self-report measures in the lab-based group (*n* = 103). In this group, internal consistency was similarly robust, with Cronbach's α ranging from .74 *(MAIA Not Worrying)* to .96 (*SIPS*). Similar to the online sample, distributions for most measures were approximately normal; PDSS and OCI scores were positively skewed (skewness 1.01 and .93 respectively).

Table 3.4 Descriptive Statistics of Lab Group Questionnaires and Subscales

Questionnaires / Subscales	*N*	*M*	*SD*	Observed Range	Skewness	Kurtosis	α
Trait Measures							
ASI	103	29.76	11.73	5 – 62	0.14	0.16	.88
IUS	103	32.29	9.13	14 – 58	0.38	-0.16	.91
STAIT-5	103	12.36	3.49	5 – 20	-0.03	-0.56	.84
Interoceptive Measures							
BPQ	103	72.58	21.16	35 – 130	0.44	-0.13	.94
IAS	103	78.76	11.61	35 – 105	-0.70	1.77	.89
MAIA Noticing	103	2.42	1.15	0 – 5	0.20	-0.73	.83
MAIA Not Distracting	103	2.17	0.94	0 – 4.67	0.08	-0.44	.87
MAIA Not Worrying	103	2.49	0.91	0.40 – 4.80	-0.08	-0.17	.74
MAIA Attention Regulation	103	2.37	0.90	0.43 – 4.43	0.03	-0.50	.85
MAIA Emotional Awareness	103	2.89	1.09	0.40 – 5	-0.17	-0.54	.84
MAIA Self-Regulation	103	2.26	0.95	0 – 4.25	-0.16	-0.18	.78
MAIA Body Listening	103	1.95	1.08	0 – 4.33	-0.04	-0.57	.83
MAIA Trusting	103	2.72	1.29	0 – 5	-0.18	-0.88	.90
Symptom Measures							

GAD-7	103	9.22	5.59	0 – 21	0.26	-0.95	.90
OCI	103	20.63	13.94	0 – 60	0.93	0.54	.92
PCL	103	26.90	17.07	0 – 60	0.05	-1.16	.93
PDSS-SR	103	4.88	4.99	0 – 23	1.02	0.52	.91
PHQ-9	103	9.76	6.48	0 – 26	0.41	-0.73	.88
SIPS	103	21.52	14.84	0 – 56	0.63	-0.34	.96

Note. IUS = Intolerance of Uncertainty Scale; STAI-T = State-Trait Anxiety Inventory – Trait; ASI = Anxiety Sensitivity Index; MAIA = Multidimensional Assessment of Interoceptive Awareness; BPQ = Body Perception Questionnaire; IAS = Interoceptive Accuracy Scale; PHQ = Patient Health Questionnaire; GAD = Generalized Anxiety Disorder scale; PCL = PTSD Checklist; PDSS = Panic Disorder Severity Scale; SIPS = Social Interaction Phobia Scale; OCI = Obsessive-Compulsive Inventory. Cronbach's α values represent internal consistency reliability for each group separately.

The self-report measures display similar central tendencies and psychometric properties across the online and lab samples. Both groups consistently exhibited strong internal consistency. Overall, these descriptive statistics suggest the self-report instruments are reliable and perform as expected within this sample. Figures 3.6 – 3.8 display violin plots of each anxiety trait measure, symptom measure and interceptive measure, split by group.

Figure 3.6 Violin Plots of Trait Measures (ASI, IUS & STAI-T) Split by Group

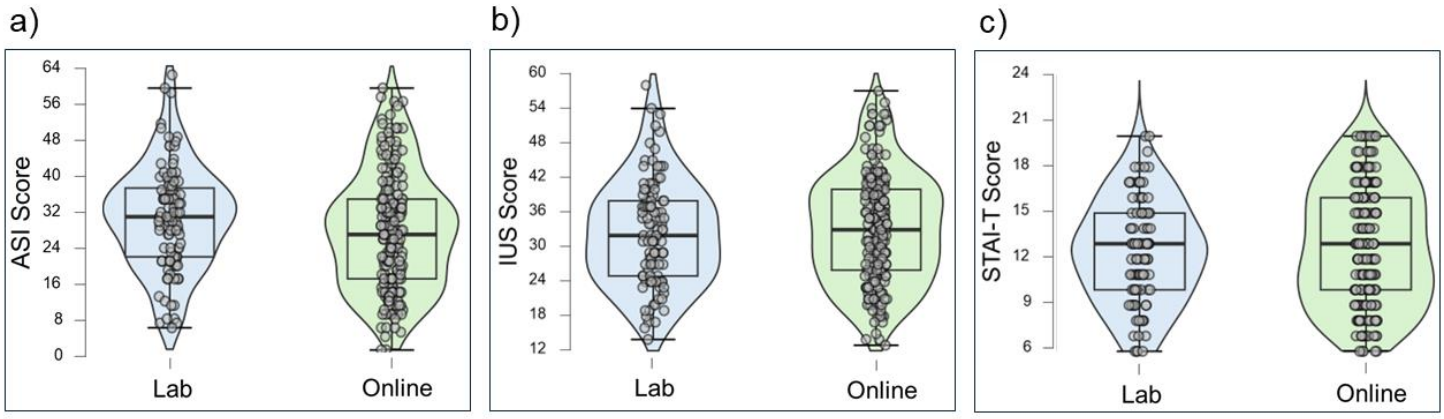
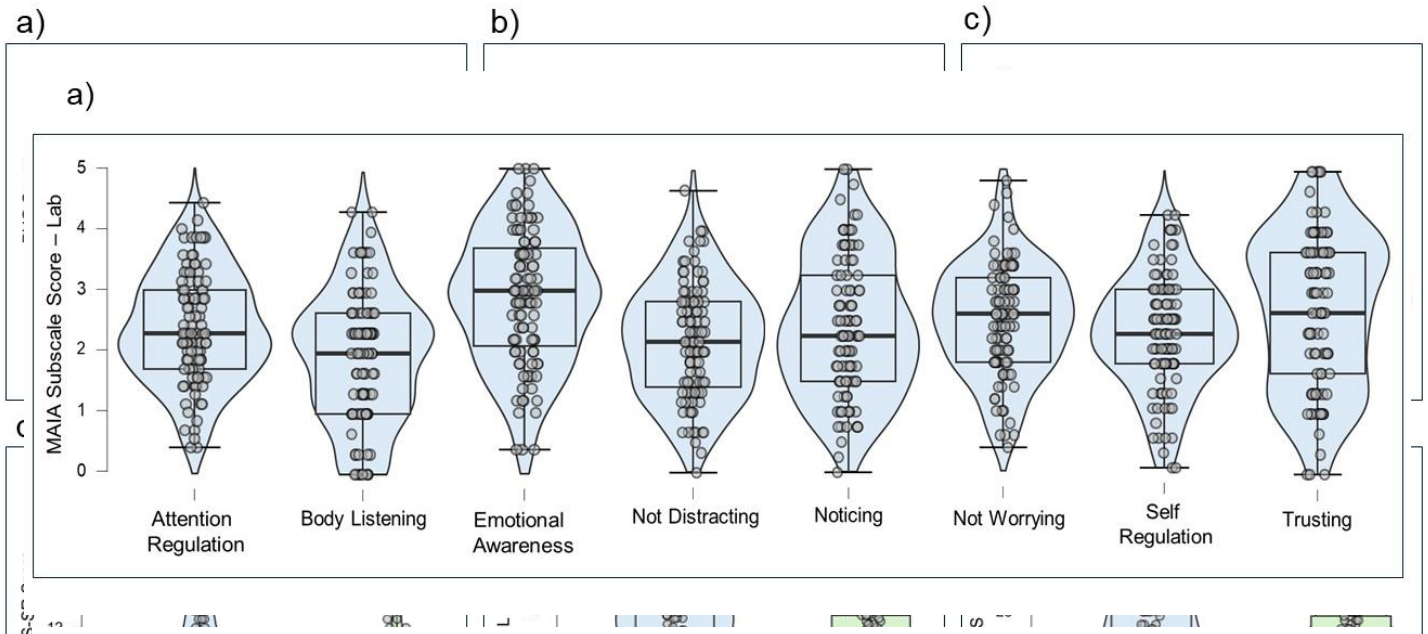
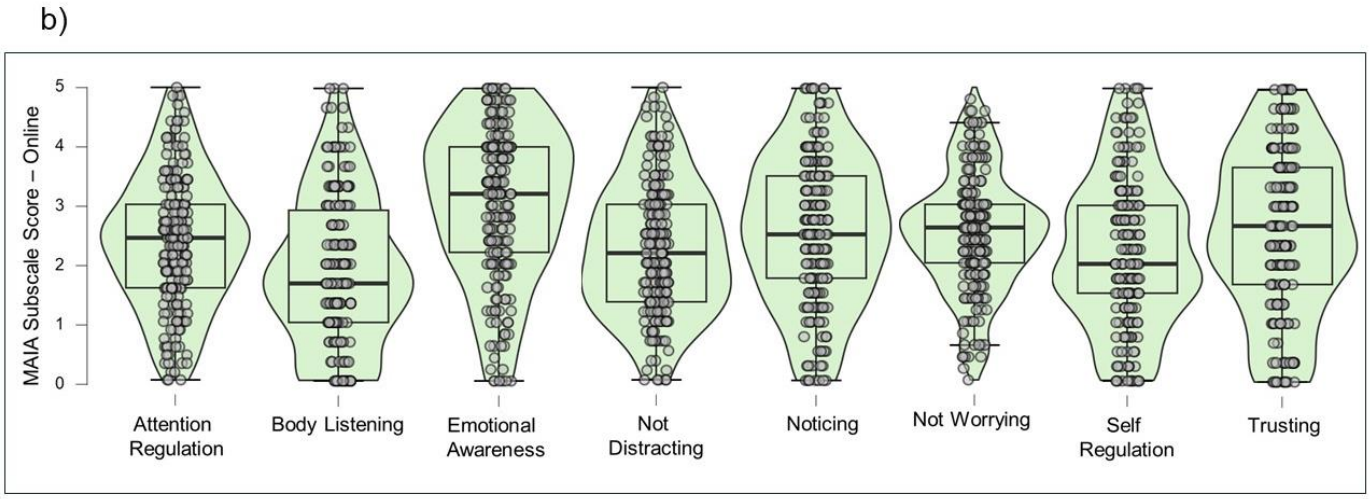


Figure 3.7 Violin Plots of Symptom Measures (GAD, OCI, PCL, PDSS-SR, PHQ & SIPS) Split by Group





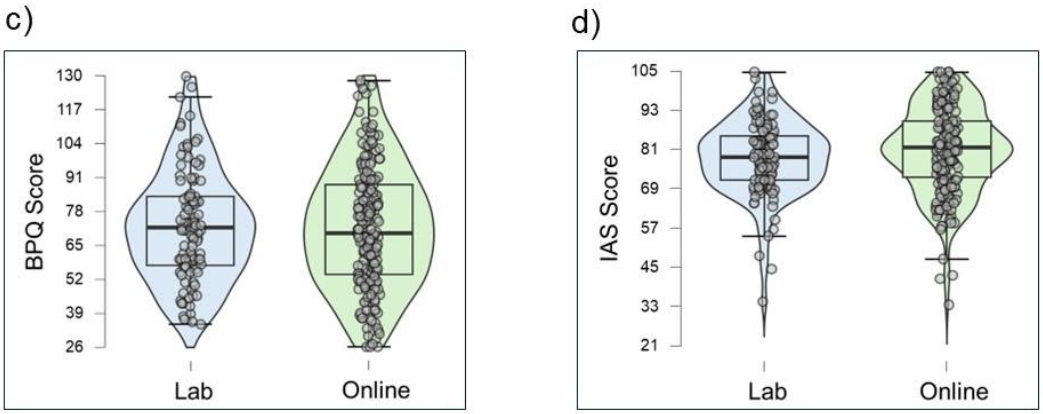


Figure 3.8 Violin Plots of Interoceptive Measures (MAIA Subscales, BPQ, IAS) Split by Group

3.4.3 H.1. Correlational Analyses Between Anxiety-Trait and Interoception Self – Report Measures

Parametric correlation coefficients were calculated among all scales. Non-parametric correlations were additionally calculated as a sensitivity check, and similar patterns were observed (see Appendices M.1–M.5). Correlations examined the associations between anxiety trait measures and interoception measures (see Table 3.5). As expected, there were significant positive relationships between the anxiety trait measures within this sample (*N* = 305). Scatterplots illustrating key associations are provided in Appendices N.1–N.3.

Trait anxiety (STAI-T) showed significant negative correlations with MAIA subscales of 'Not Distracting' (r = -.27, p < .001), 'Not Worrying' (r = -.44, p < .001), 'Self-Regulation' (r = -.24, p < .01), and 'Trusting' (r = -.26, p < .01). A positive correlation was found between STAI-T and MAIA 'Noticing' (r = .19, p < .05). STAI-T scores were also weakly correlated with BPQ scores *(*r = .14, p < .05).

Anxiety sensitivity (ASI) exhibited significant negative correlations with MAIA subscales of 'Not Distracting' (r = -.28, p < .001), 'Not Worrying' (r = -.60, p < .01), and 'Self-Regulation' (r = -.19, p < .01), and positive correlations with 'Body Listening' (r = .17, p < .01) and 'Emotional Awareness' (r = .14, p < .05). A moderate positive association was also found between ASI and BPQ scores (r = .32, p < .01), whilst a weaker negative association was found between ASI and IAS (r = -.14, p < .05).

Intolerance of uncertainty (IUS) was significantly negatively correlated with several MAIA subscales, including 'Not Distracting' (r = -.22, p < .01), 'Not Worrying' (r = -.39, p < .01), and 'Self-Regulation' (r = -.18, p < .01), A small negative relationship was identified between IU and self-reported interoceptive accuracy (IAS) (r = -.15, p < .01), and no relationship with BPQ.

Table 3.5 Correlation Matrix Illustrating the Relationship Between Anxiety Trait and Self-Report Interoception Questionnaires (N = 305)

Questionnaire / Subscale	1	2	3	4	5	6	7	8	9	10	11	12	13
1. ASI	--												
2. IUS	.51**	--											
3. STAI-T	.56**	.68**	--										
4. BPQ	.32**	.10	.14*	--									
5. IAS	-.14*	-.15**	-.15**	.08	--								
6. MAIA Noticing	.26**	.15*	.19**	.36**	.27**	--							
7. MAIA Not Distracting	-.28**	-.22**	-.27**	-.16**	.11*	-.23**	--						
8. MAIA Not Worrying	-.60**	-.39**	-.44**	-.14*	.18**	-.09	.08	--					
9. MAIA Attention Reg.	-.10	-.10	-.07	.25**	.30**	.46**	-.09	.12*	--				
10. MAIA Emotional Awa.	.14*	.04	.09	.32**	.22**	.58**	-.19**	-.08	.55**	--			
11. MAIA Self-Regulation	-.19**	-.18**	-.24**	.09	.24**	.32**	.04	.15**	.65**	.57**	--		
12. MAIA Body Listening	.04	-.05	-.09	.17**	.25**	.45**	-.01	.01	.53**	.58**	.63**	--	
13. MAIA Trusting	-.16**	-.25**	-.26**	.06	.30**	.25**	.02	.13*	.57**	.51**	.60**	.54**	--

Note. * = $p < .05$, ** = $p < .01$. Two-tailed. IUS = Intolerance of Uncertainty Scale; ASI = Anxiety Sensitivity Index; STAI-T = State Trait Anxiety Inventory – Trait; BPQ = Body Perception Questionnaire; IAS = Interoceptive Accuracy Scale; MAIA = Multidimensional Assessment of Interoceptive Awareness.

3.4.4 H.2. Correlational Analyses Between Symptom and Interoception Self – Report Measures

Table 3.6 outlines the associations between clinical symptom measures and self-report interoceptive measures. Scatterplots illustrating selected key associations are presented in Appendix N.4. As expected, there were significant positive relationships between all symptom measures in this sample (N = 305) (r = .53 - .77, p < .01). Higher levels of GAD, PTSD, and depression were significantly negatively correlated with the MAIA subscales 'Not Distracting', 'Not Worrying', 'Self-Regulation' and 'Trusting'. Similarly, elevated higher panic and OCD symptoms were also significantly negatively correlated with the MAIA subscales of 'Not Distracting', 'Not Worrying', and 'Trusting'. Social anxiety symptoms were primarily associated with lower scores on MAIA 'Not Worrying' (r - .33; p < .01).

Higher interoceptive attention (BPQ) was positively associated with greater anxiety-related symptoms, particularly social anxiety (r = .28, p < .01), panic (r = .24, p < .01), OCD (r = .23, p < .01), and generalised anxiety (r = .16, p < .01). BPQ scores were also positively correlated with symptom severity of other emotional disorders including PTSD (r = .20, p < .01) and depression (r = .16, p < .01). Interoceptive accuracy (IAS) was significantly negatively correlated with all symptom measures, although the strength of this relationship was weak (r < .22, p < .05).

Table 3.6 Correlation Matrix Illustrating the Relationship Between Symptom Questionnaires and Self-Report Interoception Questionnaire

Questionnaire / Subscales	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. GAD	--															
2. OCI	.61**	--														
3. PCL	.74**	.64**	--													
4. PDSS	.60**	.53**	.66**	--												
5. PHQ	.72**	.56**	.77**	.54**	--											
6. SIPS	.53**	.55**	.57**	.51**	.49**	--										
7. BPQ	.16**	.23**	.20**	.24**	.16**	.28**	--									
8. IAS	-.15**	-.21**	-.25**	-.16**	-.22**	-.21**	.08	--								
9. MAIA Noticing	.21**	.21**	.20**	.26**	.14*	.19**	.36**	.27**	--							
10. MAIA Not Distracting	-.25**	-.28**	-.36**	-.25**	-.28**	-.27**	-.16**	.11*	-.23**	--						
11. MAIA Not Worrying	-.38**	-.33**	-.34**	-.28**	-.21**	-.33**	-.14*	.18**	-.09	.08	--					
12. MAIA Attention Reg.	-.09	.05	-.08	-.05	-.13*	-.04	.25**	.30**	.46**	-.09	.12*	--				
13. MAIA Emotional Awa.	.10	.12*	.10	.15**	-.07	.07	.32**	.22**	.58**	-.19**	-.08	.55**	--			
14. MAIA Self-Regulation	-.20**	-.07	-.17**	-.11	-.27**	-.14*	.09	.24**	.32**	.04	.15**	.65**	.57**	--		
15. MAIA Body Listening	-.06	.05	-.02	.10	-.14*	.03	.17**	.25**	.45**	-.01	.01	.53**	.58**	.63**	--	
16. MAIA Trusting	-.26**	-.15**	-.22**	-.15*	-.29**	-.23**	.06	.30**	.25**	.02	.13*	.57**	.51**	.60**	.54**	--

Note. * = $p < .05$, ** = $p < .01$. Two-tailed. PHQ = Patient Health Questionnaire; GAD = Generalised Anxiety Disorder; OCI = Obsessive-Compulsive Inventory; PDDS-SR = Panic Disorder Severity Scale – Self Report; PCL = Post-Traumatic Stress Disorder Checklist; SIPS = Social Interaction Phobia Scale; BPQ = Body Perception Questionnaire; IAS = Interoceptive Accuracy Scale; MAIA = Multidimensional Assessment of Interoceptive Awareness.

3.4.5 Heartbeat Perception Task Performance Descriptive Statistics

Table 3.7 presents the descriptive statistics for the performance on the heartbeat perception tasks with the lab sample (*n* = 103), including means, standard deviations, range, and measures of normal distribution. Data was normally distributed for both tasks.

Table 3.7 Descriptive Statistics of Heartbeat Perception Tasks

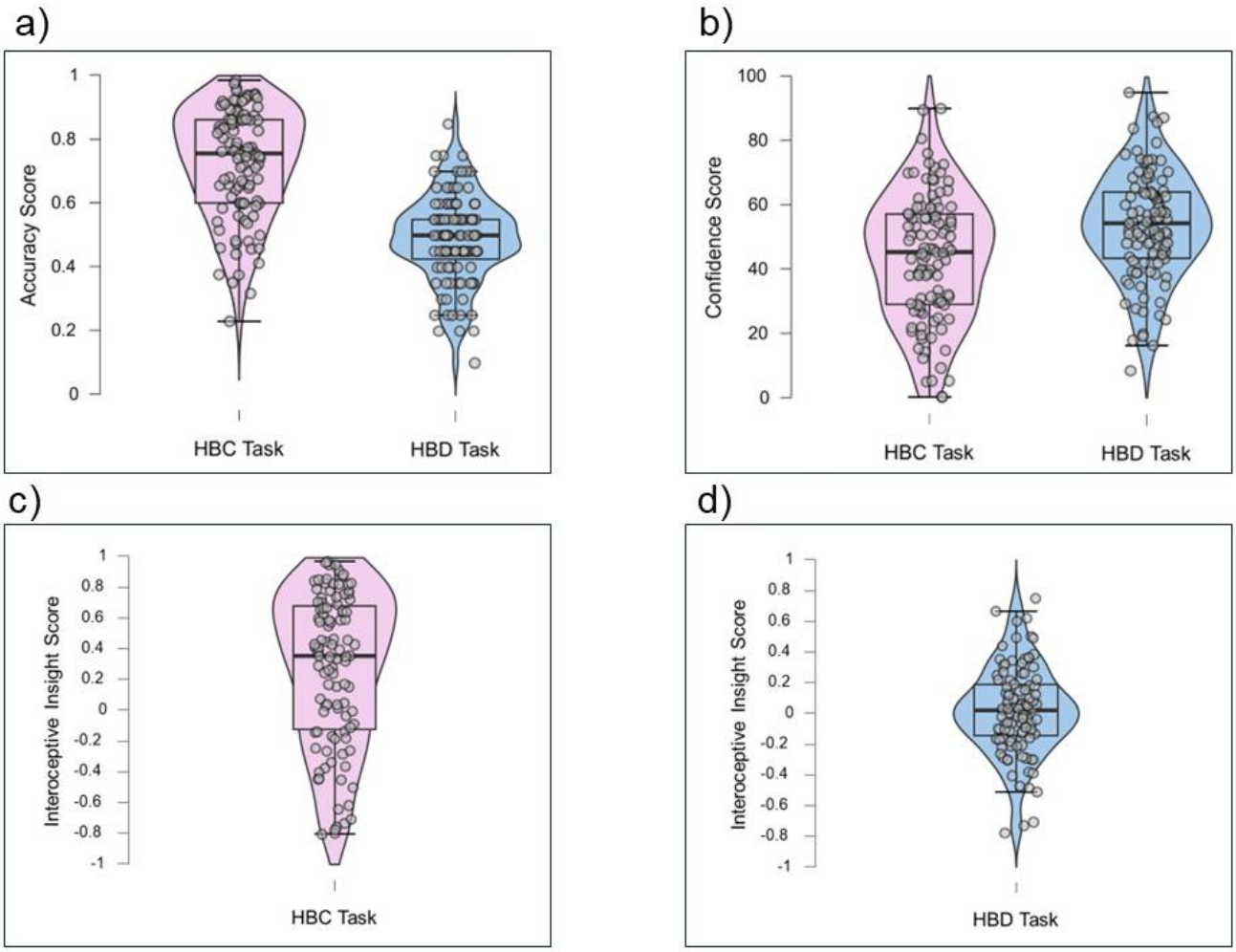
Heartbeat Task	*N*	*M*	*SD*	Range	Skewness	Kurtosis
HBC Accuracy	103	0.72	0.17	0.23 – 0.98	-0.65	-0.28
HBC Confidence	103	43.48	19.80	0.17 – 89.83	-0.11	-0.42
HBC Insight	103	0.27	0.49	-0.80 – 0.97	-0.54	-0.75
HBD Accuracy	103	0.49	0.14	0.10 – 0.85	-0.23	0.23
HBD Confidence	103	53.63	16.95	8.65 – 95.05	-0.19	0.00
HBD Insight	103	0.51	0.14	0.11 – 0.87	-0.11	0.49

Note. HBC = Heartbeat Counting; HBD = Heartbeat Detection.

For the heartbeat counting task, mean accuracy was 0.72 (*SD* = 0.17), with scores ranging from 0.23 to 0.98. Confidence ratings, measured on a scale of 0 to 100, had a mean of 43.48 (*SD* = 19.80). Insight scores for heartbeat counting averaged 0.27 (*SD* = 0.49). For the heartbeat detection task, mean accuracy was 0.49 (*SD* = 0.14), with scores ranging from 0.10 to 0.85. Confidence scores were slightly higher than in the heartbeat counting task, with a mean of 53.63 (*SD* = 16.95). Insight scores for heartbeat detection averaged 0.51 (*SD* = 0.14).

Overall, participants demonstrated overall higher accuracy in the HCT task compared to the HDT task, suggesting heartbeat counting was easier than heartbeat detection. However, overall confidence scores were lower for the heartbeat counting task than the heartbeat detection task. Figure 3.9 displays violin plots of interoceptive accuracy, confidence and insight metrics for each heartbeat perception task.

Figure 3.9 Violin Plot of Heartbeat Perception Task Performance (N = 103)



3.4.6 H.3. Correlational Analysis Between Anxiety Trait and Heartbeat Perception Task Performance

Correlation analyses were conducted to explore associations between anxiety trait vulnerability factors (i.e., trait anxiety, AS and IU) and heartbeat perception task performance (see Table 3.8). For the heartbeat counting task, trait anxiety (STAI-T) was negatively associated with Heartbeat Counting (HBC) Confidence (r = -.26, p < .05). Greater intolerance of uncertainty (IUS) was associated with increased HBC Insight (r = .20, p < .05). No significant associations were found between trait measures and Heartbeat Detection (HBD) performance. As expected, there were significant positive relationships between the anxiety-trait measures within the lab sample (N = 103).

Higher intolerance of uncertainty (IUS) was strongly associated with greater trait anxiety (STAI-T) (r = .65, p < .01) and anxiety sensitivity (ASI) (r = .59, p < .01), consistent with theoretical models that conceptualise intolerance of uncertainty as a transdiagnostic cognitive vulnerability factor for anxiety disorders. Furthermore, trait anxiety (STAI-T) and anxiety sensitivity (ASI) were moderately correlated (r = .46, p < .01).

Table 3.8 Correlation Matrix Illustrating the Relationship Between Trait Questionnaires and Heartbeat Perception Task Performance

Questionnaire / Task	1	2	3	4	5	6	7	8	9
1. ASI	--								
2. IUS	.59**	--							
3. STAI-T	.46**	.65**	--						
4. HBC Accuracy	-.02	-.08	-.05	--					
5. HBC Confidence	-.07	-.08	-.26*	.27**	--				
6. HBC Insight	-.02	.20*	.17	.13	-.02	--			
7. HBD Accuracy	.12	-.01	-.01	-.02	-.08	.10	--		
8. HBD Confidence	-.18	-.13	-.11	.09	.54**	-.11	-.07	--	
9. HBD Insight	.03	-.05	.12	.03	-.14	.13	.02	-.06	--

Note. * = p < .05, ** = p < .01. Two-tailed. IUS = Intolerance of Uncertainty Scale; ASI = Anxiety Sensitivity Index; STAI-T = State-Trait Anxiety Inventory – Trait; HBC = Heartbeat Counting; HBD = Heartbeat Detection.

3.4.7 H.4. Correlational Analysis Between Symptom Measures and Heartbeat Perception Task Performance

Correlation analyses were conducted to explore the relationships between symptom measures and performance on heartbeat perception tasks (see Table 3.9). No significant relationships emerged between symptom measures and heartbeat perception task metrics (i.e., objective interoceptive accuracy, confidence, and insight). As expected, strong positive correlations were observed between symptom questionnaires (r = .50 - .83, p < .01).

Table 3.9 Correlation Matrix Illustrating the Relationship Between Symptom Questionnaires and Heartbeat Perception Task Performance

Questionnaire / Task	1	2	3	4	5	6	7	8	9	10	11	12
1. GAD	--											
2. OCI	.64**	--										
3. PCL	.83**	.56**	--									
4. PDSS-SR	.68**	.54**	.74**	--								
5. PHQ	.73**	.54**	.75**	.58**	--							
6. SIPS	.56**	.50**	.58**	.56**	.58**	--						
7. HBC Accuracy	.09	-.03	.08	.11	.02	-.08	--					
8. HBC Confidence	-.12	-.05	-.10	-.02	-.16	-.02	.27**	--				
9. HBC Insight	-.01	.02	-.02	-.16	-.02	-.12	.13	-.02	--			
10. HBD Accuracy	.01	-.07	.06	-.01	-.04	.08	-.02	-.08	.10	--		
11. HBD Confidence	-.09	-.05	-.01	-.02	-.11	-.04	.09	.54**	-.11	-.07	--	
12. HBD Insight	.01	-.05	.03	.09	.01	-.11	.03	-.14	.13	.02	-.06	--

Note. * = $p < .05$, ** = $p < .01$. Two-tailed. GAD = Generalised Anxiety Disorder; OCI = Obsessive-Compulsive Inventory; PDDS-SR = Panic Disorder Severity Scale – Self Report; PCL = Post-Traumatic Stress Disorder Checklist; PHQ = Patient Health Questionnaire; SIPS = Social Interaction Phobia Scale; HBC = Heartbeat Counting; HBD = Heartbeat Detection.

3.5 Discussion

The present study investigates the relationship between multiple facets of interoception, anxious-related traits, and anxiety-related symptoms. Given the heterogeneity of findings in the existing literature, hypotheses regarding these relationships were primarily exploratory, though some directional predictions were made based on prior research.

3.5.1 H.1. Anxiety-related Traits and Self-Reported Interoception

As predicted, anxiety-related traits were significantly associated with self-report measures of interoception. Specifically, trait anxiety was negatively related with MAIA subscales 'Not Worrying', 'Not Distracting', 'Self- Regulation' and 'Trusting' in line with previous research (e.g., Borg et al., 2018; Bornemann et al., 2015; Ferentzi et al., 2021; Mehling et al., 2012; Slotta et al., 2021). The strongest relationship was with 'Not Worrying' and 'Trusting', also consistent with literature (Bornemann et al., 2015; Mehling et al., 2012). This suggests individuals with higher trait anxiety may have difficulty not worrying about discomforting sensations, ignoring and distracting oneself from sensations of discomfort, regulating distress by attending to bodily sensations and trusting their body as a 'safe place'. In contrast to previous findings, MAIA 'Noticing' was positively correlated with trait anxiety, although this relationship is weak. This novel finding may suggest individuals with higher trait anxiety tend to be more attuned to the presence of bodily sensations, but without the accompanying capacity to interpret or regulate them in adaptive ways in a non-clinical sample. These findings align with previous research that suggests higher trait anxiety is associated with greater self-reported sensitivity to internal bodily sensations (Garfinkel et al., 2016; Palser et al., 2018).

The BPQ findings were consistent with those from the MAIA 'Noticing' subscale, also showing a positive correlation with trait anxiety. This may reflect the conceptual overlap between the two measures, as both assess subjective awareness of bodily sensations. However, the BPQ has been criticised as a proxy measure for anxiety symptoms, as it primarily captures awareness of aversive,

anxiety-related bodily states. In contrast, the MAIA was specifically developed to assess more adaptive, regulatory aspects of interoception, such as mindfulness and coping behaviours (Mehling et al., 2018). This distinction may help explain why some MAIA subscales show negative associations with anxiety, while the BPQ consistently shows positive relationships. These differential relationships highlight a need to distinguish between maladaptive and adaptive forms of interoception (Trevisan et al., 2021).

Similarly, AS was positively correlated with the BPQ and MAIA 'Noticing'. Consistent with previous research, it showed the strongest negative correlation with MAIA 'Not-Worrying' (Mehling et al., 2012; Tünte et al., 2024). This suggests that individuals with higher anxiety sensitivity tend to be more attuned to bodily sensations but are also more likely to interpret these sensations in a distressing way. As expected, individuals with lower AS may be less likely to worry when experiencing anxiety-related bodily sensations, such as increased heartrate, shortness of breath or chest constrictions.

Given the scarcity of research examining the relationship between IU and interoception, the present study adopted an exploratory approach. Findings revealed that IU was negatively correlated with the MAIA 'Not Distracting' and 'Trusting' subscales, with the strongest negative correlation observed for 'Not Worrying', as reported in existing research (Bijsterbosch et al., 2023). These results suggest individuals with higher IU may be less likely to trust their bodily sensations, more prone to worry about them, and more inclined to distract themselves from these signals rather than engage with them adaptively. However, no significant relationship was found between IU and interoceptive attention, as measured by the BPQ, while only a weak positive association emerged with the MAIA Noticing subscale, which also assesses awareness of bodily sensation. This suggests IU may not influence the extent to which individuals attend to bodily sensations, but rather how individuals interpret and respond to those sensations. This is further supported by the observed negative association between IU and self-reported interoceptive accuracy, as measured by the IAS.

Together, these findings highlight the potential role of higher IU in maladaptive interoceptive processing, characterised by negative beliefs about bodily signals (i.e., interpreting them as threatening), and reduced perceived accuracy in detecting these signals.

3.5.2 H.2. Anxiety-related Traits and Heartbeat Perception Tasks

Results from the heartbeat perception tasks found no relationship between cardiac interoceptive accuracy and any of the anxiety-related traits examined. This adds to the body of evidence that suggests interoceptive accuracy does not play a significant role in trait anxiety (Adams et al., 2022; Desmedt et al., 2020, 2022; Slotta et al., 2021), anxiety sensitivity (Körmendi et al., 2023) and provides novel findings for IU. This supports the theoretical model that anxious traits are more closely linked to interceptive beliefs (i.e., how much they believe they notice bodily sensations), rather than objective accuracy (Murphy et al., 2019; Suksasilp & Garfinkel, 2022).

Notably, IU was weakly positively correlated with interoceptive insight on the HBC task, but not on the HBD task. This discrepancy may be due to inherent differences in task requirements (Hickman et al., 2020). Whilst both tasks are presumed to assume perception of internal sensations, the detection task is a force-choice discrimination task which requires the integration of internal and external stimuli. As such, HBD tasks are often presumed to be more difficult than the HBC task (Murphy et al., 2017; Suksasilp & Garfinkel, 2022). This increased complexity may disproportionately affect individuals with high IU, who may struggle more with ambiguity and decision-making under uncertainty (Carleton, 2016).

3.5.3 H.3. Anxiety-related Symptoms and Self-Reported Interoception

Significant relationships were found between all symptom measures and the IAS and BPQ. Notably, BPQ scores were positively correlated with symptom severity, whereas IAS scores were negatively correlated. This suggests that individuals who report poorer interoceptive accuracy tend to experience higher levels of anxiety-related symptoms, with the strongest association observed for

PTSD symptoms. Conversely, individuals with greater interoceptive attention tend to report higher symptom severity. These findings suggest that individuals may be highly attuned to their bodily sensations but lack confidence in the accuracy of their perceptions. This aligns with models suggesting that heightened bodily awareness may contribute to increased symptom severity through hypervigilance and misinterpretation of bodily sensations (Domschke et al., 2010; Paulus & Stein, 2010).

Supporting this, the negative relationships between all symptom measures and the MAIA 'Trusting' subscale suggest that individuals with more severe symptoms may struggle to trust their bodily sensations, particularly those with panic symptoms, where this association was strongest. This pattern is consistent with theories of panic disorder, which emphasise the catastrophic misinterpretation of bodily signals (Clark, 1986; Clark et al., 1997; Ehlers & Breuer, 1992). Several MAIA subscales were significantly negative associated with symptom measures. For example, PTSD symptoms were most strongly associated with lower scores on the 'Not Distracting' subscale. This is in line with the well-established role of avoidance in PTSD, particularly the avoidance of internal cues that may trigger trauma memories (Schmitz et al., 2023). This highlights that individuals with PTSD may actively disengage from bodily sensations in an effort to prevent distressing flashbacks or anxiety, reflecting interoceptive avoidance.

3.5.4 H.4. Anxiety-related Symptoms and Heartbeat Perception Tasks

No significant correlations were found between symptom measures and metrics derived from the HBC and HBD tasks (i.e., objective interoceptive accuracy, confidence, and interoceptive insight). These findings are unexpected, and challenge theoretical models that position interoception as central to anxiety disorder symptoms (e.g., Domschke et al., 2010; Paulus & Stein, 2010). This adds to the growing body of research reporting differential associations between interoceptive processes and anxiety symptoms, suggesting that anxiety may not be characterised by global interoceptive

differences (Schoeller et al., 2025). These mixed findings may be due to differences in how interoception is conceptualised and methodological variations, underscoring the need for more standardised approaches to studying interoception in psychopathology (Desmedt et al., 2025; Khalsa et al., 2018). Moreover, the absence of significant associations may be partly attributable to the non-clinical sample and the reliance on self-reported symptoms. As illustrated in the violin plots (see Figure 3.7), most symptom scores, apart from GAD, were clustered toward the lower end of the scale, which may have limited the variability needed to detect associations with behavioural interoception.

3.5.5 Strengths, Limitations, and Future Directions

This study makes a novel contribution by applying a multidimensional model of interoception to examine both transdiagnostic anxious traits and symptom dimensions across anxiety-related disorders. Strengths include the combined use of self-report and behavioural heartbeat perception tasks, a relatively large sample size, and inclusion of a range of anxiety constructs. By aligning interoceptive measures with a contemporary multidimensional framework, the study helps clarify which interoceptive domains (e.g., accuracy, attention, beliefs) are most relevant to anxiety.

Limitations should also be acknowledged. The present study focusses exclusively on cardiac interoception, therefore results may not generalise to other domains such as respiratory or gastric interoception, which have also shown associations with anxiety when measured (e.g., Harrison et al., 2021). Harrison et al., (2025) found that performance on inspiratory resistance tasks does not necessarily transfer to cardiac tasks, highlighting that interoceptive abilities may be modality specific. Future research should adopt multimodal approaches to determine whether observed associations are unique to cardiac interoception or reflect broader interoceptive mechanisms.

Secondly, despite widespread use in interoceptive research, the heartbeat perception tasks have been criticised for their validity (Corneille et al., 2020; Zamariola et al., 2018). It has been

argued that HBC performance can be influenced by non-interoceptive factors such as time estimation, knowledge of heart rate and response bias (Murphy et al., 2018; Ring & Brener, 2018; Zamariola et al., 2018). Prior knowledge of heart rate may be particularly relevant given the growing prevalence of heart rate-monitoring wearables, which could potentially confound performance on the HBC task (Prieto-Avalos et al., 2022). Desmedt et al. (2018) demonstrated that modifying task instructions to ask participants not to guess their heartbeats reduced average HCT performance by 50%, suggesting HCT performance may rely on cognitive strategies rather true interoceptive accuracy. To address these concerns and minimise estimation bias and chance-level responding, future studies should assess participants' baseline knowledge of their heart rate and time estimation abilities, as implemented in some studies (Haruki et al., 2025; Murphy et al., 2018; Sakuragi & Umeda, 2025). This would help clarify the extent to which top-down influences affect task performance and disentangle interoceptive ability from other cognitive factors.

Furthermore, the present study found no relationship between HBC and HBD performance, consistent with previous research (Forkmann et al., 2016; Schulz et al., 2013). Meta-analytic evidence suggests performance on the HBC and HBD tasks is only weakly associated, indicating these such may capture distinct constructs (Hickman et al., 2020). This raises questions about whether these tasks index a shared interoceptive ability or instead tap into distinct facets of interoception.

Group comparisons indicated that lab-based participants were significantly younger than online participants, likely reflecting recruitment from a university-based population versus the broader online population. Despite this age difference, questionnaire scores were largely comparable across groups, suggesting that the self-report measures were robust across a range of adult ages. The online group indicated significantly higher social anxiety than the lab-based group, which may reflect sample characteristics or self-selection factors, such as individuals with higher social anxiety being more likely to participate online rather than in a lab setting. While the groups were otherwise broadly comparable, it may be important to consider recruitment context when interpreting self-

report anxiety data. For example, younger participants in the lab-based group may exhibit different patterns of interoceptive awareness or anxiety-related symptom expression due to developmental or experiential factors (Carr et al., 2024), potentially influencing the generalisability of findings.

In light of the rapidly rising global prevalence of anxiety disorders (Chen et al., 2025), continued research into interoception as a transdiagnostic factor is warranted. Future studies should extend beyond single measurement paradigms and adopt a systemic, multidimensional assessment of interoception, including exploration of understudied bodily domains beyond the cardiac axis. Such an approach will help to delineate the mechanistic role of interoception in anxiety-related disorders, enhance the development of targeted clinical interventions, and enhance understanding of the real-world relevance and translational potential of interoceptive processes.

Conclusion

The present study explored the relationship between interoception and anxiety-related traits and symptoms using a multidimensional framework. By combining self-report and behavioural measures, it aimed to capture distinct facets of interoception to address the gaps in the literature. While some findings aligned with theoretical predictions, highlighting the role of interoceptive beliefs and attention in anxiety, other findings, particularly those involving behavioural task performance, were less consistent. The lack of relationship between heartbeat perception tasks and self-reported experiences highlights ongoing concerns about measurement validity. Overall, this research provides novel findings related to anxious-traits and interoception and supports the move towards multidimensional approaches to interoception. Findings highlight the importance of considering both subjective and objective interoceptive processes when investigating its role in anxiety-related processes.

Future research should prioritise methodological standardisation, for example by using consistent operationalisations of interoceptive dimensions (accuracy, attention, beliefs, and insight)

and using validated behavioural and self-report measures across studies to improve comparability. Including clinically severe and diverse populations, such as those recruited from secondary and tertiary services, would also strengthen generalisability. Finally, clarifying the translational relevance of interoceptive differences could involve examining whether these processes predict treatment response, act as mechanisms of change, or represent novel intervention targets. Such advances may guide the tailoring of treatments to individual interoceptive profiles and enhance therapeutic efficacy.

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Appendix A PRISMA Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 29
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 30
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 31
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 34
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Pages 39-40 Pages 40 - 41
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 35
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page 148
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 37
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 37
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Pages 40 – 41
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 39

Section and Topic	Item #	Checklist item	Location where item is reported
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Pages 39 – 45
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 39
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Pages 40 – 46
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 39
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 40
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 40
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page 40
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 35
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 35
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 38
	16b	Studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 38
Study characteristics	17	Cite each included study and present its characteristics.	Pages 151 – 157
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Pages 44, 158 – 160
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Pages 46 – 54
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Pages 43 – 44, 55, 57, 60, 66, 72, 78

Section and Topic	Item #	Checklist item	Location where item is reported
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	N/A
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	N/A
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	N/A
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 70 – 72
	23b	Discuss any limitations of the evidence included in the review.	Page 73 - 74
	23c	Discuss any limitations of the review processes used.	Page 74
	23d	Discuss implications of the results for practice, policy, and future research.	Page 74 – 75
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 34
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 34
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Page 34
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	N/A
Competing interests	26	Declare any competing interests of review authors.	N/A
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	N/A

Appendix B Search Term Strategy and Databases

Database	Search Terms	
	Interoception Terms	Anxiety Disorder Terms
PsychINFO	interocept* AND	("generali?ed anxiety disorder" OR GAD) ("social anxiety disorder" OR SAD OR "social phobia") ("panic disorder" OR "panic") ("obsessive-compulsive" OR "obsessive compulsive disorder" OR OCD) ("post-traumatic stress disorder" OR PTSD)
PubMed	interocept*[tiab] AND	("generalized anxiety disorder"[tiab] OR "generalised anxiety disorder"[tiab] OR "GAD"[tiab]) ("social anxiety"[tiab] OR "social anxiety disorder"[tiab] OR "SAD"[tiab] OR "social phobia"[tiab]) ("panic disorder"[tiab] OR "panic"[tiab]) ("obsessive-compulsive"[tiab] OR "obsessive compulsive disorder"[tiab] OR "OCD"[tiab]) ("post-traumatic stress disorder"[tiab] OR "PTSD"[tiab])
Web of Science	TS=(interocept* AND	("generalized anxiety disorder" OR "generalised anxiety disorder" OR GAD) ("social anxiety" OR "social anxiety disorder" OR SAD OR "social phobia") ("panic disorder" OR "panic") ("obsessive-compulsive" OR "obsessive compulsive disorder" OR OCD) ("post-traumatic stress disorder" OR PTSD)

Appendix C Population, Exposure, Comparator and Outcomes Framework

Component	Description
Population (P)	Adults (≥18 years) with a formal diagnosis or validated measure of an anxiety or stress-related disorder (e.g., GAD, SAD, Panic Disorder, OCD, PTSD), with or without comparison to a healthy control group.
Exposure (E)	Assessment of interoception using validated self-report measures (e.g., MAIA, BPQ, IAS) or experimental tasks (e.g., heartbeat counting task, heartbeat discrimination task, respiratory tasks, signal detection tasks)
Comparator (C)	Healthy adult participants (for between-group studies) or individuals with varying levels of anxiety symptom severity (for within-group designs).
Outcome (O)	Measures of interoceptive performance or self-reported interoceptive awareness, beliefs, or attention.

Appendix D Amended EPHPP Quality Assessment Tool for Quantitative Studies

Component	Question	Response Options
Selection Bias	1. Are the individuals selected to participate likely representative of the target population?	1 = Very likely / 2 = Somewhat likely / 3 = Not likely / 4 = Can't tell
	2. What percentage of selected individuals agreed to participate?	1 = 80-100% / 2 = 60-79% / 3 = <60% / 4 = Not applicable / 5 = Can't tell
Study Design	3. Indicate study design	1 = RCT / 2 = Controlled clinical trial / 3 = Cohort analytic / 4 = Case-control / 5 = Cohort pre-post / 6 = Interrupted time series / 7 = Other (specify) / 8 = Can't tell
Data Collection Methods	4. Was the method appropriate?	Yes / No
	5. Were data collection tools valid?	1 = Yes / 2 = No / 3 = Can't tell
	6. Were data collection tools reliable?	1 = Yes / 2 = No / 3 = Can't tell
Withdrawals and Drop-outs	7. Were withdrawals/drop-outs reported per group?	1 = Yes / 2 = No / 3 = Can't tell 4 = Not applicable
	8. % participants completing study (lowest group)	1 = 80-100% / 2 = 60-79% / 3 = <60% / 4 = Can't tell / 5 = Not applicable
Analyses	9. Unit of allocation	Community organisation / Institution / Practice / Office / Individual
	10. Unit of analysis	Community organisation / Institution / Practice / Office / Individual
	11. Are statistical methods appropriate?	1 = Yes / 2 = No / 3 = Can't tell

Note. EPHPP = Effective Public Health Practice Project; RCT = Randomised Control Trial

Appendix E Table of Included Study Characteristics

Author(s) & Year	Location	Design	Anxiety Sample (n)	Control Sample (n)	Mean age (SD)	Gender (F%) *
Andor et al. (2008)	Germany	Case control	GAD = 33	HC = 34	GAD = 37.2 (11.4) HC = 37.4 (11.3)	GAD = 72.7% HC = 70.6%
Antony et al. (1995)	New York, USA	Case control	Panic = 20 SAD = 20	HC = 20	Panic = 30 (5) SAD = 30.8 (5.8) HC = 28.4 (5.5)	Panic = 60% SAD = 60% HC = 60%
Asmundson et al. (1993)	Canada	Case control	Panic = 20	HC = 20	Panic = 20 HC = 19	Panic = 40% HC = 50%
Belanger et al. (2023)	New York, USA	Cross-sectional	OCD = 145	N/A – dimensional design	31.50 (11.60)	Total sample = 59.3%
Bogaerts et al. (2022)	Belgium	Case-control	Panic = 60	HC = 144	Panic = 33.7 (11.6) HC = 41 (11)	Panic = 55% HC = 86.8%

Craske et al. (2001)	Los Angeles, USA	Case control	Panic = 90	HC = 16	Total sample = 3.7 (9.5)	Total sample = 48%
Cui et al. (2016)	Shanghai, China	Case-control	GAD = 21 Panic = 18	HC = 22	GAD = 39.5 Panic = 37.7 HC = 38.1	GAD = 33.3% Panic = 33.3% HC = 36.4%
Cui et al. (2020)	Shanghai, China	Case-control	GAD = 32	HC =30	GAD = 33.1 (8.3) HC= 31 (6.4)	GAD = 34.4% HC = 43.3%
Demartini et al. (2021)	Italy	Case control	OCD = 18	HC = 18	OCD = 40.7 (15.8) HC = 44.3 (16.8)	OCD = 55.5% HC = 50%
Ehlers & Breuer (1992)	Germany	Cross-sectional	Panic = 65 Panic Attacks = 50 Phobias = 27	HC = 46	Panic = 33.3 (9.3) Panic attacks = 30.2 (9.4) Phobias = 31.9 (9.8) HC = 31.7 (7.3)	Panic = 73.8% Panic attacks = 72% Phobias = 81.5% HC = 73.9%
Eng et al. (2020)	New York, USA	Cross-sectional	OCD = 81	HC =76	OCD = 34.1 (12.6) HC = 31 (10.1)	OCD = 65.4% HC = 51.3%

Eng et al. (2022)	New York, USA	Cross-sectional	OCD = 77	HC = 53	OCD = 31.6 (10.9) HC = 31.8 (10.8)	OCD = 64.9% HC = 49.1%
Eng et al. (2024)	New York, USA	Cross-sectional	OCD (Low) = 19 OCD (Mod) = 49 OCD (High) = 38	HC = 38	OCD (Low) = 28.3 (9.7) OCD (Mod) = 30.61 (11) OCD (High) = 32.1 (11.2) HC = 31 (11.4)	OCD (Low) = 63.2% OCD (Mod) = 63.3% OCD (High) = 71.4% HC = 76.3%
Gaebler et al. (2013)	Germany	Case control	SAD = 21	HC = 21	SAD = 40 HC = 29.1	SAD = 76.2% HC = 76.2%
Giardino et al. (2010)	Michigan, USA	Case control	COPD-PD = 10 COPD-NP = 9	HC = 9	COPD-PD = 65.1 (3.7) COPD-NP = 65.8 (3) HC = 64.3 (3.2)	COPD=PD = 30% COPD-NP = 33.3% HC = 33.3%
Ironside et al. (2023)	Oklahoma, USA	Case control	Mixed anxiety & depression = 104	Depression = 52	Mixed anxiety & depression = 36.2 (11) Depression = 37.8 (11.9)	Mixed anxiety & depression = 72% Depression = 69%
Jin et al (2020)	Shanghai, China	Case control	Panic = 18	HC = 21	Panic = 38.1 HC = 38.1	Panic = 66.6% HC = 61.9%

Kroeze et al. (1996)	Netherlands	Case control	Panic = 16	HC = 17	Panic = 41.1 HC = 41.9	Panic = 75% HC = 76.5%
Lapidus et al. (2020)	Oklahoma, USA	Case control	Anxiety / mood = 51 ED = 51	HC = 51	Anxiety / mood = 28.61 ED = 25.82 HC = 26.57	Anxiety mood = 96% ED = 96% HC = 96%
Lee et al. (2024)	South Korea	Cross-sectional	Mixed Anxiety = 67	N/A – dimensional design	Mean age not reported 18 – 65 years range	Total sample = 72.7%
Li et al. (2023)	Shanghai, China	Cross-sectional	GAD = 21 Panic = 18	HC = 22	GAD = 39.9 (12.2) Panic = 37.2 (11.1) HC = 38.5 (10.3)	GAD = 38% Panic = 33.3% HC = 36.4%
Li et al. (2020)	Shanghai, China	Case control	GAD = 18	HC = 18	GAD = 41.9 HC = 38.1	GAD = 68.4% HC = 36.6%
Limmer et al. (2015)	Germany	Case control	Panic = 40	HC = 53	Panic = 44 (12) HC = 41 (14)	Panic = 63% HC = 72%

Machorrinho et al. (2022)	Portugal	Case control	38 DV victims: PTSD = 24 Anxiety = 27	38 DV victims: No PTSD = 12 No anxiety = 10	Total sample = 40 (10.9)	PTSD = 100% Mixed Anxiety = 100% Depression = 100%
Mussgay et al. (1999)	Germany	Case control	Panic = 53	HC = 48	Panic = 41.3 HC = 35.8	Panic = 64.6% HC =60.4%
Pang et al. (2019)	Shanghai, China	Case control	GAD = 25	HC = 15	GAD = 37.7 (10.7) HC = 39.9 (8.9)	GAD = 60.7% HC = 75%
Poppa et al. (2019)	Los Angeles, USA	Case control	PTSD & SUD = 14	SUD = 29	PTSD & SUD = 32.9 SUD = 29.2	PTSD & SUD = 100% SUD = 100%
Richards et al. (1996)	Australia	Case control	Panic = 26	HC = 14	Panic = 40.5 HC = 38.4	Panic = 53.8% HC = 64.3%
Schmitz et al. (2021)	Germany	Case control	PTSD = 24	HC = 32	PTSD = 36.2 (11.1) HC = 31.1 (9.2)	PTSD = 95.8% HC = 90.6%

Schultchen et al. (2019)	Germany	Longitudinal case control	OCD = 26	HC = 26	OCD = 28.6 (7.2) HC = 26.5 (5.6)	OCD = 46.2% HC = 46.2%
Smith et al. (2021)	Oklahoma, USA	Case control	Anxiety & depression = 221	HC = 53 Substance use = 136	Anxiety & Depression = 36.2 (11.2) Substance use = 33.7 (8.8) HC = 32 (11)	Anxiety & Depression = 72.4% Substance use = 55.9% HC = 47.2%
Teed et al. (2022)	Oklahoma, USA	RCT	GAD = 29	HC = 29	GAD = 26.9 (6.8) HC = 24.4 (5)	GAD = 100% HC = 100%
Verdonk et al. (2024)	Oklahoma, USA	RCT	GAD = 24	HC = 24	GAD = 26.5 HC = 24.3	GAD = 100% HC = 100%
Wölk et al. (2014)	Germany	Case control	Panic = 17	HC = 17	Panic = 41.59 (13.3) HC = 36.5 (12.1)	Panic = 47.1% HC = 47.1%
Yoris et al. (2017)	Buenos Aires, Argentina	Case control	OCD = 15 Panic = 15	HC = 25	OCD = 30.4 Panic = 35.5 HC = 33.4	OCD = 53.3% Panic = 60% HC = 56%

Yoris et al. (2015)	Buenos Aires, Argentina	Case control	Panic attack = 21	HC = 13	Panic attack = 32.3 (10.2) HC = 32.5 (10)	Panic attack = 42.3% HC = 46.1%
Zoellner & Craske (1999)	Los Angeles, USA	RCT	Panic attack = 31	HC = 27	Panic attack = 19 (3.11) HC = 18.6 (1)	Panic attack = 45.2% HC = 51.9%

Note. *Other gender identities were not reported beyond female / male. COPD-PD = Chronic Obstructive Pulmonary Disease-Panic Disorder; COPD-NP = Chronic Obstructive Pulmonary Disease-No Panic; DV = Domestic Violence; ED = Eating Disorder; GAD = Generalised Anxiety Disorder; HC = Healthy Control; OCD = Obsessive-Compulsive Disorder; PTSD = Post-Traumatic Stress Disorder; RCT = Randomised Control Trial; SAD = Social Anxiety Disorder; SD = Standard Deviation; SUD = Substance Use Disorder

Appendix F Quality Assessment for Included Papers

Author(s) and Year	Quality Domain					Global Quality Rating (LS)	Global Quality Rating (JM)	Inter-Rater Agreement
	Selection Bias	Study Design	Data Collection	With-drawal	Analyses			
Andor et al. (2008)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Antony et al. (1995)	Weak	Strong	Strong	Weak	Strong	**Weak**	-	-
Asmundson et al (1993)	Weak	Strong	Moderate	Weak	Strong	**Weak**	-	-
Belanger et al. (2023)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Bogaerts et al. (2022)	Moderate	Strong	Strong	Strong	Strong	**Strong**	-	-
Craske et al. (2001)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Cui et al. (2016)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	**Moderate**	**100%**
Cui et al. (2020)	Weak	Strong	Strong	Weak	Strong	**Weak**	-	-
Demartini et al. (2021)	Moderate	Strong	Strong	Strong	Strong	**Strong**	**Strong**	**100%**
Ehlers & Breuer (1992)	Weak	Strong	Moderate	Weak	Strong	**Weak**	-	-
Eng et al. (2020)	Moderate	Strong	Strong	Strong	Strong	**Strong**	-	-

Eng et al. (2022)	Moderate	Strong	Strong	Strong	Strong	**Strong**	-	-
Eng et al. (2024)	Moderate	Strong	Strong	Moderate	Strong	**Strong**	-	-
Gaebler et al. (2013)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Giardino et al. (2010)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	**Moderate**	**100%**
Ironside et al. (2023)	Moderate	Strong	Strong	Strong	Strong	**Strong**	-	-
Jin et al. (2020)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Kroeze et al. (1996)	Weak	Strong	Strong	Weak	Strong	**Weak**	-	-
Lapidus et al. (2020)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Lee et al. (2024)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Li et al. (2023)	Moderate	Strong	Strong	Strong	Strong	**Strong**	-	-
Li et al. (2020)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	**Moderate**	**100%**
Limmer et al. (2015)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Machorrinho et al. (2022)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	**Moderate**	**100%**
Mussgay et al (1999)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Pang et al. (2019)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-

Poppa et al. (2019)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Richards et al. (1996)	Weak	Strong	Strong	Weak	Strong	**Weak**	**Weak**	**100%**
Schmitz et al. (2021	Weak	Strong	Strong	Weak	Strong	**Weak**	-	-
Schultchen et al. (2019)	Weak	Strong	Strong	Weak	Strong	**Weak**	-	-
Smith et al. (2021)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	-	-
Teed et al. (2022)	Moderate	Strong	Strong	Moderate	Strong	**Strong**	-	-
Verdonk et al. (2024)	Moderate	Strong	Strong	Strong	Strong	**Strong**	-	-
Wölk et al. (2014)	Moderate	Strong	Strong	Weak	Strong	**Moderate**	**Moderate**	**100%**
Yoris et al. (2017)	Weak	Strong	Strong	Weak	Strong	**Weak**	-	-
Yoris et al. (2015)	Weak	Strong	Strong	Weak	Strong	**Weak**	-	-
Zoellner & Craske (1999)	Weak	Strong	Strong	Weak	Strong	**Weak**	-	-

Note. This table presents the component and global quality ratings for each included study, based on the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies. Ratings for each domain were assigned as strong, moderate, or weak. The global rating was derived according to the EPHPP guidance, where two or more 'weak' ratings result in an overall 'weak' score, one 'weak' rating results in a 'moderate' score, and no 'weak' ratings result in a 'strong' score. Withdrawals/drop-outs were rated only for longitudinal studies with follow-up data.

Appendix G University of Southampton Ethical Approval

Approved by Faculty Ethics Committee - ERGO II 89229.A4

University of Southampton

ERGO II – Ethics and Research Governance Online https://www.ergo2.soton.ac.uk

Submission ID: 89229.A4
Submission Title: The relationship between Interoception, Intolerance of Uncertainty, and emotional disorders in a sub clinical sample (Amendment 4)
Submitter Name: Jayne Morriss

Your submission has now been approved by the Faculty Ethics Committee. You can begin your research unless you are still awaiting any other reviews or conditions of your approval.

Appendix H Lab-Task Instructions

00:05 - 00:10 (~ 5 minutes)

- ✓ Briefly explain the procedure to your participant and offer information sheet.

Please say to the participant:

"For this study, you will also be asked to complete some questionnaires, two computer-based tasks, and heartrate/blood pressure readings. The entire session will take around one hour in total."

- ✓ Verify exclusion criteria, **get signature of the consent form.**

00:10 - 00:30 Questionnaires (~ 20 minutes)

Load the questionnaires on E-prime.

Please say to the participant:

''I'd like you to complete a series of questionnaires on the computer using the keyboard. These questionnaires will ask you about your demographics, and your feelings and moods. Please read through the instructions for each questionnaire carefully, as sometimes they are asking you about how you feel in general or how you feel over a specified amount of time (like a week/month). Go with your gut instinct and don't think too much about your answers. It's completely confidential, I can't see your answers so please answer honestly. I will be in the room across the corridor, please let me know when you are done by simply saying 'I'm done'".

□ 1. Demographic Information (age, sex, ethnicity)

□ 2. Intolerance of Uncertainty Scale (IUS-12; Carleton et al., 2007)

□ 3. Trait Anxiety Shortened (STAI-T; Zsido et al, 2020)

□ 4. Generalised Anxiety Disorder Questionnaire (GAD-7; Spitzer et al., 2006)

□ 5. Patient Health Questionnaire (PHQ-9; Kroenke et al, 2001)

□ 6. Obsessive Compulsive Inventory - Revised (OCI-R; Foa et al., 2002)

□ 7. Panic Disorder Severity Scale (PDSS-SR; Shear et al., 1997)

□ 8. Social Interaction Phobia Scale (SIPS; Menatti et al., 2015)

□ 9. Posttraumatic Stress Disorder Checklist for DSM-5 (PCL-5; Weathers et al., 2013)

□ 10. Multidimensional Assessment of Interoceptive Awareness-v2) (MAIA-v2; Mehling et al., 2018)

□ 11. Body Awareness Subscale of the Body Perception Questionnaire-Short Form (BPQ-SF; Cabrera et al., 2018)

□ 12. Interoceptive Accuracy Scale (IAS, Murphy et al., 2020)

□ 13. Anxiety Sensitivity Index (Reiss et al., 1986)

00:30 – 01:00 Cardiac Perception Tasks (~ 30 minutes)

Explain to your participant that they will now be completing two tasks to measure their heartbeat perception. **Use the explanation below to instruct your participant:**

For the cardiac perception tasks, you will be wearing headphones and a pulse oximeter which will record your pulse continuously.

Please wipe the fingers of your non-dominant hand and put the pulse oximeter on your index or middle finger (the fingers might change throughout the tasks in case of signal loss).

With your dominant hand, you will need to provide confidence ratings during the task using pen and paper.

Sit close to the table, resting your elbow on the table. It is very important that you keep your arm and hand very still during the trials to avoid signal loss. Signal loss is common and may well happen on a few occasions throughout the task. We try to reduce the occurrence by asking you to keep your hand still.

- [*Note for experimenters: ask participants if they have cold hands as this can also introduce signal loss. If cold, ask them to rub their hands or offer a warm cup of herbal tea to warm up their hands.*
- *Check that they do not wear nail varnish!*].

While I get the tasks set up, please sit back in your chair and relax a bit. …

We will now begin with the heartbeat counting task and run a couple of practice trials.

Heartbeat Counting Task

- Through the headphones you will hear a voice saying “Start”. After this, please silently count your heartbeat without manually checking your pulse.
- At the end of the trial, the voice will say “Stop”, and you will be asked to report how many heartbeats you counted.
- We then ask you to rate your confidence on the piece of paper by placing a X on the horizontal line after each trial.
- There are 6 short trials for this task.
- (Do two practice trials first – no confidence ratings are required for the practice trials. Do not give your participants feedback on their performance).

Heartbeat Discrimination (Detection) Task

- Through the headphones, you will hear your own heartbeat presented as auditory tones.
- The tones are played either in sync with your own heartbeat, or slightly out of sync.
- Please pay attention to the auditory tones and evaluate whether they are played on or off your own heartbeat.
- At the end of each trial, you will be required to decide whether the tones were presented in or out of sync with your heartbeat.
- We then ask you to rate your confidence on the piece of paper by placing a X on the horizontal line after each trial.
- There are 20 trials in this task, each trial lasting 20 seconds.

- As before, we begin with a couple of practice trials.
    - [*Note for experimenters: use the first two trials of the main task as practice trials and discard these for the data analysis*].

At the end of the tasks, you may show the output file to your participants, letting them know their interoceptive accuracy.

1:00 - 1:05 Physiological Measures (5 minutes)

✓ Measure heartrate and blood pressure

- Heart rate

- Blood pressure

Systole: Diastole:

01:05 – 01:10 End of Experiment (~5 min)

✓ Debrief participants
✓ Thank them for taking part in your study
✓ Payment or Credits
- **If you pay them, get participants to sign the payment sheet.**

Appendix I Confidence Rating Scales

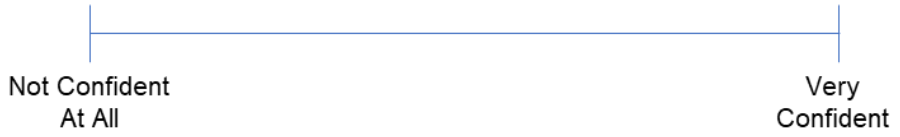
Participant ID: ……

HEARTBEAT COUNTING TASK

Please indicate how confident you are in your decision on a scale of "Not Confident at All" to "Very Confident" in my decision.

TRIAL 1

TRIAL 2



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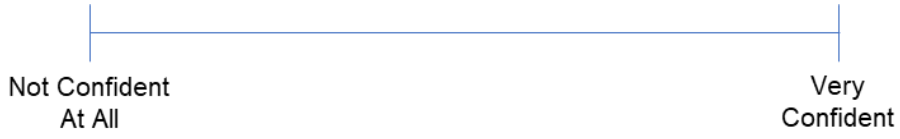

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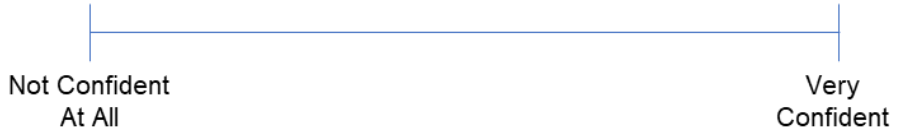
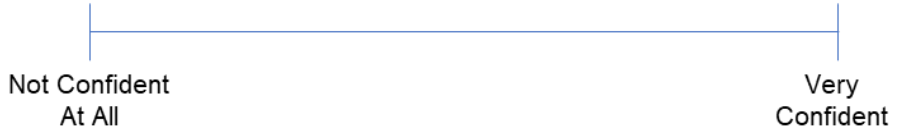


TRIAL 5

TRIAL 6

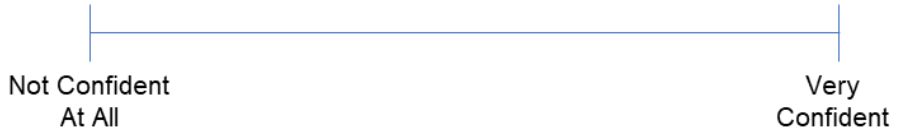


HEARTBEAT DISCRIMINATION TASK

Please indicate how confident you are in your decision on a scale of “Not Confident At All” to “Very Confident” in my decision.

TRIAL 1

TRIAL 2



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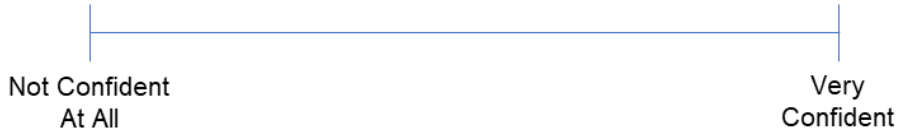

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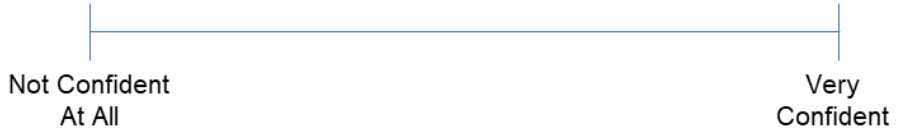

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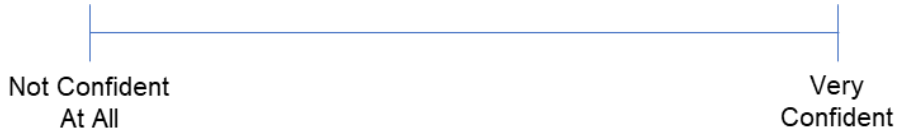

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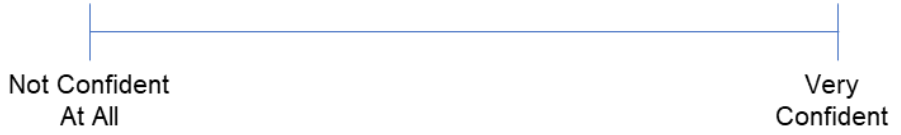
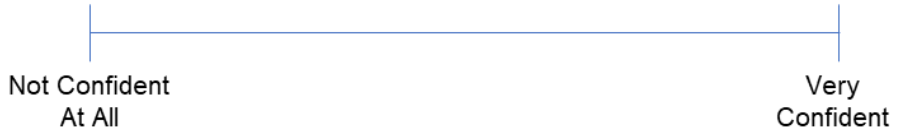


TRIAL 7

TRIAL 8



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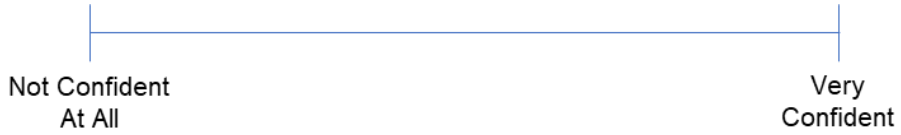

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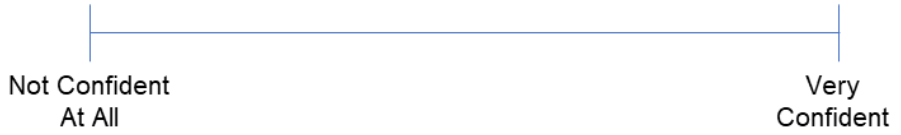

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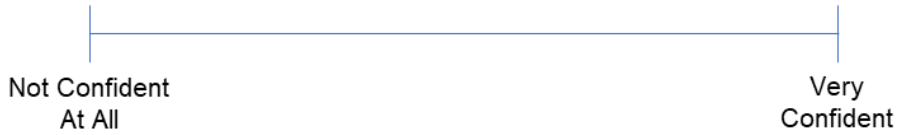
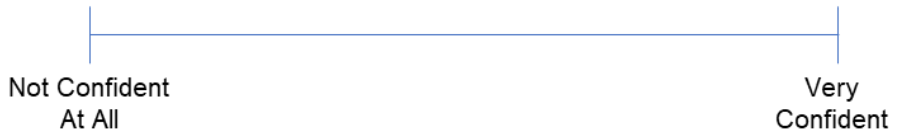


TRIAL 12



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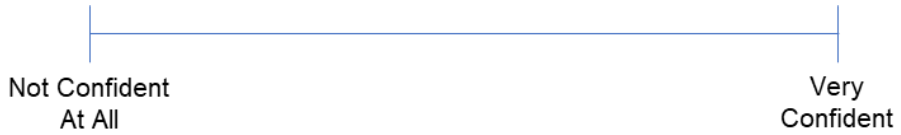

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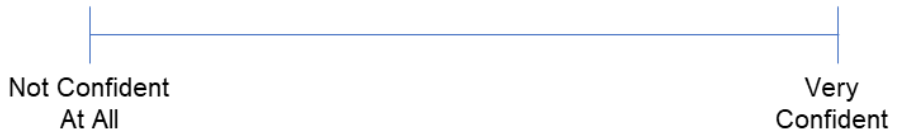

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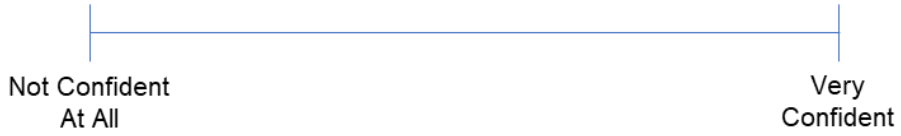

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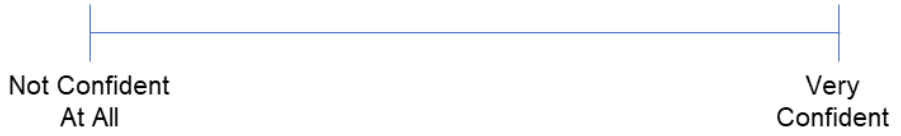

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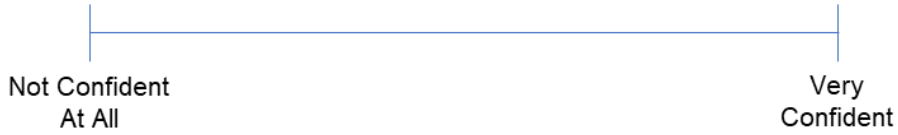

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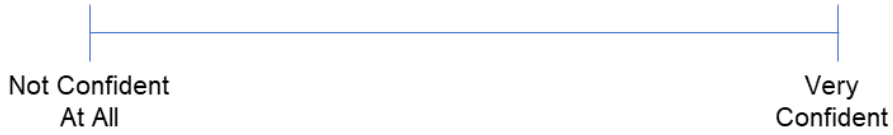

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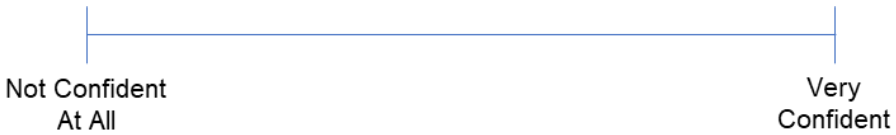
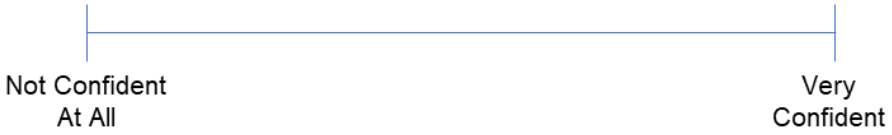


TRIAL 20



Appendix J Participant Information Sheet

J.1 Online Participant Information Sheet

UNIVERSITY OF Southampton

Participant Information Sheet

Study Title: The relationship between Interoception, Intolerance of Uncertainty, and Anxiety-related Disorders in a Non-Clinical Sample.

Researcher: Dr Jayne Morriss, Dr Gaby Pfeifer

Students: Lucy Snell, Isabelle Fortune, Niamh Harding, Caitlin Neville, Rebecca Baughan, Zoe Farrant, Lara Sanders, and Rhys Bartholomew

ERGO number: 89229

You are being invited to take part in the above research study. To help you decide whether you would like to take part or not, it is important that you understand why the research is being done and what it will involve. Please read the information below carefully and ask questions if anything is not clear or you would like more information before you decide to take part in this research. You may like to discuss it with others, but it is up to you to decide whether or not to take part. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

This study was designed to examine how interoception (our ability to detect internal bodily signals such as our heartbeat) is related to experiencing intolerance of uncertainty and emotional disorders. Ultimately, we are hoping that the findings from this study can be used to inform future diagnosis and treatment of mental health disorders.

Why have I been asked to participate?

We are hoping to collect a large pool of participants for this type of research (e.g., over 200 participants).

What will happen to me if I take part?

- You will be asked to fill in some questionnaires relating to demographics (e.g. age, sex, ethnicity), individual differences in negative dispositionality (e.g. Intolerance of Uncertainty, Anxiety Sensitivity Index, Trait Anxiety) and emotional disorders (e.g., obsessive-compulsive disorder, post-traumatic stress disorder, depression). Your interoceptive sensitivity will be assessed with a number of questions relating to the perception of internal bodily sensations (e.g. "I notice my mouth being dry").

Each questionnaire measure will be preceded with detailed explanations and if there are any questions asked of you that you decide you do not want to take part in or answer, please let the researcher know and you can be withdrawn from the study.

Are there any benefits in my taking part?

Participating in this study might help you to reflect, and better understand, the factors contributing to different emotional disorders. Your participation will help improve our current understanding of individual differences in affective processing, and its relevance to mental health disorders.

For psychology students who sign up via SONA, you will gain further understanding as to how research in psychology is conducted. If you are a psychology student at the University of Southampton, you will be granted 2 SONA credits for filling in the questionnaires.

Are there any risks involved?

We foresee few risks from the above procedures. Some participants may find filling out the questionnaires to be boring or tiresome, and there may be some feelings of psychological discomfort associated with sharing information about your personality and the ways that you manage or monitor your emotions. You are free to stop your participation at any time and for any reason during the procedure.

Should you experience any discomfort or distress as a result of participating in this study, please contact the following support services:

- You can call the Samaritans for free 24 hours a day, 7 days a week on 116 123
- Students at University of Southampton can access advice on campus by visiting the wellbeing services on https://sotonac.sharepoint.com/teams/StudentWellbeingSupport
- The organisation 'Mind' provides helpful information around self-care for anxiety, which can be accessed on https://www.mind.org.uk/information-support/types-of-mental-health-problems/anxiety-and-panic-attacks/self-care/

In addition, if you have any remaining questions or feel upset by any emotions experienced during the study, you may contact Dr Jayne Morriss (j.morriss@soton.ac.uk) or Dr Gaby Pfeifer (g.pfeifer@soton.ac.uk).

What data will be collected?

Consent forms along with all other GDPR special category data (e.g., demographics such as ethnicity, sexual orientation, etc), and self-report data will be anonymised via an ID number

and will be stored on a password-protected University of Southampton server on OneDrive. At the end of the project, summary statistics of the GDPR special category data (for representation purposes only), and self-report anonymised data will be reported in a scientific article. Furthermore, at the end of the project, only the self-report anonymised data will be uploaded to an open access data repository. These types of anonymised data will only be shared with other researchers when written informed consent has been provided.

Will my participation be confidential?

Your participation and the information we collect about you during the course of the research will be kept strictly confidential. Participants will be referred to using a consistent ID number on all GDPR special category data and self-report data generated to allow confidentiality to be maintained.

Only members of the research team and responsible members of the University of Southampton may be given access to data about you for monitoring purposes and/or to carry out an audit of the study to ensure that the research is complying with applicable regulations. Individuals from regulatory authorities (people who check that we are carrying out the study correctly) may require access to your data. All of these people have a duty to keep your information, as a research participant, strictly confidential.

Do I have to take part?

No, it is entirely up to you to decide whether or not to take part. If you decide you want to take part, you will need to sign a consent form to show you have agreed to take part.

What happens if I change my mind?

You have the right to change your mind and withdraw at any time before, during and after filling in the questionnaires (up until the 26th of April 2023) without giving a reason and without your participant rights being affected.

You can have your data removed after filling in the questionnaires (until the 26th of April 2023). However, once your data has been anonymised, we cannot remove these data as there is no way of knowing whose data belongs to who.

What will happen to the results of the research?

Your personal details will remain strictly confidential. Research findings made available in any reports or publications will not include information that can directly identify you without your specific consent. At the end of the project, the anonymised data will be uploaded to an open access repository such as the Open Science Framework (https://osf.io/).

Data sharing is important for assessing the reliability and replicability of the study design, as well as for combining data for future meta- and mega- analyses. If you would like to discuss this further or file a complaint, please contact the University of Southampton Research Integrity and Governance Manager (023 8059 5058, rgoinfo@soton.ac.uk).

Where can I get more information?

If you would like further information, you may contact the research leads, Dr Jayne Morriss (j.morriss@soton.ac.uk) or Dr Gaby Pfeifer (g.pfeifer@soton.ac.uk).

What happens if there is a problem?

If you have a concern about any aspect of this study, you should speak to the research leads, Dr Jayne Morriss (j.morriss@soton.ac.uk) or Dr Gaby Pfeifer (g.pfeifer@soton.ac.uk), who will do their best to answer your questions.

If you remain unhappy or have a complaint about any aspect of this study, please contact the University of Southampton Research Integrity and Governance Manager (023 8059 5058, rgoinfo@soton.ac.uk).

Data Protection Privacy Notice

The University of Southampton conducts research to the highest standards of research integrity. As a publicly-funded organisation, the University has to ensure that it is in the public interest when we use personally-identifiable information about people who have agreed to take part in research. This means that when you agree to take part in a research study, we will use information about you in the ways needed, and for the purposes specified, to conduct and complete the research project. Under data protection law, 'Personal data' means any information that relates to and is capable of identifying a living individual. The University's data protection policy governing the use of personal data by the University can be found on its website (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page).

This Participant Information Sheet tells you what data will be collected for this project and whether this includes any personal data. Please ask the research team if you have any questions or are unclear what data is being collected about you. Our privacy notice for research participants provides more information on how the University of Southampton collects and uses your personal data when you take part in one of our research projects and can be found at http://www.southampton.ac.uk/assets/sharepoint/intranet/ls/Public/Research%20and%20Integrity%20Privacy%20Notice/Privacy%20Notice%20for%20Research%20Participants.pdf

Any personal data we collect in this study will be used only for the purposes of carrying out our research and will be handled according to the University's policies in line with data protection law. If any personal data is used from which you can be identified directly, it will not be disclosed to anyone else without your consent unless the University of Southampton is required by law to disclose it.

Data protection law requires us to have a valid legal reason ('lawful basis') to process and use your Personal data. The lawful basis for processing personal information in this research study is for the performance of a task carried out in the public interest. Personal data collected for research will not be used for any other purpose.

For the purposes of data protection law, the University of Southampton is the 'Data Controller' for this study, which means that we are responsible for looking after your information and using it properly. Sensitive and identifying information will be destroyed as soon as possible after the completion of the research, and only the anonymised data will be stored long-term.

Thank you

J.2 Lab-based Participant Information Sheet

UNIVERSITY OF Southampton

Participant Information Sheet

Study Title: The relationship between Interoception, Intolerance of Uncertainty, and Anxiety-related Disorders in a Non-Clinical Sample.

Researcher: Dr Jayne Morriss, Dr Gaby Pfeifer

Students: Lucy Snell, Katie Bannister, Rachel Runton, Yeetung Hong, Amber Davies

ERGO number: 89229

You are being invited to take part in the above research study. To help you decide whether you would like to take part or not, it is important that you understand why the research is being done and what it will involve. Please read the information below carefully and ask questions if anything is not clear or you would like more information before you decide to take part in this research. You may like to discuss it with others, but it is up to you to decide whether or not to take part. If you are happy to participate you will be asked to sign a consent form.

What is the research about?
The study is being organised by Drs Jayne Morriss and Gaby Pfeifer, two lecturers at the University of Southampton, and conducted by the above-named students. This study was designed to examine how interoception (our ability to detect internal bodily signals such as our heartbeat) is related to experiencing intolerance of uncertainty and emotional disorders. Ultimately, we are hoping that the findings from this study can be used to inform future diagnosis and treatment of mental health disorders.

Why have I been asked to participate?
We are hoping to collect a large pool of participants for this type of research (e.g., over 200 participants).

What will happen to me if I take part?

- You will be asked to fill in some questionnaires relating to demographics (e.g. age, sex, ethnicity), individual differences in negative dispositionality (e.g. Intolerance of Uncertainty, Anxiety Sensitivity Index, Trait Anxiety) and emotional disorders (e.g., obsessive-compulsive disorder, post-traumatic stress disorder, depression). Completion of the questionnaires is expected to take approximately 20 minutes.

- Your interoceptive sensitivity will be assessed in the laboratory, using a test where you will focus on your heartbeat. This test includes two short tasks, each lasting around 15 minutes. First, in the *Heartbeat Counting Task,* you will be wearing a pulse oximeter on your index finger which will record your pulse

continuously. While your pulse is being recorded, you will be asked to silently count your heartbeat without manually checking your pulse. There are six trials in this task and at the end of each trial, you will be asked to report how many heartbeats you counted. The second, *Heartbeat Discrimination Task,* will involve you listening to your own heartbeat whilst wearing headphones. The headphones will present auditory tones which will sometimes match to your heartbeat and on other times be slightly out of sync with your heartbeat. After each trial, you will be required to decide whether the tones presented were in or out of sync with your heartbeat. There are 20 trials in this task.

You will receive detailed explanations and if there are any questions or tasks asked of you that you decide you do not want to take part in or answer, please let the researcher know and you can be withdrawn from the study.

Are there any benefits in my taking part?
Participating in this study might help you to reflect, and better understand, the factors contributing to different emotional disorders. Your participation will help improve our current understanding of individual differences in affective processing, and its relevance to mental health disorders. For psychology students who sign up via SONA, you will gain further understanding as to how research in psychology is conducted.

To recompense you for your time (50 mins) and effort in participating, we shall give you 10 SONA credits if you take part in the lab study.

Are there any risks involved?
We foresee few risks from the above procedures. Some participants may find filling out the questionnaires to be boring or tiresome, and there may be some feelings of psychological discomfort associated with sharing information about your personality and the ways that you manage or monitor your emotions. Also, some participants may find the repeated trials of the heartbeat perception tasks monotonous. You are free to stop your participation at any time and for any reason during the procedure.
Should you experience any discomfort or distress as a result of participating in this study, please contact the following support services:

- You can call the Samaritans for free 24 hours a day, 7 days a week on 116 123
- Students at University of Southampton can access advice on campus by visiting the wellbeing services on https://sotonac.sharepoint.com/teams/StudentWellbeingSupport
- The organisation 'Mind' provides helpful information around self-care for anxiety, which can be accessed on https://www.mind.org.uk/information-support/types-of-mental-health-problems/anxiety-and-panic-attacks/self-care/

In addition, if you have any remaining questions or feel upset by any emotions experienced during the study, you may contact Dr Jayne Morriss (j.morriss@soton.ac.uk) or Dr Gaby Pfeifer (g.pfeifer@soton.ac.uk).

What data will be collected?
Consent forms with identifying information (e.g. participant names) will be stored in a locked filing cabinet (stored in lead researchers office). All other GDPR special category data (e.g., demographics such as ethnicity, sexual orientation, etc), self-report and psychophysiology data will be anonymised via an ID number and will be stored on a password-protected University of Southampton server on OneDrive. At the end of the project, summary statistics of the GDPR special category data (for representation purposes only), self-report, and

psychophysiology anonymised data will be reported in a scientific article. Furthermore, at the end of the project, only the self-report and psychophysiology anonymised data will be uploaded to an open access data repository. These types of anonymised data will only be shared with other researchers when written informed consent has been provided.

Will my participation be confidential?
Your participation and the information we collect about you during the course of the research will be kept strictly confidential. Participants will be referred to using a consistent ID number on all GDPR special category data, self-report, and psychophysiology data generated to allow confidentiality to be maintained.

Only members of the research team and responsible members of the University of Southampton may be given access to data about you for monitoring purposes and/or to carry out an audit of the study to ensure that the research is complying with applicable regulations. Individuals from regulatory authorities (people who check that we are carrying out the study correctly) may require access to your data. All of these people have a duty to keep your information, as a research participant, strictly confidential.

Do I have to take part?
No, it is entirely up to you to decide whether or not to take part. If you decide you want to take part, you will need to sign a consent form to show you have agreed to take part.

What happens if I change my mind?
You have the right to change your mind and withdraw at any time before, during and after the experiment (up until the 26th of April 2024) without giving a reason and without your participant rights being affected.

You can have your data removed during the experiment and after the experiment (until the 26th of April 2024). However, once your data has been anonymised, we cannot remove these data as there is no way of knowing whose data belongs to who.

What will happen to the results of the research?
Your personal details will remain strictly confidential. Research findings made available in any reports or publications will not include information that can directly identify you without your specific consent. At the end of the project, the anonymised data will be uploaded to an open access repository such as the Open Science Framework (https://osf.io/).

Data sharing is important for assessing the reliability and replicability of the study design, as well as for combining data for future meta- and mega- analyses. If you would like to discuss this further or file a complaint, please contact the University of Southampton Research Integrity and Governance Manager (023 8059 5058, rgoinfo@soton.ac.uk).

Where can I get more information?
If you would like further information, you may contact the research leads, Dr Jayne Morriss (j.morriss@soton.ac.uk) or Dr Gaby Pfeifer (g.pfeifer@soton.ac.uk).

What happens if there is a problem?
If you have a concern about any aspect of this study, you should speak to the research leads, Dr Jayne Morriss (j.morriss@soton.ac.uk) or Dr Gaby Pfeifer (g.pfeifer@soton.ac.uk), who will do their best to answer your questions.
If you remain unhappy or have a complaint about any aspect of this study, please contact the University of Southampton Research Integrity and Governance Manager (023 8059 5058, rgoinfo@soton.ac.uk).

Data Protection Privacy Notice
The University of Southampton conducts research to the highest standards of research integrity. As a publicly-funded organisation, the University has to ensure that it is in the public interest when we use personally-identifiable information about people who have agreed to take part in research. This means that when you agree to take part in a research

study, we will use information about you in the ways needed, and for the purposes specified, to conduct and complete the research project. Under data protection law, 'Personal data' means any information that relates to and is capable of identifying a living individual. The University's data protection policy governing the use of personal data by the University can be found on its website (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page).

This Participant Information Sheet tells you what data will be collected for this project and whether this includes any personal data. Please ask the research team if you have any questions or are unclear what data is being collected about you.

Our privacy notice for research participants provides more information on how the University of Southampton collects and uses your personal data when you take part in one of our research projects and can be found at http://www.southampton.ac.uk/assets/sharepoint/intranet/ls/Public/Research%20and%20Integrity%20Privacy%20Notice/Privacy%20Notice%20for%20Research%20Participants.pdf

Any personal data we collect in this study will be used only for the purposes of carrying out our research and will be handled according to the University's policies in line with data protection law. If any personal data is used from which you can be identified directly, it will not be disclosed to anyone else without your consent unless the University of Southampton is required by law to disclose it.

Data protection law requires us to have a valid legal reason ('lawful basis') to process and use your Personal data. The lawful basis for processing personal information in this research study is for the performance of a task carried out in the public interest. Personal data collected for research will not be used for any other purpose.

For the purposes of data protection law, the University of Southampton is the 'Data Controller' for this study, which means that we are responsible for looking after your information and using it properly. Sensitive and identifying information will be destroyed as soon as possible after the completion of the research, and only the anonymised data will be stored long-term.

Thank you

Appendix K Consent Form

UNIVERSITY OF Southampton

CONSENT FORM

Study title: The Relationship between Interoception, Intolerance of Uncertainty, and Anxiety-related Disorders in a Non-Clinical Sample.

Researcher name: Dr Jayne Morriss, Dr Gaby Pfeifer, Lucy Snell, Katie Bannister, Rachel Runton, Yeetung Hong, Amber Davies

ERGO number: 89229

Please initial the box(es) if you agree with the statement(s):

I have read and understood the information sheet (08/10/2024 – version 1.3 of participant information sheet) and have had the opportunity to ask questions about the study.	
I agree to take part in this research project and agree for my data to be used for the purpose of this study.	
I understand that the data collected from me in this study will be preserved and made available in anonymised form, so that they can be consulted and re-used by others.	
I give permission for any of the GDPR special category data (e.g. ethnicity, sexual orientation, etc.) that I choose to provide to be stored and held by Drs Jayne Morriss and Gaby Pfeifer at the University of Southampton as described in the participant information sheet so it can be used for summary statistics (representation purposes only) in the final scientific report.	
I understand my participation is voluntary and I may withdraw up until the 26th April 2025 for any reason without my participation rights being affected.	
I understand that if I withdraw from the study that it may not be possible to remove the data once my personal information is no longer linked to the data.	

Name of participant (print name)……

Signature of participant……

Date……

Name of researcher (print name)……

Signature of researcher ……

Date……

Appendix L Debrief Forms

L.1 Online Participant Debrief Form

Debriefing Form

Study Title: The Relationship between Interoception, Intolerance of Uncertainty, and Anxiety-related Disorders in a Non-Clinical Sample.

Ethics/ERGO number: 89229
Researcher(s): Drs Jayne Morriss and Gaby Pfeifer
Students: Lucy Snell, Katie Banister, Rachel Runton, Yeetung Hong, Amber Davies

University emails: j.morriss@soton.ac.uk ; g.pfeifer@soton.ac.uk

Version and date: v1.0; 27/09/2023
Thank you for taking part in our research project. Your contribution is very valuable and greatly appreciated.

Purpose of the study
The aim of this research was to examine how interoception is related to experiencing intolerance of uncertainity and emotional disorders. Interoception refers to the ability to detect internal bodily signals, such as heartrate, breathing and gastrointestinal functions. Interoception is thought to underpin our subjective experience of emotions. For example, increased interoceptive sensitivity to bodily signals correlates with heightened processing of fear (Pfeifer, Garfinkel, et al., 2017) and threat (Garfinkel & Critchley, 2016). Moreover, a body of evidence supports the direct link between interoception and emotional disorders, such as anxiety and depression (Paulus & Stein, 2010).

On the other hand, Intolerance of Uncertainty (IU) refers to a tendency to find uncertainty distressing, often correlating with heightened threat perception (Morriss, Bell, et al., 2022) and difficulty in new safety learning (Morriss, Wake, et al., 2021). IU is generally recognized as a transdiagnostic risk factor for conditions related to anxiety. Despite the shared emotional behaviours associated with interoception and IU, the relationship between interoceptive sensitivity, IU and specific emotional disorders (e.g. generalised anxiety disorder, obsessive-compulsive disorder, post-traumatic stress disorder, and depression) remains unclear. Your data will help our understanding of how IU and interoception could be used as possible treatment targets in transdiagnostic or specific disorder treatments. The results might open new treatment avenues for emotional disorders.

Deception
No deception was used in this study.

Confidentiality
Results of this study will not include your name or any other identifying characteristics.

Study results

When we have the results of this research, a summary in article form will be uploaded to the lead researchers open science framework profile, which is freely accessible to anyone (https://osf.io/9sgh7/). Please do not hesitate to contact us if you have any further questions (research leads: Dr Jayne Morriss (j.morriss@soton.ac.uk) and Dr Gaby Pfeifer (g.pfeifer@soton.ac.uk).

Further support
If taking part in this study has caused you discomfort or distress, you can contact the following organisations for support:

- **Mind (UK-based):** Helpful information around self-care for anxiety is available at: https://www.mind.org.uk/information-support/types-of-mental-health-problems/anxiety-and-panic-attacks/self-care/
- **Samaritans (UK-based):** Free, confidential support available 24/7 at **116 123** (UK & ROI). **For international access,** see: https://www.samaritans.org/how-we-can-help/contact-samaritan/find-your-local-branch/
- **International Helplines Directory:** Befrienders Worldwide provides a directory of international hotlines for emotional support: https://findahelpline.com
- **University of Southampton students:** You can also access advice on campus via the Student Wellbeing Service: https://sotonac.sharepoint.com/teams/StudentWellbeingSupport

Further reading
If you would like to learn more about this area of research, you can refer to the following resources:

Morriss, J., Wake., Elizabeth, C., & van Reekum, C. M. (2021). I Doubt It Is Safe: A Meta-analysis of Self-reported Intolerance of Uncertainty and Threat Extinction Training. Biological psychiatry global open science, 1(3), 171-179. https://doi.org/10.1016/j.bpsgos.2021.05.011

Pfeifer, G., Garfinkel, S. N., Gould van Praag, C. D., Sahota, K., Betka, S., & Critchley, H. D. (2017). Feedback from the heart: Emotional learning and memory is controlled by cardiac cycle, interoceptive accuracy and personality. Biological psychology, 126, 19-29. https://doi.org/10.1016/j.biopsycho.2017.04.001

Further information
If you have any concerns or questions about this study, please contact the research leads, Dr Jayne Morris at j.morriss@soton.ac.uk or Dr Gaby Pfeifer at g.pfeifer@soton.ac.uk who will do their best to help.

If you remain unhappy or would like to make a formal complaint, please contact the Head of Research Integrity and Governance, University of Southampton, by emailing: rgoinfo@soton.ac.uk, or calling + 44 2380 595058. Please quote the Ethics/ERGO number which can be found at the top of this form. Please note that if you participated in an anonymous survey, by making a complaint, you might be no longer anonymous.

Thank you again for your participation in this research.

L.2 Lab-based Participant Debrief Form

UNIVERSITY OF Southampton

Debriefing Form

Study Title: The Relationship between Interoception, Intolerance of Uncertainty, and Anxiety-related Disorders in a Non-Clinical Sample.

Ethics/ERGO number: 89229
Researcher(s): Drs Jayne Morriss and Gaby Pfeifer
Students: Lucy Snell, Katie Banister, Rachel Runton, Yeetung Hong, Amber Davies

University emails: j.morriss@soton.ac.uk ; g.pfeifer@soton.ac.uk ; l.snell@soton.ac.uk

Version and date: v1.1; 08/10/2024

Thank you for taking part in our research project. Your contribution is very valuable and greatly appreciated.

Purpose of the study
The aim of this research was to examine how interoception is related to experiencing intolerance of uncertainty and emotional disorders.

Interoception refers to the ability to detect internal bodily signals, such as heartrate, breathing and gastrointestinal functions. Interoception is thought to underpin our subjective experience of emotions. For example, increased interoceptive sensitivity to bodily signals correlates with heightened processing of fear (Pfeifer, Garfinkel, et al., 2017) and threat (Garfinkel & Critchley, 2016). Moreover, a body of evidence supports the direct link between interoception and emotional disorders, such as anxiety and depression (Paulus & Stein, 2010).

On the other hand, Intolerance of Uncertainty (IU) refers to a tendency to find uncertainty distressing, often correlating with heightened threat perception (Morriss, Bell, et al., 2022) and difficulty in new safety learning (Morriss, Wake, et al., 2021). IU is generally recognized as a transdiagnostic risk factor for conditions related to anxiety.

Despite the shared emotional behaviours associated with interoception and IU, the relationship between interoceptive sensitivity, IU and specific emotional disorders (e.g. generalised anxiety disorder, obsessive-compulsive disorder, post-traumatic stress disorder, and depression) remains unclear. Your data will help our understanding of how IU and interoception could be used as possible treatment targets in transdiagnostic or specific disorder treatments. The results might open new treatment avenues for emotional disorders.

Deception
No deception was used in this study.

Confidentiality
Results of this study will not include your name or any other identifying characteristics.

Study results
When we have the results of this research, a summary in article form will be uploaded to the lead researchers open science framework profile, which is freely accessible to anyone

(https://osf.io/9sgh7/). Please do not hesitate to contact us if you have any further questions (research leads: Dr Jayne Morriss (j.morriss@soton.ac.uk) and Dr Gaby Pfeifer (g.pfeifer@soton.ac.uk).

Further support
If taking part in this study has caused you discomfort or distress, you can contact the following organisations for support:

- The organisation 'Mind' provides helpful information around self-care for anxiety, which can be accessed on https://www.mind.org.uk/information-support/types-of-mental-health-problems/anxiety-and-panic-attacks/self-care/
- You can call the Samaritans for free 24 hours a day, 7 days a week on 116 123
- Students at University of Southampton can access advice on campus by visiting the wellbeing services on https://sotonac.sharepoint.com/teams/StudentWellbeingSupport

Further reading
If you would like to learn more about this area of research, you can refer to the following resources:

Morriss, J., Wake, S., Elizabeth, C., & van Reekum, C. M. (2021). I Doubt It Is Safe: A Meta-analysis of Self-reported Intolerance of Uncertainty and Threat Extinction Training. *Biological psychiatry global open science*, *1*(3), 171–179. https://doi.org/10.1016/j.bpsgos.2021.05.011

Pfeifer, G., Garfinkel, S. N., Gould van Praag, C. D., Sahota, K., Betka, S., & Critchley, H. D. (2017). Feedback from the heart: Emotional learning and memory is controlled by cardiac cycle, interoceptive accuracy and personality. *Biological psychology*, *126*, 19–29. https://doi.org/10.1016/j.biopsycho.2017.04.001

Further information
If you have any concerns or questions about this study, please contact the research leads, Dr Jayne Morris at j.morriss@soton.ac.uk or Dr Gaby Pfeifer at g.pfeifer@soton.ac.uk who will do their best to help.

If you remain unhappy or would like to make a formal complaint, please contact the Head of Research Integrity and Governance, University of Southampton, by emailing: rgoinfo@soton.ac.uk, or calling: + 44 2380 595058. Please quote the Ethics/ERGO number which can be found at the top of this form. Please note that if you participated in an anonymous survey, by making a complaint, you might be no longer anonymous.

Thank you again for your participation in this research.

Appendix M Non-Parametric Equivalent Correlation Tables

M.1 Non-Parametric Correlation Matrix: Trait & Interoception Questionnaires

Questionnaire / Subscale	1	2	3	4	5	6	7	8	9	10	11	12	13
14. ASI	--												
15. IUS	.49**	--											
16. STAI-T	.55**	.66**	--										
17. BPQ	.31**	.11	.16**	--									
18. IAS	-.12*	-.16**	-.13*	.05	--								
19. MAIA Noticing	.26**	.16**	.20**	.34**	.28**	--							
20. MAIA Not Distracting	-.25**	-.21**	-.26**	-.15**	.10	-.24**	--						
21. MAIA Not Worrying	-.61**	-.39**	-.44**	-.15*	.15*	-.11*	.07	--					
22. MAIA Attention Reg.	-.08	-.12*	-.05	.24**	.27**	.44**	-.10	.12*	--				
23. MAIA Emotional Awa.	.11*	.04	.11	.27**	.25**	.56**	-.20**	-.06	.52**	--			
24. MAIA Self-Regulation	-.19**	-.18**	-.24**	.09	.23**	.30**	.03	.15**	.63**	.54**	--		
25. MAIA Body Listening	.06	-.06	-.08	.16**	.24**	.42**	.00	-.02	.496**	.54**	.61**	--	
26. MAIA Trusting	-.17**	-.25**	-.25**	.06	.30**	.24**	.01	.13*	.56**	.48**	.59**	.52**	--

Note. * = $p < .05$, ** = $p < .01$. Two-tailed. ASI = Anxiety Sensitivity Index; BPQ = Body Perception Questionnaire; IAS = Interoceptive Accuracy Scale; IUS = Intolerance of Uncertainty Scale; MAIA = Multidimensional Assessment of Interoceptive Awareness; STAI-T = State Trait Anxiety Inventory – Trait.

M.2 Non-Parametric Correlation Matrix: Symptom & Interoception Questionnaires

Questionnaire / Subscales	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. GAD	--															
2. OCI	.62**	--														
3. PCL	.75**	.65**	--													
4. PDSS	.59**	.55**	.64**	--												
5. PHQ	.75**	.56**	.77**	.53**	--											
6. SIPS	.51**	.54**	.58**	.47**	.48**	--										
7. BPQ	.16**	.22**	.20**	.23**	.17**	.29**	--									
8. IAS	-.15*	-.22**	-.24**	-.14*	-.19**	-.22**	.05	--								
9. MAIA Noticing	.21**	.25**	.21**	.25**	.15**	.20**	.34**	.28**	--							
10. MAIA Not Distracting	-.25**	-.30**	-.38**	-.26**	-.29**	-.25**	-.15**	.10	-.24**	--						
11. MAIA Not Worrying	-.37**	-.37**	-.34**	-.28**	-.23**	-.36**	-.15*	.15*	-.11*	.07	--					
12. MAIA Attention Reg.	-.09	.05	-.08	-.06	-.13*	-.07	.24**	.27**	.44**	-.10	.12*	--				
13. MAIA Emotional Awa.	.10	.12*	.10	.12*	-.05	.04	.27**	.25**	.56**	-.20**	-.06	.52**	--			
14. MAIA Self-Regulation	-.20**	-.06	-.17**	-.09	-.27**	-.13*	.09	.23**	.30**	.03	.15**	.63**	.54**	--		
15. MAIA Body Listening	-.05	.06	-.03	.10	-.14*	.03	.16**	.24**	.42**	.00	-.02	.50**	.54**	.61**	--	
16. MAIA Trusting	-.26**	-.14*	-.24**	-.13*	-.28**	-.23**	.06	.30**	.24**	.01	.13*	.56**	.48**	.59**	.52**	--

Note. * = $p < .05$, ** = $p < .01$. Two-tailed. BPQ = Body Perception Questionnaire; GAD = Generalised Anxiety Disorder; IAS = Interoceptive Accuracy Scale; MAIA = Multidimensional Assessment of Interoceptive Awareness; OCI = Obsessive-Compulsive Inventory; PDDS-SR = Panic Disorder Severity Scale – Self Report; PCL = Post-Traumatic Stress Disorder Checklist; PHQ = Patient Health Questionnaire; SIPS = Social Interaction Phobia Scale.

M.3 Non-Parametric Correlation Matrix: Trait Questionnaire & Heartbeat Task Performance

Questionnaire / Task	1	2	3	4	5	6	7	8	9
1. ASI	--								
2. IUS	.49**	--							
3. STAI-T	.55**	.66**	--						
4. HBC Accuracy	-.02	-.09	-.02	--					
5. HBC Confidence	-.06	-.11	-.22*	.23*	--				
6. HBC Insight	-.05	.18	.17	.10	-.05	--			
7. HBD Accuracy	.15	-.03	-.07	.02	-.02	.06	--		
8. HBD Confidence	-.16	-.12	-.12	.13	.53**	-.10	-.05	--	
9. HBD Insight	.01	-.06	.10	.04	-.08	.09	-.04	-.07	--

Note. * = $p < .05$, ** = $p < .01$. Two-tailed. ASI = Anxiety Sensitivity Index; HBC = Heartbeat Counting; HBD = Heartbeat Detection; IUS = Intolerance of Uncertainty Scale; STAI-T = State-Trait Anxiety Inventory – Trait.

M.4 Non-Parametric Correlation Matrix: Symptom Questionnaires & Heartbeat Task Performance

Questionnaire / Task	1	2	3	4	5	6	7	8	9	10	11	12
1. GAD	--											
2. OCI	.62**	--										
3. PCL	.75**	.65**	--									
4. PDSS-SR	.59**	.55**	.64**	--								
5. PHQ	.75**	.56**	.77**	.53**	--							
6. SIPS	.51**	.54**	.58**	.47**	.48**	--						
7. HBC Accuracy	.11	-.04	.09	.15	.00	-.09	--					
8. HBC Confidence	-.14	-.06	-.10	-.03	-.18	-.03	.23*	--				
9. HBC Insight	.00	.06	-.02	-.07	.03	-.14	.10	-.05	--			
10. HBD Accuracy	-.01	-.07	.05	.03	-.03	.10	.02	-.02	.06	--		
11. HBD Confidence	-.13	-.07	-.06	-.11	-.15	-.07	.13	.53**	-.10	-.05	--	
12. HBD Insight	.01	-.03	.04	.14	.01	-.12	.04	-.08	.09	-.04	-.07	--

Note. * = $p < .05$, ** = $p < .01$. Two-tailed. GAD = Generalised Anxiety Disorder; HBC = Heartbeat Counting; HBD = Heartbeat Detection; OCI = Obsessive-Compulsive Inventory; PCL = Post-Traumatic Stress Disorder Checklist; PDDS-SR = Panic Disorder Severity Scale – Self Report; PHQ = Patient Health Questionnaire; SIPS = Social Interaction Phobia Scale.

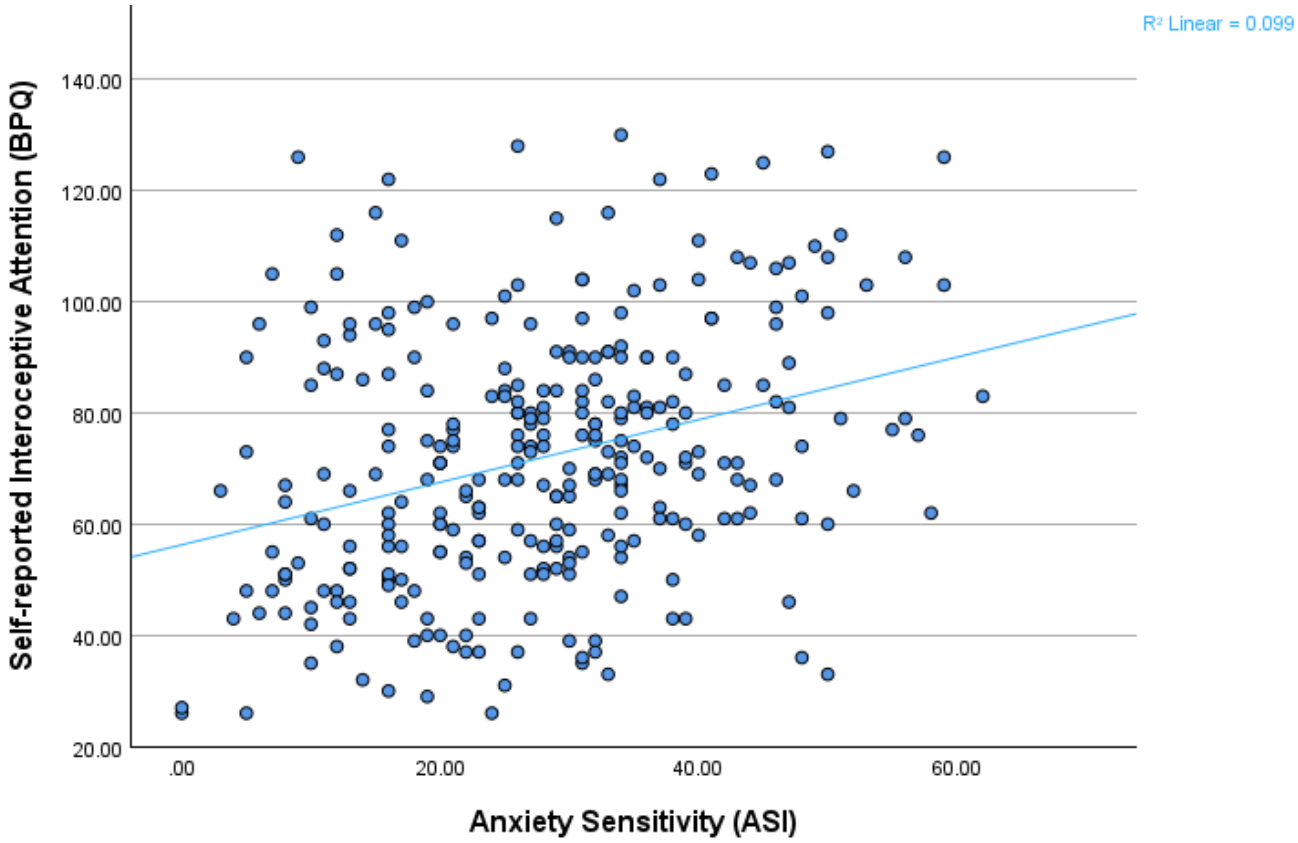
M.5 Non-Parametric Correlation Matrix: Interoception Questionnaires & Heartbeat Task Performance

Questionnaire / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. BPQ	--															
2. IAS	.05	--														
3. MAIA Noticing	.34**	.28**	--													
4. MAIA Not Distracting	-.15**	.10	-.24**	--												
5. MAIA Not Worrying	-.15*	.15*	-.11*	.07	--											
6. MAIA Attention Reg.	.24**	.27**	.44**	-.10	.12*	--										
7. MAIA Emotional Awa.	.27**	.25**	.56**	-.20**	-.06	.52**	--									
8. MAIA Self-Regulation	.09	.23**	.30**	.03	.15**	.63**	.54**	--								
9. MAIA Body Listening	.16**	.24**	.42**	.00	-.02	.50**	.54**	.61**	--							
10. MAIA Trusting	.06	.30**	.24**	.01	.13*	.56**	.48**	.59**	.52**	--						
11. HBC Accuracy	.09	.13	.02	-.02	.11	.09	.12	.17	.02	-.01	--					
12. HBC Confidence	.00	.19	.24*	.01	.19	.29**	.22*	.24*	.20*	.26**	.23*	--				
13. HBC Awareness	-.14	-.10	-.03	-.11	.02	.00	.01	.02	-.22*	-.11	.10	-.05	--			
14. HBD Accuracy	-.03	-.05	-.07	-.07	.05	-.01	-.07	.04	-.03	.00	.02	-.02	.06	--		
15. HBD Confidence	-.05	.23*	.17	.14	.21*	.07	.21*	.14	.17	.12	.13	.53**	-.10	-.05	--	
16. HBD Awareness	.07	-.01	.11	-.04	-.07	.02	-.03	-.10	.06	-.05	.04	-.08	.09	-.04	-.07	--

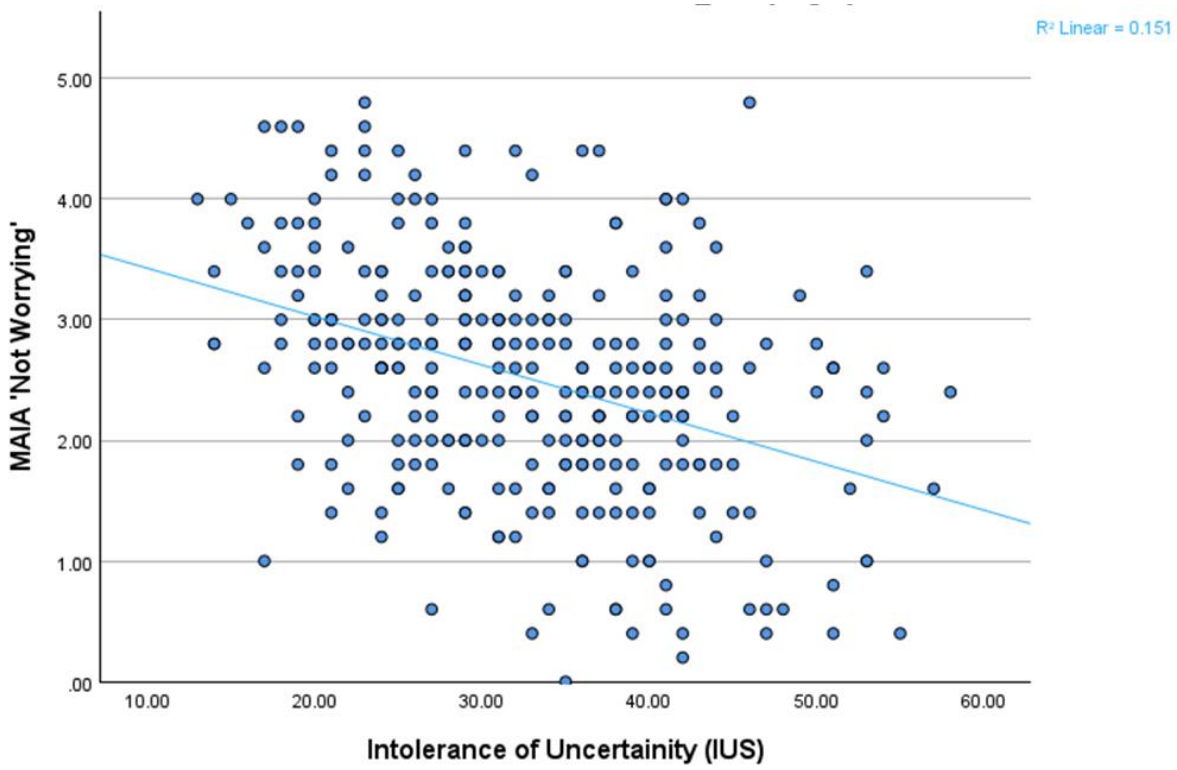
Note. * = $p < .05$, ** = $p < .01$. Two-tailed. BPQ = Body Perception Questionnaire; HBC = Heartbeat Counting; HBD = Heartbeat Detection; IAS = Interoceptive Accuracy Scale; MAIA = Multidimensional Assessment of Interoceptive Awareness.

Appendix N Scatterplots of Key Relationships

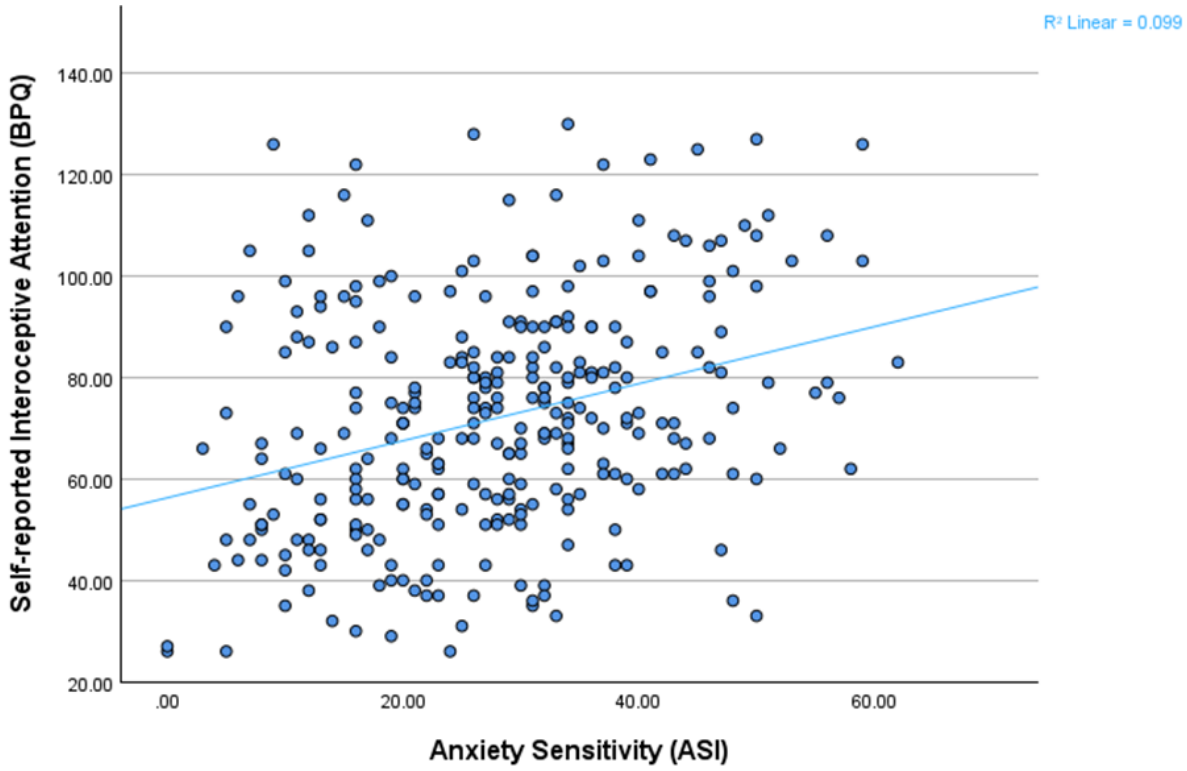
N.1 Scatterplot of Anxiety Sensitivity & Self-reported Interoceptive Attention



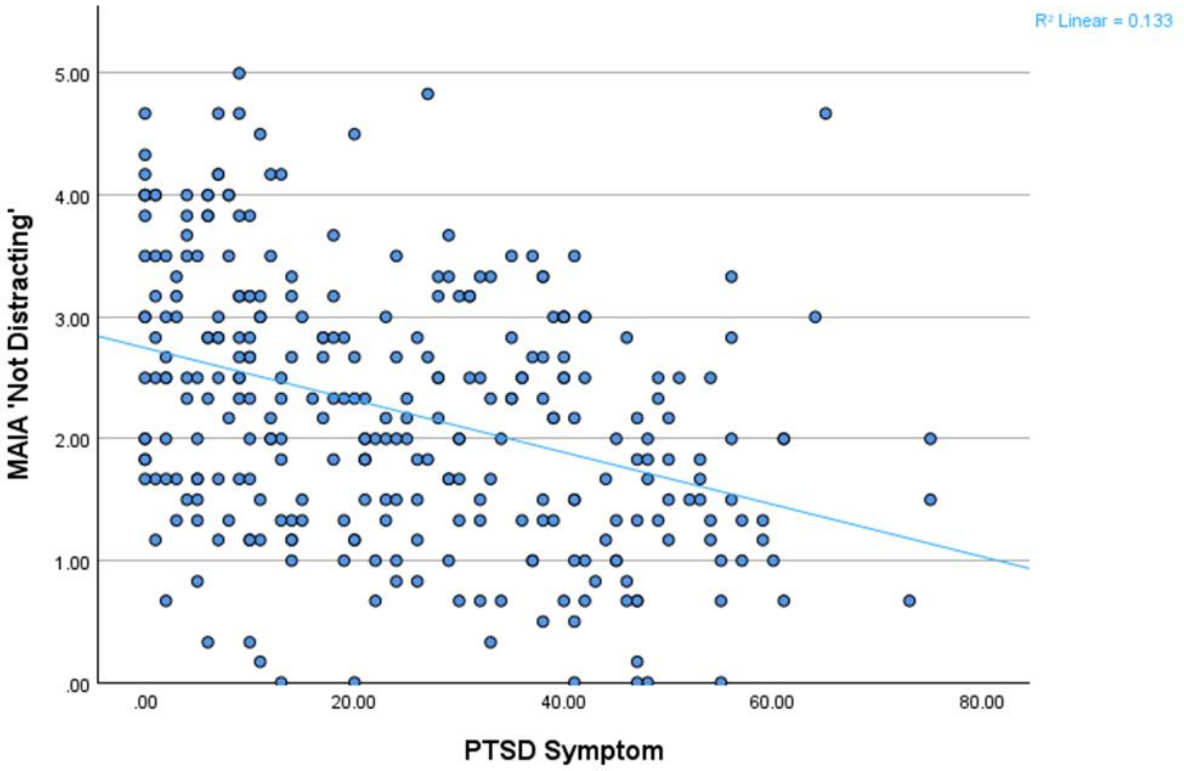
N.2 Scatterplot of Intolerance of Uncertainty & MAIA 'Not Worrying'



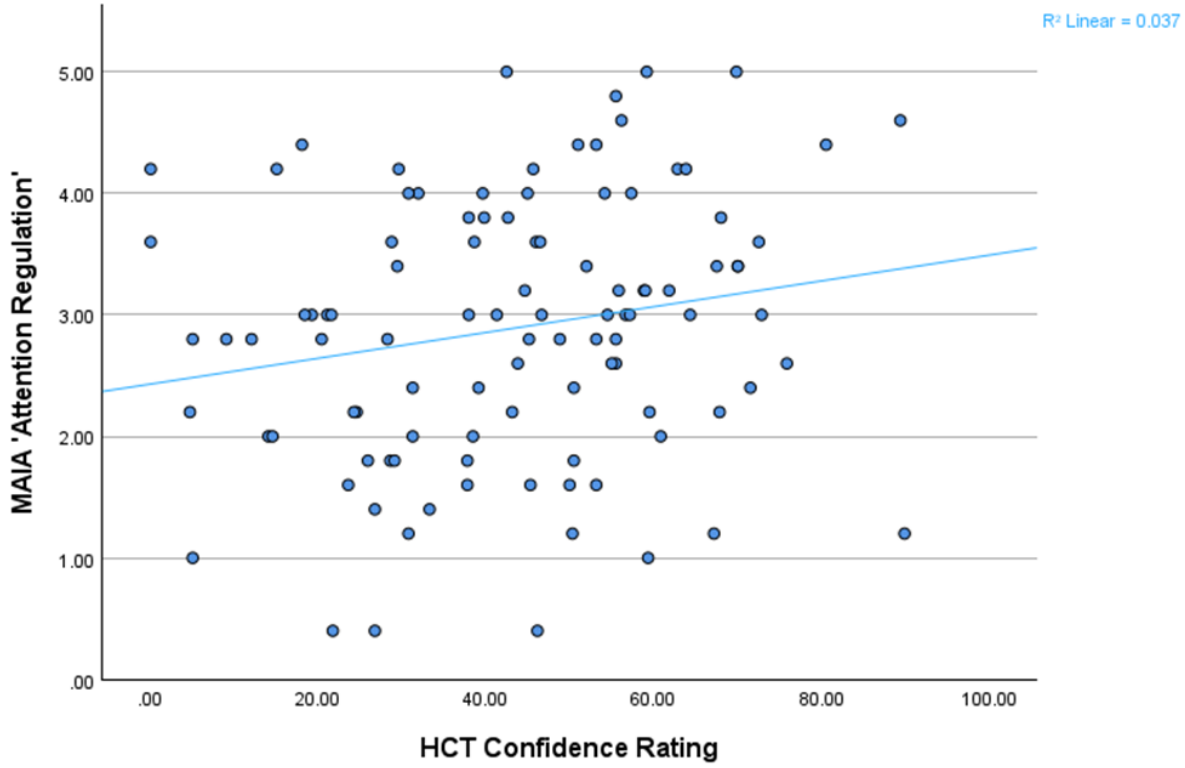
N.3 Scatterplot of Anxiety Sensitivity & Self-reported Interoceptive Attention



N.4 Scatterplot of PTSD Symptom Severity & MAIA 'Not Distracting'



N.5 Scatterplot of Heartbeat Counting Confidence & MAIA 'Attention Regulation'



N.6 Scatterplot of Heartbeat Detection Confidence & MAIA 'Emotional Awareness'