

Interoception in anxiety, depression, and psychosis: a review

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Summary

Research has examined the relationship between interoception and anxiety, depression, and psychosis; however, it is unclear which aspects of interoception have been systematically examined, what the combined findings are, and which areas require further research. To answer these questions, we systematically searched and narratively synthesised relevant reviews, meta-analyses, and theory papers (total $n = 34$). Existing systematic reviews and meta-analyses (anxiety $n = 2$; depression $n = 2$; psychosis $n = 0$), focus on cardiac interoceptive accuracy (heartbeat perception), and indicate that heartbeat perception is not systematically impaired in anxiety or depression. Heartbeat perception might be poorer in people with psychosis, but further evidence is needed. Other aspects of interoception, such as different body systems and processing levels, have been studied but not systematically reviewed. We highlight studies examining these alternative bodily domains and levels, review the efficacy of interoception-based psychological interventions, and make suggestions for future research.

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Introduction

Traditional approaches to mental health have predominantly sought to categorise and diagnose mental health difficulties as ‘disorders’ within distinct taxonomic systems (e.g., the Diagnostic and Statistical Manual of Mental Disorders; DSM¹). Although this approach has several recognised advantages (such as providing a common language for effective communication amongst patients, clinicians and researchers), growing concerns have been expressed regarding several fundamental aspects of such diagnostic frameworks.² As a result, contemporary mental health research and clinical practice has shifted towards a transdiagnostic approach that seeks to understand and treat mental health conditions independent of traditional diagnostic categories.³

One approach to identifying transdiagnostic mechanisms and markers is to find factors (e.g., variables, traits, or symptoms) that are shared across multiple conditions. In this paper, we summarise reviews and meta-analyses that consider whether *interoception*, the sensing and awareness of signals about the physiological state of the body, serves as a transdiagnostic marker for mental health disorders.⁴ Interest in interoception as

a transdiagnostic marker of mental health has increased since the publication of seminal works,^{5,6} and continues to grow following the publication of a landmark White Paper on interoception and mental health.⁷ However, it is unclear which aspects of interoception have been systematically examined, what are the combined findings, and which areas require further research. We synthesise evidence concerning the role of interoception in anxiety, depression, and psychosis, given their broad and significant contribution to global burden of disease,⁸ the presence of interoceptive symptoms in all three conditions, and theoretical proposals of interoceptive deficits (discussed below). Our aim is to provide applied health professionals and researchers with a single source, overarching meta-summary of current evidence relating to all three conditions. To do so we take a hierarchical approach (see Fig. 1), first drawing on the accumulated knowledge from recent systematic reviews and meta-analyses, which provide a ‘gold standard’ in evidence synthesis. We also incorporate ideas from narrative reviews and theory papers which, whilst not being systematic, provide authoritative discussions of contemporary issues by experts in the field. Finally, we discuss primary research which has examined aspects of interoception that have not yet been systematically reviewed, to highlight the diversity of interoceptive work and new developments in the field that require further attention.

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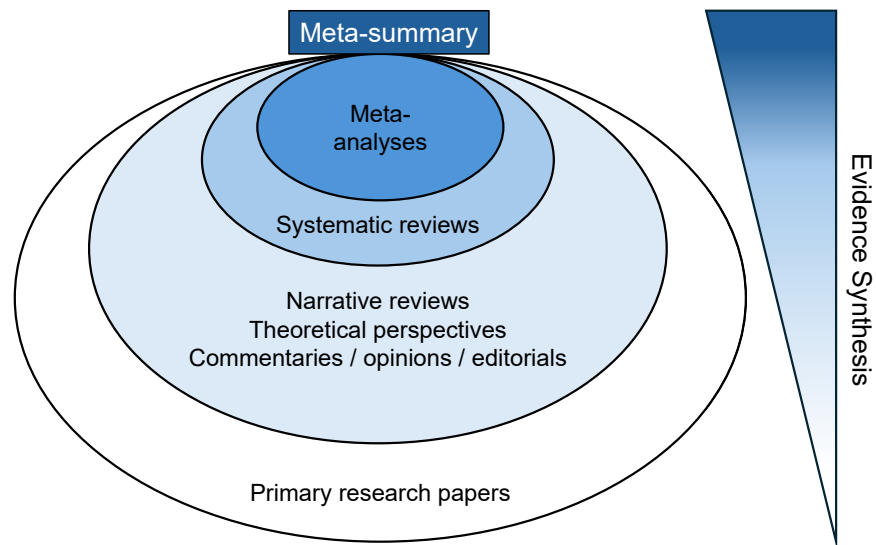


Fig. 1: Hierarchical approach to literature synthesis and summarisation. A meta-summary of available evidence was produced by combining recent meta-analyses and systematic reviews, narrative reviews, theoretical perspective papers, commentaries, opinion pieces and editorials, and primary research papers. A high level of evidence synthesis was achieved by combining these different sources, each with their own degree of evidence synthesis (represented on the right and via different shades of colour).

We aimed to ensure that the review covered areas prioritised by people with lived experience of mental health and wellbeing challenges as having a negative impact on their life goals. Thus, our review was shaped by the active involvement of individuals with these lived experiences (see [Box 1](#)). Such involvement can occur on a continuum from consultation, to collaboration and co-construction, to user-controlled and executed research. The benefits of involvement are widely recognised for improving the quality, integrity and relevance of research,⁹ with several health agencies (such as the UK Health Research Authority¹⁰ and Wellcome Trust¹¹) highlighting these benefits. Details of our lived experience consultations are fully reported in [Supplementary Materials](#). We integrate throughout the main text where and how the input from these consultations informed our work.

We begin our review by providing a brief background to the definition and measurement of interoception, for readers unfamiliar with interoception. We then explain the significance of interoception to everyday life, mental wellbeing, and conditions such as anxiety, depression, and psychosis, including how recent explanations of these conditions propose various interoceptive deficits. After giving details of our methods, we proceed to summarise the current evidence in anxiety, depression, and psychosis (respectively). Guided by our lived experience consultants, who emphasised the need for alternatives to pharmacological treatments, we subsequently consider the efficacy of psychological therapies that focus on improving interoception (i.e., interoception-based interventions; see [Box 2](#)). In the subsequent

section we discuss primary evidence which highlights the diversity of interoception research and new developments in the field. We then provide key recommendations for future research, before we consider the limitations and conclusions of our work.

Search strategy and selection criteria

We used EBSCOHost to search the electronic databases Medline, Academic Search Ultimate, APA PsycInfo, and APA PsychArticles to identify relevant papers published between database inception and April 14, 2023, using the search terms: 1) ‘interoception’ OR ‘interoceptive awareness’ OR ‘interoceptive sensibility’ OR ‘interoceptive accuracy’ OR ‘interocept*’ AND 2) ‘depression’ OR ‘depressive disorder’ OR ‘depressive symptoms’ OR ‘major depressive disorder’ OR 3) ‘anxiety’ OR ‘anxiety disorders’ OR ‘generalized anxiety disorder’ OR 3) ‘psychosis’ OR ‘psychotic disorder’ OR ‘psychotic’ OR ‘schizophrenia’ OR ‘severe mental illness’ OR ‘serious mental illness’ OR ‘mental illness’ AND 4) ‘review’ OR ‘systematic review’ OR ‘meta-analysis’. In separate searches we specified (or left open and unspecified) the document type as ‘review’. We also used the reference list of identified papers, special issues on the subject of interoception known to the research team, and the websites of leading researchers in the field of interoception to identify additional papers of relevance. We included all meta-analyses, systematic reviews, and narrative reviews that directly examined the subject of interoception in anxiety, depression, and psychosis. In addition, we included reviews not specifically addressing

Box 1.**Summary of lived experience advisory panel (LEAP) consultation findings.**

Members of the LEAP described several uncomfortable body sensations associated with their mental health and wellbeing, such as: increased heart rate, rapid breathing, chest pressure, heightened anxiety levels, extreme hunger, heightened senses, gastrointestinal discomfort, nausea, fatigue, muscle tension, headaches, soreness, shivers, and heaviness. The challenges these symptoms pose in performing daily tasks (e.g., chores), work, having an active social life, and maintaining relationships were highlighted. The consultation identified several things that might help improve daily life, including being open about one's feelings and knowing that others felt the same way, having a supportive community of people around, healthy eating and exercise, and self-care. Body-focused techniques such as mindfulness, meditation, deep breathing, yoga and sensory deprivation were discussed, with LEAP members expressing the importance of the mind-body connection in mental health, but difficulties practicing self-care techniques like mindfulness and yoga due to a wandering mind. Many of those consulted reported having tried body-focused techniques to improve their mental health and wellbeing, but found the effects to be short-lived due to a lack of ongoing engagement. The consultation also voiced the need for better alternatives to medication for improving mental health. Further elaboration of these themes are provided in [Supplementary Materials](#).

the question of interoception in anxiety, depression, or psychosis, but clearly related to this subject, as well as any theory, commentary, editorial, or perspective papers on the subject of interoception and/or anxiety, depression, or psychosis. Our search identified 34 relevant papers which were read in full by PMJ. Four of these were existing narrative or systematic reviews or meta-analyses focused specifically on interoceptive deficits in anxiety, depression and/or psychosis.¹²⁻¹⁵ The remaining papers were reviews, theory papers, commentaries, editorials, and perspective pieces (see [Supplementary Materials](#) for details) selected to provide relevant context or background information to our review.

Interoception definition and assessment

Interoception can be defined as the sense of the physiological condition of the body.¹⁶ Contemporary definitions have refined this idea to encompass the act of sensing, interpreting, integrating, regulating and predicting information about the state of inner body systems across both conscious and unconscious levels of processing.^{7,17,18} However, definitions continue to evolve and be controversial, as discussed by Crucianelli and Ehrsson,¹⁹ who provided a summary of changes over time (see [Table 1](#)), and Nord and Garfinkel²⁰ who highlight the different bodily domains and their level of acceptance as interoceptive systems (summarised in

[Table 2](#)). These examples show that the concept of interoception has developed from one characterised by a limited number of sensory nerve channels, to a much broader definition that includes a wide range of bodily systems and sensations.

The most widely used interoception framework proposes a simple 3-dimensional (level) delineation,²¹ comprising interoceptive *accuracy* (i.e., performance on objective measures of interoception such as heartbeat perception tasks²²), *sensibility* (i.e., self-reported beliefs about one's own interoception measured via questionnaires or confidence ratings), and *awareness* (i.e., a metacognitive measure of interoception typically assessed via the correlation between measures of accuracy and sensibility). The majority of studies use cardiac (heartbeat) perception as a general measure of interoceptive accuracy,¹² while questionnaires are used as measures of interoceptive sensibility.²³ However, several limitations of existing interoceptive measures have been identified, leading to the development of new assessments (see²³⁻²⁸), as well as further refinement of the concept of interoception to include further dimensions (i.e., levels of processing) and domains (e.g., gastric, respiratory).¹⁸ These different interoceptive dimensions and domains are dissociable^{21,29,30}; therefore, understanding the role of interoception in any condition requires a comprehensive assessment of interoceptive dimensions within and across bodily domains.

Box 2.**Interoception-based psychological interventions.**

Psychological or behavioural interoception-based interventions (IBIs) are defined as interventions that include "first-person reflection upon or cultivation of specific modes of experience and practices that explicitly involve interoceptive awareness".⁵⁶ This definition stems from a broad, interdisciplinary conceptualisation of interoception which draws on clinical, contemporary scientific and traditional contemplative approaches to the role of attention to bodily signals in mental health.^{35,79} IBIs vary considerably in their specific elements, but share an emphasis on targeting body awareness in the enhancement of mental wellbeing. Interoceptive exposure is one of the most common forms of contemporary IBI used by psychologists and psychotherapists.⁸⁰ Interoceptive exposure involves having an individual repeatedly induce and experience their feared physical sensations (e.g., shortness of breath, heart palpitations, dizziness) which can be achieved through non-invasive procedures such as vagal nerve stimulation⁸¹ or exercises such as hyperventilation, chair spinning, and breathing through a straw, with a view to challenging and reducing their fear of these sensations. Certain types of meditation, yoga and mindfulness are other examples of IBIs that cultivate well-being by attending to the body.⁷⁹

Reference	Definition
Sherrington (1906)	The sensory nerve receptors that react to stimuli originating within the body
Sherrington (1948)	Body-to-brain axis of sensations concerning the state of the visceral body and its internal organs
Ádám (1998)	Processing of information that is picked up by sensory receptors innervating the internal organs and transmitted by ascending pathways of the autonomic nervous system
Cameron (2001)	Visceral sensory nervous system impulses connecting body to brain to behaviour and thought, with or without awareness
Craig (2002)	The sense of the physiological condition of the body at any given time
Critchley et al. (2004)	The sensing of the internal state of the body
Dworkin (2007)	Sensory visceral receptors that monitor the internal state of the body
Damasio (2010)	The sensing of the organism's interior
Barrett & Simmons (2015)	The perception and integration of autonomic, hormonal, visceral, and immunological homeostatic signals that collectively describe the physiological state of the body
Ceunen et al. (2016)	A multimodal integration not restricted to any sensory channel or mere sensations but also relying on learned associations, memories, and emotions and integrating these in the total experience, which is the subjective representation of the body state
Khalsa et al. (2018)	The overall process of how the nervous system senses, integrates, stores, and represents information about the state of the inner body
^a Suksasilp & Garfinkel (2023)	The sensing, interpretation and integration of signals originating from within the body across both conscious and unconscious levels of processing.

Note: table reproduced and modified from Crucianelli and Ehrsson (2023). ^aDefinition added since publication of original paper.

Table 1: Summary of common interoception definitions.

The importance of interoception for activities of daily life, anxiety, depression and psychosis

Contemporary theories of brain function highlight the fundamental importance of interoception in the body–brain interactions that underpin adaptive behaviour³¹ and to respond to allostatic environmental demands.^{32,33} Interoception is foundational to experiencing the body and self in a reliable way, providing trust in one's body to generate consistent, relevant sensations, and the basis for engaging in daily activities.³⁴ Interestingly, individuals with lived experiences of mental health and wellbeing report experiencing interoceptive symptoms, which are connected to changes in their mental health, and major barriers performing activities of daily life (see [Box 1](#) and [Supplementary Materials](#)), including difficulties at home (e.g., basic self-care, cleaning/tidying), work (e.g., being able to keep a job), and social life (e.g., making and maintaining friendships). For example, physiological symptoms such as a racing heart and rapid breathing are prototypical of anxiety disorders and part of their diagnostic criteria.¹ Similarly, individuals with depression frequently suffer from several bodily complaints, including fatigue, pain, constipation, heart palpitations and shortness of breath,³⁵ while individuals with psychosis (schizophrenia) experience dysfunction in various bodily systems, including cardiovascular, respiratory, genitourinary, gastrointestinal, nociceptive and thermoregulatory systems see.¹³

Although the nature and impact of interoceptive disturbances differ depending on the specific condition, several accounts of anxiety, depression, and psychosis predict that atypical interoception should be observed within at least one bodily system (domain) and level (dimension). Paulus and Stein³⁶ propose that both

anxiety and depression are the result of 'noisy' (unreliable) interoceptive information and an exaggerated aversive response to somatic signals. Yoa and Thakkar¹³ propose an account of psychosis using a (Bayesian predictive coding) model, which suggests that faulty processing of interoceptive information may occur because of multiple possible alterations in the perception or interpretation of interoceptive signals. According to these, and several other accounts,^{13,20,31,37–41} multiple bodily systems and interoceptive dimensions are potentially involved in anxiety, depression, and psychosis. As such, a comprehensive assessment of interoception in these conditions is needed to identify possible interoceptive disturbances. With this in mind, an ever-growing body of empirical research has examined interoception in anxiety, depression, and psychosis; however, it is currently unclear which aspects of interoception have been systematically examined, what are the combined findings, and which areas require further research. We set out to address these questions in a high-level, single-source, meta-summary of existing knowledge that would be of use to applied health professionals and researchers.

Findings from existing (systematic) reviews of interoception in anxiety, depression and psychosis

Interoception in anxiety

Desmedt¹² examined the association between cardiac interoceptive accuracy (i.e., heartbeat perception using a well-established heartbeat counting task²²) and mental disorders, including trait anxiety and major depressive disorder in both healthy and clinical samples. Forty studies were meta-analysed, with no overall effect found

Reference	Bodily organ / sense
Sherrington (1906)	Cardiovascular
Sherrington (1906)	Gastrointestinal (oesophageal, gastric, intestinal, colorectal)
Sherrington (1906)	Bladder
Sherrington (1906)	Respiratory
Sherrington (1906)	Visceral pain
Craig (2002)	Hunger
Craig (2002)	Thirst
Khalsa et al (2018)	Fatigue
Khalsa et al (2018)	Blood/serum (pH, osmolality, glucose)
Craig (2002)	Internal temperature
Khalsa et al (2018)	Muscle tension
Craig (2002); Khalsa et al (2018)	Itch
Craig (2002); Khalsa et al (2018)	Tickle
Craig (2002); Crucianelli et al (2018); Björnsdotter et al (2010)	Affective touch
Khalsa et al (2018)	Inflammation
Khalsa et al (2018)	Inflammatory/mechanical joint pain
Craig (2002); Khalsa et al (2018)	Skin temperature

Note: reproduced from Nord and Garfinkel (2022). Colour coding reflects the varying degrees of acceptance and controversy within the field (as suggested by Nord & Garfinkel, 2022). Green indicates organs and senses universally recognised as interoceptive. Light green indicates those widely accepted as interoceptive today although absent from Sherrington's original conceptualisation. Yellow indicates more recently or less consistently recognised sources of interoceptive information. Red indicates more controversial sources of information which are considered by some to be interoceptive but are often excluded from traditional definitions.

Table 2: Summary of interoceptive sensations.

(and a small association of $r = 0.03$) when trait anxiety was examined ($N = 2130$). Investigating healthy and clinical samples separately did not influence the association between trait anxiety and cardiac accuracy and the effect remained non-significant. However, the lack of association between cardiac interoceptive accuracy and trait anxiety does not rule out the possibility that interoception may be affected in anxiety when assessed via other measures of cardiac interoceptive accuracy (such as cardiac discrimination tasks; e.g.,⁴²) or in different bodily domains (e.g., respiration) and levels (via e.g., questionnaires).

Adams¹⁴ also analysed the association between cardiac interoceptive accuracy and trait anxiety in a comprehensive series of meta-analyses that examined the effect of several moderator variables, including: the interoception task used to examine cardiac accuracy (i.e., heartbeat counting vs. heartbeat discrimination), task instructions used (for the counting task), anxiety measure used, inclusion vs. exclusion of a clinically diagnosed anxiety group, effect of comorbid depression, age and gender, and whether there was a heart rate manipulation (which may alter the ability to detect one's heartrate and therefore influence the observed relationship between interoception and anxiety). A meta-analysis of 51 participant samples using the Schandry heartbeat detection task ($N = 2913$) across healthy and clinical samples (comparable to the analysis conducted by Desmedt¹²), indicated no overall association between trait anxiety and cardiac accuracy ($r = 0.02$). This lack of effect was not influenced by study design or the specific anxiety measure used. A parallel analysis of 17 samples using the same measure of cardiac interoceptive accuracy but examining state anxiety ($N = 620$) similarly showed no association ($r = 0.01$). Separate analysis of a much smaller set of 9 samples ($N = 322$) using an alternative measure (i.e., the heartbeat *discrimination* task), similarly found no association with trait anxiety ($r < -0.01$). Analysis of the moderators variables (outlined above) had no impact on the observed (null) effects.

This comprehensive set of meta-analyses suggest no relationship between cardiac interoceptive accuracy and trait anxiety. It should be noted that several of the moderator analyses were underpowered (with fewer than 10 studies to meta-analyse), and even those with sufficient power failed to find evidence of a moderating effect or relationship. Several other limitations are also worth noting. The primary analysis with the largest sample was, like that of Desmedt,¹² based on studies using the Schandry²² heartbeat counting task, which has several known limitations, such as bias caused by beliefs about one's heartrate or the ability to estimate time accurately.^{24,26} This finding was confirmed by a second analysis using an alternative measure (heartbeat discrimination), although in a much smaller overall sample. Moreover, conclusions are limited to cardiac

interoceptive accuracy, although anxiety may relate to other levels of interoception such as negative interpretations of interoceptive states, signals that are captured via self-report rather than objective performance, or other interoceptive domains such as respiration or nociception.

Overall, although some individual studies have found an association between cardiac interoceptive accuracy and trait anxiety, two meta-analyses looking at the overall, combined effect across studies have failed to find a strong or significant association between cardiac interoceptive accuracy and trait anxiety. The specific aims and subsequent inclusion/exclusion criteria of these meta-analyses mean that other interoceptive bodily domains (e.g., respiration, gastrointestinal, nociceptive) or dimensions (self-reported beliefs or interpretations about bodily signals captured via questionnaires) were not examined, although primary research into these alternative aspects of interoception does exist (see below).

Interoception in depression

Eggart¹⁵ examined cardiac interoceptive accuracy in patients with a clinically-diagnosed major depressive disorder, excluding individuals with co-morbid panic or anxiety disorder, or psychosis. Six studies met inclusion criteria. Sample sizes of depressed patients were relatively small ($n = 16$ ⁴³⁻⁴⁵; $n = 18$ ⁴⁶) with the exception of one study ($n = 141$ neurotic depression & $n = 106$ depressive psychogenic reactions⁴⁷). There was wide variability in study design and no meta-analysis was carried out to calculate a pooled effect size. The authors concluded that cardiac interoceptive accuracy was poorer in depressed individuals, with a possible curvilinear (inverted U) relationship, such that moderately depressed individuals experience greater impairment relative to severely depressed. However, the review provided only preliminary evidence for poorer cardiac interoceptive accuracy in patients with depression, based on a descriptive synthesis of a small number of studies with limited samples and mixed designs.

Desmedt¹² also examined the association between cardiac interoceptive accuracy and trait anxiety in health and clinically depressed people, including a larger number of samples ($k = 31$) and bigger overall sample size ($N = 1622$). Contrary to Eggart,²² no overall association between cardiac interoceptive accuracy and depression was found ($r = -0.04$). There was a trend for a significant association ($r = -0.08$, $p = 0.09$) when an identified outlier⁴⁵ was removed; even so the association between heartbeat accuracy and depression was extremely small (accounting for only 0.6% shared variance), which may be explained by non-interoceptive processes, such as a general tendency to underestimate time, which would bias performance on the heartbeat counting task.^{12,25} Population type (healthy vs. clinical) and the measure used to assess depression

were examined as moderators, with no influence on the association between cardiac interoceptive accuracy and depression.

Current evidence suggests that cardiac interoceptive accuracy is not associated with depression. An initial systematic review of the early evidence suggested that cardiac interoceptive accuracy was impaired in individuals with depression, however, a subsequent meta-analysis including several new studies and more robust, statistical methods failed to find a significant association. Although Desmedt¹² provide a more robust and up-to-date analysis of current evidence, their conclusions remain limited to the link between depression and cardiac interoceptive accuracy. Depression may still be linked to other aspects of interoception (discussed below), that should be systematically analysed.

Interoception in psychosis

There are no existing systematic reviews or meta-analyses examining the association between interoception and psychosis. Yao and Thakkar¹³ conducted a narrative review of direct and indirect evidence regarding interoceptive abnormalities in schizophrenia. We report here the direct evidence, which comprises four studies^{48–51} that have examined cardiac interoceptive accuracy in individuals with schizophrenia using the heartbeat counting task²² (note that two studies included in Yao and Thakkar¹³ were pre-prints at the time of publication and have since been published as a peer-reviewed articles: Critchley and colleagues⁴⁸ and Torregrossa and colleagues⁵⁰). All four studies found significantly lower cardiac interoceptive accuracy in schizophrenia. The relationship with specific clinical symptoms was mixed, with one study⁵¹ finding *better* interoceptive accuracy associated with more severe positive symptoms, while another⁴⁹ found that *poorer* interoceptive accuracy was associated with more severe positive and negative symptoms, and a third found *no relationship* between specific symptoms and interoceptive measures.⁵⁰

Yao and Thakkar also highlighted findings regarding self-reported interoceptive sensibility.¹⁸ Critchley⁴⁸ found lower interoceptive sensibility in patients with schizoaffective disorder compared to anxiety/depression and schizophrenia patients. Koreki⁴⁹ found a greater tendency to notice bodily sensations, and lower tendency to not ignore pain or discomfort (i.e., ‘not-distracting’) in patients with schizophrenia. Contrastingly, Torregrossa⁵⁰ found a greater tendency for not-distracting in schizophrenia patients, but lower ability to sustain attention to body sensations (‘attention regulation’), not worry about pain or discomfort (‘not-worrying’) or to experience one’s body as safe and trustworthy (‘trusting’). Koreki⁴⁹ also examined the relationship between subjective and objective measures of interoception (i.e., a ‘discrepancy’ score used as a proxy for prediction error), finding that prediction error was correlated with

positive but not negative symptoms. Two empirical studies not included in Yao and Thakkar also found evidence of self-reported interoceptive sensibility abnormalities in psychosis. Barbato⁵² found that a combination of *lower* non-distracting, not-worrying, attention regulation and trusting, together with *higher* emotional awareness and body listening predicted increased risk of psychosis. By contrast, Damiani⁵³ found increased noticing, emotional awareness, self-regulation, and body listening in patients with psychosis relative to a healthy control sample.

Overall, direct evidence regarding interoceptive ability in psychosis is scarce, but has suggested poor cardiac interoceptive accuracy in patients with schizophrenia. The relationship with specific symptomology is mixed and inconclusive, as is the relationship with other interoceptive dimensions/levels (e.g., self-reported interoceptive sensibility). More primary research and systematic analysis of the accumulating evidence is needed to establish if there is a reliable link between interoception and psychosis.

Conclusions from existing reviews

Recent meta-analyses fail to find evidence of a reliable association between cardiac interoceptive accuracy and anxiety or depression. There has been no systematic review or meta-analysis of this association in psychosis. Systematic reviews that have been performed in anxiety and depression had a narrow focus on cardiac interoceptive accuracy. This represents a significant limitation, given the multidimensional nature of interoception.¹⁸ Although cardiovascular symptoms are present in anxiety, depression, and psychosis, and a deficit is predicted by some accounts (e.g.³⁶), cardiac accuracy may not be a good marker of general interoceptive abilities.^{18,29,54} Anxiety and depression may be linked to other aspects of interoception (e.g., other bodily systems and levels of interoception measurement) for which there is an abundance of primary research that has not yet been systematically reviewed (see section 6 for examples). Further systematic examination of this primary research is needed to fully understand the involvement of interoceptive deficits in anxiety, depression, and psychosis, and develop new, more effective treatments for these conditions (see below).

Interoception-based interventions for anxiety, depression, and psychosis

An important theme emerging from our lived experience consultations was the desire to have alternatives to traditional pharmacological treatments (see [Box 1](#) and [Supplementary Materials](#)), which often have severe, negative side effects (such as weight gain). The importance of the mind-body connection and self-care techniques such as meditation, yoga and mindfulness as alternative forms of treatment for mental health

challenges were also raised during our consultations. Several individuals with lived experience reported trying interoception-based psychological interventions (see [Box 2](#) for a definition) as part of their treatment (i.e., relaxation- and breathing exercises), with some benefits in terms of reduced anxiety or improved mood, but no change in psychotic symptoms. Difficulties with motivation when experiencing severe symptoms of psychosis, anxiety and depression were highlighted as factors that potentially limited the effectiveness of these interventions. As a result of these consultations, we decided to include in our review evidence concerning the efficacy of interoception-based psychological interventions for anxiety, depression, and psychosis.

In previous work from our lab, we conducted a systematic review, synthesis and quality evaluation of interoception-based psychological interventions for mental health disorders following a pre-registered protocol and using PRISMA guidelines.⁵⁵ This extended the findings of a similar but not systematic review of fourteen randomised controlled trials using interoception-based interventions to treat mental health disorders.⁵⁶ Neither review contained specific search terms covering psychosis, and no studies involving psychotic disorders were found. We thus report here only the findings in relation to anxiety and depression, and we focus on the results of the systematic and more recent review.

Heim⁵⁵ examined randomised controlled trials of interoception-based psychological therapies involving adults (18+ years old) with a diagnosis of (DSM-IV, DSM-5 or ICD-10) anxiety or depression. These interoception-based psychological interventions vary considerably in their components (including techniques such as interoceptive exposure, mindfulness-based cognitive therapy, body-awareness therapy, and flotation sensory-deprivation therapy), but share the common goal of improving interoception. The effect of intervention on interoceptive ability, depression and anxiety was examined. Amongst 32 RCTs of interoception-based psychological interventions found, one examined (comorbid) depression in patients with chronic pain,⁵⁷ two depression alone,^{58,59} and one anxiety with (comorbid) depression.⁶⁰ All but one study (3 out of 4) found improved interoceptive ability after the intervention. Improvements in self-reported anxiety⁶⁰ and clinician- or self-rated depression symptoms were found in two studies,^{58,59} and a reduction in depression was mediated by self-reported interoceptive ability in two studies.^{57,59} These results suggest that interoception-based psychological interventions for depression and anxiety may be useful; however, there are several limitations to these findings.

There was considerable heterogeneity in the design of interoceptive interventions, with variability in treatment protocol, assessment of interoception, and symptom improvement measurement. Greater standardisation of

these key elements, and pre-registration/publication of study protocols, would help improve study quality and allow future research establish the efficacy of interventions. Heim⁵⁵ only examined studies including individuals with a clinical diagnosis of anxiety or depression. Interventions might be less effective in more severe instances of depression or anxiety, such as those with a clinical diagnosis and extreme form of the psychiatric condition. These individuals may lack the necessary motivation or focus (as indicated by our lived experience consultations) to engage with interoception-based interventions, or may be excluded from taking part in research because of the severity of their psychiatric symptoms. Future research should examine symptom change in a wider population that includes individuals with subclinical mood problems. There are other studies of interoceptive interventions in subclinical populations with anxiety and depression (e.g., biofeedback therapy), which may yield valuable insights, but have not been systematically reviewed. In addition, all four studies that examine interoception in individuals with anxiety or depression actively excluded patients with a current or past diagnosis of psychotic disorder. Thus, individuals with psychosis are specifically underrepresented and more research into this population is needed.

Other aspects of interoception in anxiety, depression, and psychosis

Existing research into interoception in anxiety, depression, and psychosis has been dominated by studies of cardiac awareness (as reflected by the existing reviews summarised above). However, a large and ever-growing body of primary research has examined other aspects of interoception, such as interoception of other bodily systems (e.g., respiration,⁶¹ gastrointestinal⁶²) using various levels of measurement. While a comprehensive review of this research is beyond the scope of the current work, below we provide examples of such work to highlight the diversity of interoceptive research and new developments in the field.

Primary research in anxiety has found that greater self-reported interoceptive sensibility is associated with greater trait anxiety.^{63,64} However, this relationship depends on factors such as the interaction between different dimensions of interoceptive sensibility,⁶⁵ form and severity of anxiety (e.g., panic disorder vs. social anxiety vs. health anxiety⁶³), and influence of other psychological traits (e.g., alexithymia—a difficulty identifying and describing one's own emotions⁶⁴).

Work in depression has found a similarly complicated association with interoceptive sensibility. Some research finds that depression is linked to *greater* interoceptive sensibility; specifically, awareness of the body in stressful situations or in relation to autonomic reactions, but not awareness of body processes.⁶⁶ By contrast, other research finds that depression is related

to *poorer* interoceptive sensibility, and particularly *less* trust in one's body sensations.⁶⁷ Higher depression severity is associated with lower self-reported interoception, and improvements in interoceptive sensibility predict a positive treatment response in severely depressed hospitalised individuals.⁶⁸ Divergent findings may be the result of several factors, such as heterogeneous samples and different measurement protocols.

As discussed in detail above, interoceptive sensibility has also been examined in psychosis,^{48–53} with mixed findings. These findings paint a complicated picture, which cannot be easily interpreted without a solid theoretical foundation (e.g.^{13,41}), further studies, and systematic analysis.

Interoception has also been examined across different bodily systems and levels in the same study. For example, Garfinkel⁵⁴ examined interoception for both cardiac and respiratory signals, and across different levels of interoceptive accuracy (i.e., objective performance) and awareness (i.e., metacognitive insight into one's interoceptive ability), finding that increased anxiety was related to poor respiratory accuracy, while good metacognitive awareness was associated with reduced anxiety. A multilevel approach has also been taken by recent research examining how anxiety is related to interoception of breathing,⁶¹ involving several measures of interoception including brain responses, advanced computer modelling of a breathing task, and self-report questionnaires. Similar multilevel work has examined different aspects of interoceptive processing in depression,⁶⁹ where both cardiac interoceptive accuracy and heartbeat-evoked potentials (i.e., the electrophysiological brain response that reflects cortical processing of individual heartbeats) were found to be no different from those of healthy controls.⁶⁹ Similar work is needed in psychosis, which has so far focused on cardiac interoceptive accuracy and interoceptive sensibility.¹³ Yao⁷⁰ provide a recent example of innovation in psychosis, where structural brain connectivity was used to identify altered connectivity in interoceptive brain networks in patients with schizophrenia.

Recommendations for future research

In this final section we suggest future research, guided by the priorities of individuals with lived experience of mental health and wellbeing challenges. We start with practical suggestions to improve existing research practices, and then progress to more complex, exploratory and long-term goals.

First, with the exception of cardiac interoceptive accuracy, which has dominated the field, there are no systematic reviews or meta-analyses of different interoceptive dimensions (levels) and bodily systems (domains) in anxiety, depression, or psychosis. Systematic reviews of these different interoceptive dimensions and bodily domains are needed to disambiguate findings

from primary research (see above for examples) that are conflicting and difficult to interpret (e.g., different patterns of findings regarding self-reported interoceptive deficits in anxiety, depression, and psychosis). Even within the field of cardiac awareness, studies that use newly-developed procedures (such as new heartbeat tapping tasks combined with computational modelling and 'perturbation' measures taken during different states of arousal) suggest possible differences in the processing of interoceptive information in people with anxiety and depression (see e.g.,²⁸). Further research is needed to confirm and establish the reliability of these initial findings. Second, longitudinal and intervention research is needed, which uses comprehensive, multidimensional assessments of interoception, with different levels and bodily domains measured in the same participants. This research design allows a more complete interoceptive profile to be captured, and more definitive conclusions regarding interoceptive abilities in different conditions. Third, our lived experience panel highlighted the potential for culture (defined in its broad sense as the complex system of behaviours and cognitions that are shared by individuals within some definable population^{71,72}) to influence the interpretation of interoceptive signals and access to interoception-based psychological interventions. However, other than a handful of empirical studies,^{71,73,74} which have found interesting differences in interoceptive ability based on cultural background, there has been little attempt to understand how interoception might differ cross-culturally and impact mental health. More cross-cultural research is needed. Fourth, research needs to examine the impact of interoception on engagement with activities of daily living. Interoception is foundational to successful engagement with everyday activities,³⁴ and difficulties with such activities were emphasised as a priority by our lived experience consultations, as were difficulties engaging with interoception (body) based psychological interventions. Clarifying the relationship between interoception and activities of daily life may help motivate engagement with interoception-based interventions. Finally, an interesting and emerging area of future research is the role of the immune system, in particular the inflammatory response, in the pathogenesis of common psychiatric conditions,⁷⁵ such as anxiety, depression, and psychosis. Although the focus of interoceptive signalling has typically been neural pathways, interoceptive mechanisms include humoral and cellular signals that communicate the physiological state of the body to the brain. The importance of these humoral signals is increasingly recognised, with immune system dysfunction commonly found in patients with mental health disorders including psychosis, trauma- and stress-related disorders, and depression, and prolonged activation of the immune system directly linked to increased episodes of depression.^{20,75} These ideas open exciting possibilities for repurposing existing (anti-inflammatory) pharmacological treatments for the treatment of mental

health conditions.²⁰ This is especially important given feedback from our lived experience consultations, which emphasised the negative impact of current medications, and need to prioritise the development of more effective treatments with fewer side-effects.

Conclusion

By aiming to provide a high-level, ‘one stop’ meta-summary of existing evidence across three mental health conditions, we drew on evidence from existing systematic reviews and meta-analyses. Our work is therefore limited by the parameters (e.g., specific criteria and analyses) of these existing reviews, which have primarily focused on cardiac interoceptive awareness in adults. We provide a critical analysis of these reviews and their findings, and incorporate examples of primary research that demonstrate the diversity of interoception research beyond cardiac interoceptive accuracy. These studies suggest the existence of interoceptive disturbances in various bodily systems when measured via neural signatures of interoceptive processing (e.g., heartbeat-evoked potentials), self-reports of interoceptive sensibility, and other contemporary methods (e.g., using ‘perturbation’ methods that measure interoception under different levels of arousal, computational modelling, and new heartbeat tapping tasks). Further studies are needed that comprehensively assess interoception across bodily domains and levels of measurement, in both children and adults. The connection between interoceptive abilities and mental health in children remains particularly poorly understood and in need of further work (see e.g.^{76,77}; and⁷⁸ for a useful narrative review and model).

In conclusion, there has been significant interest into the role of interoception in mental health and wellbeing. We focused on evidence regarding the role of interoception in anxiety, depression and psychosis. Although considerable progress has been made since the 2018 White paper on interoception in mental health,⁷ much work is still needed to address issues defining, measuring, and understanding the functional consequences of interoceptive disturbances.

Outstanding questions

To what extent do interoceptive disturbances at different levels and bodily domains contribute to anxiety, depression, and psychosis? Can a standardised, comprehensive, and multidimensional assessment of interoception be developed, and used to capture interoceptive profiles across different conditions and populations? How does cultural background influence interoceptive processing, and what are the implications of these differences for the manifestation and treatment of mental health disorders across cultures? What is the impact of interoceptive abilities on everyday activities and engagement with interoception-based interventions

that promote psychological wellbeing and self-care? Can existing pharmacological treatments, such as e.g., those targeting the immune system and inflammatory response, be repurposed to offer new treatments for anxiety, depression, and psychosis? Future research should address these questions to enhance our understanding of the mechanisms underpinning anxiety, depression, and psychosis, and pave the way for novel therapeutic approaches.

Contributors

PJ: Conceptualisation (equal); funding acquisition (equal); investigation (lead); project administration (equal); supervision (equal); writing—original draft preparation (lead); writing—review & editing (equal).

SR: Conceptualisation (equal); funding acquisition (equal); project administration (equal); resources (lead); supervision (equal); writing—original draft preparation (supporting); writing—review & editing (equal).

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AI: Conceptualisation (equal); writing—original draft preparation (supporting); writing—review & editing (equal).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.eclinm.2024.102673>.

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