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Alexithymia mediates the relationship between interoceptive sensibility and anxiety

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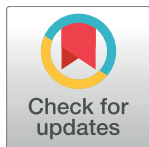
Abstract

A number of empirical and theoretical reports link altered interoceptive processing to anxiety. However, the mechanistic understanding of the relationship between the two remains poor. We propose that a heightened sensibility for interoceptive signals, combined with a difficulty in attributing these sensations to emotions, increases an individual's vulnerability to anxiety. In order to investigate this, a large sample of general population adults were recruited and completed self-report measures of interoceptive sensibility, trait anxiety and alexithymia. Results confirmed that the positive association between interoceptive sensibility and trait anxiety was partially mediated by alexithymia, such that those most at risk for clinically significant levels of trait anxiety have both significantly higher levels of interoceptive sensibility and alexithymia. A subsequent factor analysis confirmed the independence of the three measures. Altered interoceptive processing in combination with alexithymia, increased the risk for anxiety above and beyond altered interoceptive processing alone. We suggest that a heightened sensibility for interoceptive signals, combined with a difficulty in attributing these sensations to emotions, leaves these sensations vulnerable to catastrophizing interpretation. Interventions that target the attribution of bodily sensations may prove valuable in reducing anxiety.

Introduction

Anxiety disorders represent the most prevalent mental disorder worldwide [1], yet an understanding of their underlying psychological causes remains elusive. One promising research avenue concerns altered interoceptive processing. Interoception is defined as the detection of the physiological state of the body [2]. The accurate detection and response to these physiological states is crucial for maintaining homeostasis [2]. Interoceptive signals are conveyed via small diameter afferent fibers originating in the tissues and organs of the body, terminating in the posterior insula [2,3]. Interoception has been theoretically [4, 5] and empirically (e.g. [6]), linked to anxiety. Specifically, the misattribution of bodily sensations has been proposed as the key interoceptive component of anxiety [7], however the psychological and neurological mechanisms of this relationship are not well understood. Here, we propose that the reason

these signals are misattributed is the presence of the sub-clinical construct alexithymia: a difficulty in identifying and describing one's own emotions [8].

Interoceptive processing has been measured using a number of methods, for example self-report questionnaires (e.g. Autonomic Perception Questionnaire [9]; Body Perception Questionnaire [10]) and objective behavioral paradigms, which are most commonly heartbeat detection tasks [11, 12]. There has been some inconsistency in the literature in terms of the terminology used to describe the seemingly independent facets recorded using these different methods. In order to address this issue, a three-dimensional construct of interoception has been proposed [13, 14]. Paradigms that objectively quantify participants' performance in detecting internal events represent measures of 'interoceptive accuracy' (or 'sensitivity' in [13]). Questionnaire based self-report measures of interoceptive processing, and average confidence judgements on objective tasks, are thought to quantify an individual's perceived awareness of interoceptive signals and are termed 'interoceptive sensibility'. Finally, the trial-wise correspondence between performance on objective measures and confidence judgements, referred to as 'interoceptive awareness', is thought to reflect an individual's metacognitive insight into their interoceptive ability.

The inconsistent and interchangeable use of terminology has contributed to some of the confusion in the literature on interoception and anxiety. However, there have also been mixed results within a single domain of interoceptive processing. For example, in some studies, enhanced interoceptive accuracy, measured using a heartbeat counting task [11], is over-represented amongst anxiety patients [15, 16, 17]. However, in other studies no relationship has been found (e.g. [18]). Some studies have reported the inverse relationship, with higher anxiety symptoms in those with poorer interoceptive accuracy [19]. Varying levels of anxiety across samples and different measurement protocols likely play some role in these divergent findings, but it is also possible that a third construct mediates the relationship between altered interoception and anxiety.

When the perception of somatic sensations is measured using self-report questionnaires–termed interoceptive sensibility in Garfinkel & Critchley's [13] formulation of interoceptive processing–patients with anxiety disorders tend to report a hypersensitivity to these sensations [20, 21, 22, 23]. These questionnaire measures (e.g. Body Sensations Questionnaire [24]; Body Vigilance Scale [25]) ask participants to rate how aware they are of a wide range of bodily states.

It has been proposed that individuals with high anxiety have a reduced signal-to-noise ratio of afferent interoceptive information, such that it is more difficult to differentiate between meaningful interoceptive signals that may flag pleasant or aversive consequences, and constant low-level fluctuations in the interoceptive state. This is paired with an altered belief system such that these individuals are biased to believe these low-level fluctuations are meaningful and aversive [4, 5]. Under this model, incorrect inferences about the causes of these interoceptive prediction error signals may directly contribute to the symptoms of anxiety disorder (e.g. changes in affect, worrisome thoughts and avoidance behaviors).

Here, we propose that one of the reasons interoceptive prediction error signals are misattributed, often to aversive causes, is due to the presence of alexithymia. Alexithymia, a specific difficulty in identifying and describing one's own emotions [8] is found in approximately 13% of the general population [26]. A number of studies have found an association between alexithymia and anxiety traits in nonclinical samples (e.g. [27, 28]) and an association between alexithymia and altered interoceptive processing (e.g. [29]). Alexithymia is seen in much higher rates in individuals diagnosed with an autism spectrum disorder [30], with comorbidity of around 50% frequently reported [31, 32]. Both interoceptive differences and anxiety are also common in this population [33, 34], suggesting an association between these constructs.

Indeed, a co-occurrence of comorbid anxiety, alexithymia and interoceptive differences are present in a number of psychological conditions, including eating and feeding disorders [35, 36, 37, 38, 39, 40, 41], substance dependence [42, 43, 44] and depression [27, 45, 46].

In the domain of interoceptive accuracy, a number of reports have found reduced performance in detecting and using interoceptive signals in individuals with alexithymia ([47, 48], although see [49, 50] for recent null results). In the domain of interoceptive sensibility, by contrast, there is evidence to suggest that alexithymics are hypersensitive to interoceptive sensations [51, 52, 53]. Divergent findings across interoceptive domains are not unusual either in normative [14], or clinical populations [33, 34]. Indeed, correspondence across dimensions is generally only seen in individuals with very good interoceptive accuracy. Taken together, these results suggest an interoceptive profile in alexithymia of reduced interoceptive accuracy and heightened interoceptive sensibility, similar to that previously reported in autism [33, 34].

Here, we propose that heightened interoceptive sensibility in combination with a difficulty attributing these signals to emotional states, operationalized here as alexithymia, predisposes an individual to anxiety-related characteristics. This elevates their risk for anxiety over and above altered interoceptive processing or alexithymia alone. The hereto mixed results in the interoceptive accuracy literature suggests that it may be the perceived awareness of interoceptive signals that is most robustly related to anxiety, not objective ability to accurately detect interoceptive signals. As such, we measure interoceptive sensibility here using a self-report questionnaire measure. As in previous research (e.g. [27, 28]), we probe anxiety traits in the general population to inform our understanding of the clinical disorder. We therefore test the hypothesis that the relationship between self-report interoceptive sensibility and anxiety is mediated by alexithymia.

Methods

Participants

A total of 426 adults participated as part of a science engagement project at a music festival. Ethical approval was granted by University College London Ethics Committee, all procedures were conducted in accordance with the Declaration of Helsinki and informed written consent was obtained from all. Any participants either missing questionnaire or demographic data were excluded, leaving a final sample of 384. Ages ranged between 16 and 65 years (mean = 33.49, SD = 13.87), and 255 were female (66%).

Measures

Participants completed both State and Trait forms of the State Trait Anxiety Inventory (STAI [54]), the Awareness subsection of Porges Body Perception Questionnaire (BPQ [10]) and the Toronto Alexithymia Scale (TAS-20 [55]). A simplified version of the BPQ, developed in-house (S1 Text; [33]), was used to measure interoceptive sensibility. This version contains 39 items describing various sensations experienced in the body, and participants rate how often they experience each on a five-point scale of 1 ('Never') to 5 ('Always'). The TAS-20 contains 20 items which are scored by participants on a five-point scale from 1 ('Strongly Disagree') to 5 ('Strongly Agree'). The STAI contains two forms, the STAI-STATE asks participants to score twenty items on a four-point scale from 1 ('Not at all') to 4 ('Very much so') based on how well each item best describes them in the present moment. Similarly, the STAI-TRAIT asks participants to score twenty items on the same scale as the STAI-STATE based on how they generally feel. As we were primarily interested in dispositional anxiety traits, we only included anxiety data from the STAI-TRAIT in the present analysis.

Procedure

The experiment was explained to participants by one of the researchers and informed consent was obtained from all. Participants were given a questionnaire booklet to complete, containing all three measures.

Data analysis

Preliminary analyses assessed the influence of demographic characteristics (age, sex) on the variables under investigation using independent t-tests (sex) and Pearson correlations (age). Then, relative contributions of interoceptive sensibility and alexithymia to anxiety scores were assessed using simple and multiple regression analysis, using the four-step method of testing for mediation proposed by Baron and Kenny [56]. Thirdly, factor analysis using Varimax (orthogonal) rotation was used to assess whether any associations found between the variables of interest were a result of similarity between the measures.

Results

Of the final sample of 384, 66 participants were above the cut-off for alexithymia (17.19%), a little higher than the previous 13% seen in a general population sample [26] using the same cut-off of a total score greater than 61. Trait anxiety was significantly higher in women (mean = 44.94, SD = 10.69) than men (mean = 41.60, SD = 10.35) [t(382) = 2.93, p = 0.004, d = 0.32]. Alexithymia was significantly higher in men (mean = 51.88, SD = 9.07) than women (mean = 48.48, SD = 10.69) [t(297.28) = 3.268, p = 0.001, d = 0.34]. Interoceptive sensibility was significantly higher in women (mean = 2.59, SD = 0.51) than men (mean = 2.43, SD = 0.53) [t(382) = 2.81, p = 0.005, d = 0.30]. All three measures were found to significantly decrease with age, including trait anxiety [r = -0.30, p<0.001], alexithymia [r = -0.24, p<0.001] and interoceptive sensibility [r = -0.26, p<0.001] [df = 382]. Sex and age were therefore entered as control variables in subsequent analyses.

A four-step regression analysis was used test our hypothesis that alexithymia mediates the relationship between interoceptive sensibility and anxiety. Firstly, simple regression confirmed that interoceptive sensibility significantly predicted trait anxiety [β = 0.36, p<0.001], interoceptive sensibility predicted alexithymia [β = 0.20, p<0.001], and alexithymia predicted trait anxiety [β = 0.40, p<0.001]. A multiple regression with age, sex, interoceptive sensibility and alexithymia as predictors revealed both interoceptive sensibility [β = 0.23, p<0.001] and alexithymia [β = 0.34, p<0.001] to be significant predictors of trait anxiety, explaining more of the variance in anxiety scores [Adjusted R^2 = 0.28] than either interoceptive sensibility or alexithymia alone [Adjusted R^2 = 0.12 and 0.16, respectively]. Those with high interoceptive sensibility and alexithymia most likely also had high trait anxiety (Fig 1).

As Kolmogorov-Smirnov tests indicated that responses to individual items within the measures were not normally distributed (p<0.001), a factor analysis using the principal axis factors method of extraction with Varimax (orthogonal) rotation was used to verify that the associations observed were not a result of similarity between measures. The Kaiser-Meyer-Olkin measure of adequate sample size (KMO = 0.86) and the Bartlett's test of sphericity (p<0.001) returned satisfactory values to proceed. The scree test suggested there were three separate factors in the data, representing the three separate questionnaires (see Factors 1–3, S1 Table). However, these three factors only cumulatively explained 27.91% of the variance. Using the criterion of retaining all factors with an Eigenvalue of greater than 1.0, indicated 20 separate factors in the data. Retaining these 20 factors, a component matrix was obtained after 22 iterations, suggesting that the measures of interoceptive sensibility, alexithymia and trait anxiety all loaded onto separate factors (see S1 Table).
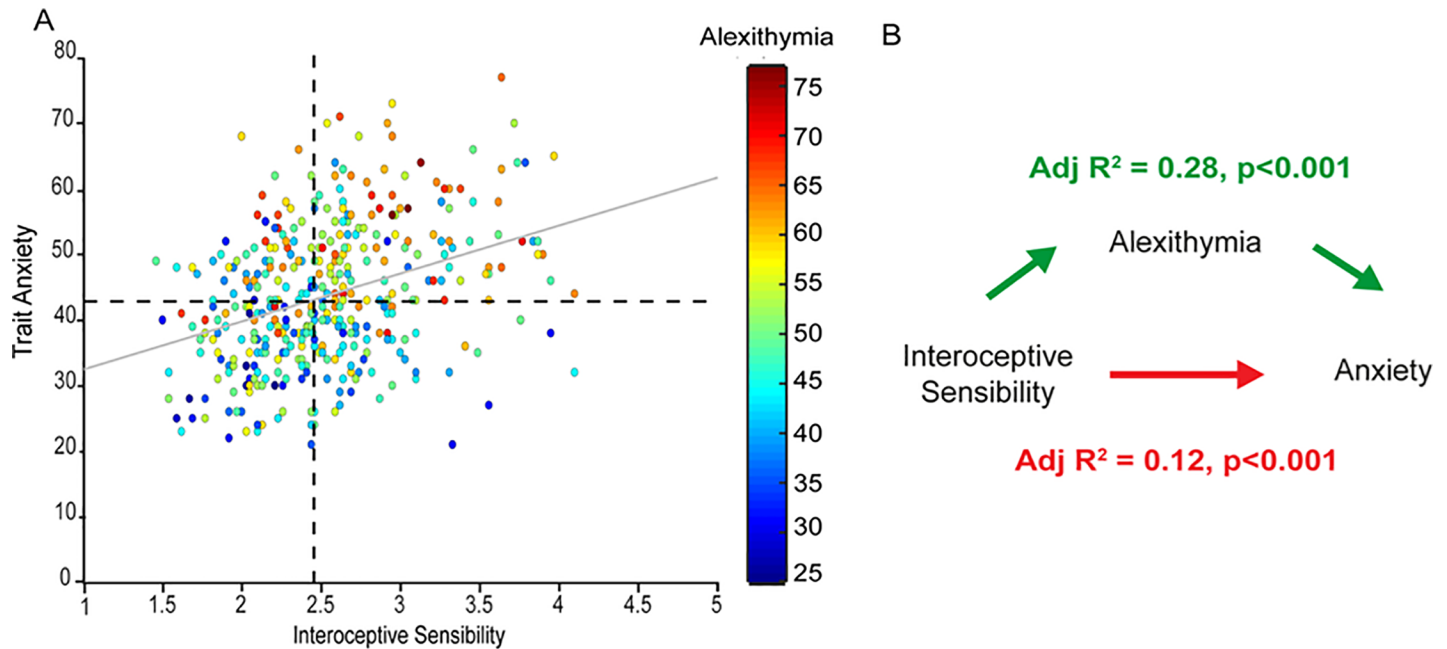
Fig 1. The positive association between interoceptive sensibility and trait anxiety is partially mediated by alexithymia, such that those most at risk for clinically significant levels of trait anxiety have both a propensity for high interoceptive sensibility and high levels of alexithymia (represented in the upper right quadrant of the plot [Panel A]). Including both alexithymia and interoceptive sensibility in the model explains more variance than simply including interoceptive sensibility alone [Panel B].

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Discussion

Our hypothesis that alexithymia plays a mediating role between interoceptive sensitivity and anxiety traits was supported—individuals with both high interoceptive sensibility and alexithymia scores are the most likely to report clinically significant levels of anxiety. Factor analysis confirmed that this was not the result of overly similar items across the questionnaires. These data provide support for the theory that the perception and misattribution of bodily sensations is a key component of anxiety [7], highlighting the additive role that alexithymia plays in this relationship. Indeed, individuals with anxiety may struggle to attribute bodily sensations accurately due to the presence of alexithymia.

The relationship between anxiety and interoception is clearly complicated, as demonstrated by the mixed results to date. Some studies find heightened interoceptive accuracy in anxiety [15, 16, 17], while others find it to be reduced [19]. Anxiety disorders represent a diverse category of conditions including panic disorder, social anxiety disorder, generalized anxiety disorder and specific phobias [57]. As such, it is likely that heterogeneous samples with diverse symptoms, as well as varying levels of symptom severity, contribute to the divergent findings to date. This is in addition to the role of different measurement protocols.

However, while the present findings relate only to the domain of interoceptive sensibility, it is worth considering that the inconsistencies in the literature may also be explained by the neglect of alexithymia as a mediating factor. Indeed, it was recently reported that alexithymia may fulfil this role in the relationship between interoceptive processing and autism [48, 58], with the relationship between autism and reduced interoceptive accuracy disappearing after controlling for alexithymia (however, see [59]).

Doubt is shed on this hypothesis however, by two recent publications, which find no association between alexithymia and interoceptive accuracy in both the general population, and

autism [49, 50]. It was also recently reported that the relationship between interoceptive accuracy and alexithymia is only significant when a number of potential psychological and physiological confounds are accounted for [60]. These 11 confound variables include age, sex, time perception, anxiety, depression, body mass index (BMI), mean heart rate, knowledge about heart rate, systolic blood pressure, and heart rate variability [60]. The absence of measures of many of these confound variables in both [49] and [50] may account of these null findings.

Within the domain of interoceptive sensibility, the majority of previous studies find heightened perceived awareness of interoceptive signals in alexithymia [51, 52, 53]. Mehling [61] highlights the importance of differentiating maladaptive anxiety-driven attention to interoceptive sensations and a more adaptive, mindful attention style. The Multidimensional Assessment of Interoceptive Awareness (MAIA [62]) was developed as a measure of adaptive interoceptive sensibility and has been found to be negatively associated with alexithymia [50, 63]. Complimentary preliminary findings, of an association between interoceptive confusion and alexithymia, using an Interoceptive Confusion Questionnaire, have also been reported [64]. Taken together with the more traditional questionnaire measures of interoceptive sensibility, the picture in alexithymia appears to be of an anxiety-related, maladaptive interoceptive style.

This study provides empirical evidence to support current theories that describe an inability to cognitively appraise and affectively label interoceptive signals as a key component in the development of anxiety. There is debate in the existing literature as to whether anxiety sufferers more or less accurately perceive interoceptive signals, pay greater attention to them, or simply attribute these sensations to more catastrophic interpretations. The present findings do not provide information about the accuracy with which high-anxiety individuals perceive interoceptive signals, as this was not objectively measured. What is clear, however, is that these individuals report noticing bodily states more often than those with low anxiety. This is suggestive of an attentional style that focusses on interoceptive sensations. The present results also suggest this is combined with a difficulty in accurately interpreting and labelling these sensations, which fits well with the idea that these sensations may be misattributed as troubling or dangerous [65].

Theoretically, it has been suggested that anxiety is associated with altered inference about the causes of interoceptive signals [4]. Contributing to this is a reduced signal to noise ratio for afferent interoceptive information, and altered beliefs about, and heightened anticipation of, the aversive consequences of interoceptive states [4, 5]. As such, anxiety-prone individuals detect random fluctuations in the bodily state that would normally remain sub-threshold, and then associate those signals with aversive or negative outcomes. In a complimentary but orthogonal literature, interoception has been conceptualized within a Bayesian predictive coding framework, whereby afferent interoceptive prediction errors update predictions about the condition of the body (e.g. [66, 67, 68]). Bayesian predictive coding models are guided by the free energy principle, which states that living organisms are motivated to reduce the difference between expected and encountered sensory inputs [69]. In predictive coding terms, this is actualized by having beliefs (or 'priors') about the world which guide predictions about incoming sensory input. Any differences between expected and encountered sensory input is represented as prediction error. Importantly, the relative weight or importance that we attribute to prediction errors is called 'precision'. It is argued that precision is represented physiologically as post-synaptic gain of superficial pyramidal cells (which signal prediction error) [70, 71].

Within such a framework, altered beliefs that focus on the negative consequences of interoceptive states can be conceptualized as negatively biased priors. Similarly, a reduced afferent signal to noise ratio in anxiety can be likened to increased precision or synaptic gain on afferent interoceptive information. As suggested by Paulus and Stein [4, 5], these two mechanisms

may work in tandem to increase the risk of anxiety. Specifically, in predictive coding terms, increased precision increases the weighting of prediction error signals, exacerbating the influence of biased priors on explaining the causes of the perceived sensations. The present findings suggest that the development of incorrect priors may in part be due to alexithymia.

A growing body of evidence now implicates altered interoceptive processing in a number of clinical conditions, including autism [33, 34, 72], eating disorders [35, 36, 37, 39, 41], and substance dependence [43, 73]. Alexithymia is also often seen in higher levels in these conditions than in the general population. Future work should seek to disentangle the relationship between the processing of somatic sensations and their integration into emotional states in each of these diagnostic categories. Approaching interoception from a dimensional perspective, as proposed by Garfinkel and colleagues [13, 14], is likely to prove crucial in this endeavor.

A few limitations of the present investigation are worth noting. The measures used in this study all rely on the validity of self-report. In addition, strong conclusions about the directionality of the effects are difficult to draw, due to the correlational nature of the observations. That is, it is also feasible that individuals who suffer from anxiety become increasingly alexithymic and sensitive to interoceptive sensations. Future research employing a longitudinal or interventionist approach may be required to fully delineate this. If it is confirmed that individuals who display both high levels of interoceptive sensibility and alexithymia go on to develop anxiety, interventions that target the attribution of bodily sensations may prove valuable in reducing anxiety.

Here, we present evidence that high levels of interoceptive sensibility, in combination with alexithymia, heightens the risk for clinically significant trait anxiety. We suggest that a heightened sensibility for interoceptive signals, combined with a difficulty in attributing these sensations to emotions, leaves these sensations vulnerable to catastrophizing interpretation. Within a Bayesian predicative coding framework, heightened interoceptive sensibility can be likened to increased precision on afferent interoceptive signals. This is combination with negatively biased priors about interoceptive states, which we argue may be caused by alexithymia, increases the individual's risk for anxiety. Interventions that target the accurate attribution and interpretation of bodily sensations may prove valuable in reducing anxiety.

Supporting information

S1 Text. Simplified awareness subscale of the Porges Body Perception Questionnaire. The scale was modified by simplifying the language and removing 6 items, which were deemed collapsible into other items. As an example of language simplification, item 3) 'An urge to cough to clear my throat' became 'A need to cough to clear my throat'. As an example of collapsing, items 17) 'A bloated feeling because of water retention' and 24) 'Stomach distension or bloatedness' were deemed collapsible into one: 'A swollen tummy'. Care was taken to ensure the integral meaning of the items was not altered. This modification was originally designed to make the questionnaire mare accessible for children, such that child and adult participants could complete the same measure in future research, and has been validated in a sample of participants aged 6 to 18 years old, showing good reliability [33].
(DOCX)

S1 Table. Factor analysis of items. Component loadings of items in abbreviated version of Awareness subsection of Porges Body Perception Questionnaire (BPQ [10, 33]), Toronto Alexithymia Scale (TAS-20 [54]) and Trait Form of the State Trait Anxiety Inventory (STAI [53]). The highest factor loading for each item is given below. The rotation converged in 66 iterations on 21 factors. Factors associated with the BPQ are shown in yellow, the TAS-20 in green, and

the STAI-Trait in blue. Items from the BPQ, the TAS-20 and the STAI-Trait all loaded onto separate factors. That is, no factor contained items from different questionnaires.
(DOCX)

S1 Data. Data.
(XLSX)

Author Contributions

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