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Associations Between Autism and Self-Reported Dimensions of Interoception

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Abstract

Despite a wealth of research on autism and interoception, there is not a clear consensus about which dimensions of interoception (if any) are related to autism. This study explored whether self-reported interoceptive accuracy, attention and evaluation are related to autism diagnosis and autistic traits. We analysed questionnaire responses from 519 participants, including 232 autistic participants. We found that people with an autism diagnosis had more negative interpretations of their bodily signals than people without an autism diagnosis, and increasing autistic traits in a general population sample were associated with higher interoceptive attention, lower interoceptive accuracy and higher negative interoceptive evaluation. Our findings suggest that interoceptive evaluation should be a priority for future research.

Lay Abstract

Autism is thought to be linked to differences in the way people notice, process and understand signals coming from inside of their bodies. This study explored how both autistic traits and autism diagnoses are associated with the processing of bodily signals. We found that among 519 participants, having more autistic traits meant that people paid more attention to body signals, reported lower accuracy at detecting them and had more negative interpretations of those signals. Autism diagnoses were associated with more negative interpretations of bodily signals.

Keywords

interoception, interoceptive accuracy, interoceptive attention, interoceptive evaluation, mental health

Introduction

Interoception (the processing of internal, bodily signals; Craig, 2002) is a multidimensional construct. The most used taxonomy splits interoception into accuracy (performance on objective behavioural tests of interoceptive perception) and sensibility (self-evaluated assessment of subjective interoception) (Garfinkel et al., 2015). However, some have suggested this model conflates the method of assessment (objective or subjective) with the dimension of interoception (Murphy et al., 2018). Another model was proposed which separated interoceptive accuracy (whether an individual can correctly identify the occurrence of a particular interoceptive event) and attention (the amount of time individuals are aware of interoceptive signals, and how salient these signals are; Murphy et al., 2018), both of which can be measured subjectively and objectively. A further dimension of interoception which is currently garnering more research attention is evaluation (how signals are interpreted, including affective experience and ascribed meaning; Herbert, 2020), which can also theoretically be measured both objectively and subjectively. At present, it is difficult to compare the relative contribution of these different dimensions to clinical symptoms or cognitive or affective processes, as interoceptive accuracy is typically measured objectively, while interoceptive attention and evaluation are measured subjectively.

It has been argued that autism is linked to atypical interoception (Hatfield et al., 2019; Quattrocki & Friston, 2014); however, empirical findings are inconsistent. With respect to self-reported interoceptive attention, results of

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one meta-analysis indicate no difference between autistic and non-autistic participants when using questionnaires such as the Noticing Scale of the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012) and the Awareness subscale of the Body Perception Questionnaire (BPQ, Porges, 1993). However, the analysis indicated high levels of heterogeneity across studies (Williams et al., 2023). Moreover, the BPQ includes questions on signals that may be considered exteroceptive (e.g., sweat on the forehead) and mainly focuses on inherently negative signals, limiting generalisability across all interoceptive signals.

A later study by Yang and colleagues (2023) found a negative association between MAIA total scores and autistic traits in a general population sample. However, the MAIA was designed to be used as a series of separate subscales; thus, using total scores conflates multiple dimensions of interoception.

A theoretical paper (Trevisan, Mehling, & McPartland, 2021) suggested that autistic individuals may show lower levels of adaptive interoceptive attention to neutral signals but higher levels of maladaptive interoceptive attention or increased anxiety-driven somatisation. While a study using the BPQ, which is claimed to capture the maladaptive form of interoceptive attention, found higher scores in autistic compared to non-autistic participants (Garfinkel et al., 2016), studies found adaptive interoceptive attention (measured with the MAIA and Interoception Sensory Questionnaire) showed no relationship with autism (Fiene & Brownlow, 2015; Fiene et al., 2018; Mul et al., 2018). Trevisan and colleagues substantiated their claims with their own qualitative study, in which autistic participants reported lower adaptive but higher maladaptive attention to interoceptive signals (Trevisan, Parker, & McPartland, 2021). According to this theory, autistic individuals would be expected to show lower interoceptive attention and higher negative interoceptive evaluation than non-autistic participants, or that there will be no overall difference between total interoceptive attention scores, but that when split into anxiety- and non-anxiety-related signals, attention will be higher in the former and lower in the latter in autistic compared to non-autistic groups.

Few studies have considered self-reported interoceptive accuracy in autism. Some studies have used the Awareness Subscale of the Body Awareness Questionnaire (BAQ; Shields et al., 1989). Several items in this subscale correspond to interoceptive accuracy, but the subscale also includes items that measure interoceptive attention. Fiene and Brownlow (2015) found autistic individuals scored significantly lower on this subscale than non-autistic individuals. Contrastingly, other studies have found no difference in this subscale between autistic and non-autistic adults (Jeon et al., 2024) and youth (Butera et al., 2023).

Self-reported interoceptive accuracy can also be assessed by taking confidence measures during interoceptive accuracy task performance. Meta-analytic results indicate that there is higher self-reported confidence in cardiac interoceptive accuracy task performance in autistic compared to non-autistic participants. However, results are reliant on only five effect sizes, with three conducted on children (which may limit generalisability to autism in adulthood; Williams et al., 2023). As results were restricted to the cardiac domain, it is unknown how cross-domain subjective interoceptive accuracy may be related to autism.

One qualitative paper suggests that interoception may show similar patterns to exteroceptive sensory processing in autism (Proff et al., 2022), with the potential for both increased and reduced attention and accuracy, depending on the individual and context (Adams et al., 2025). If so, one might expect to see different distributions of interoceptive attention and accuracy scores in autistic and non-autistic individuals, reflecting a tendency for autistic individuals to show either hyper- or hypo-accuracy and attention, resulting in a greater quantity of high and low scores. This could either manifest as a bimodal distribution or one which is more platykurtic in autism. Despite qualitative support, there has not yet been much empirical work exploring this possibility. Overall, the literature on interoceptive accuracy and attention in autism remains inconclusive as to whether either is different in autistic versus non-autistic individuals.

There is a lack of empirical work considering self-reported interoceptive evaluation in autistic compared to non-autistic individuals. One study found no significant association between the physical subscale of the Anxiety Sensitivity Index (ASI) and autistic traits, as measured by the Autism Quotient (AQ-50) (Baiano et al., 2022). Given qualitative work that highlights overly negative interoceptive evaluation as both common and causative of anxiety in autistic adolescents (Adams et al., 2025), interoceptive evaluation in autism may warrant further investigation.

An important covariate when considering the association between autism and interoception is anxiety, which appears associated with both autism and interoception (Garfinkel et al., 2016; Paulus & Stein, 2006; van Steensel et al., 2011). Alexithymia is also known to be associated with autism (Kinnaird et al., 2019) and interoception (Brewer et al., 2016) and may act as a confounder if not controlled for (Bird & Cook, 2013). Similarly, other mental health conditions are more likely to occur in autistic individuals (Underwood et al., 2023) and may also be influenced by or influence interoception (Brewer et al., 2021).

Those in the autistic community have highlighted mental health interventions and anxiety as, respectively, the first and fourth most pressing concerns for future research (Cusack & Sterry, 2016). Interoception is an important lens through which we may better be able to understand some of the associations between autism and mental health conditions such as anxiety (Brewer et al., 2021). This study addresses gaps in the literature by employing three self-report measures which measure distinct interoceptive dimensions (accuracy, attention and evaluation). This study aimed to address limitations of prior research by using a measure of autistic traits that is more valid in women than the commonly used AQ (Baron-Cohen et al., 2001). Moreover, analyses in this study controlled for relevant covariates, including alexithymia. In addition, this study explores autism at both the diagnostic level and as a trait in the general population, in response to debates as to whether autism is better conceptualised as a dimension or a discrete diagnosis (Lord & Jones, 2012).

Our hypotheses were as follows:

Hypothesis 1 (H1): Autistic traits in our general population sample will be positively associated with negative interoceptive evaluation, but not interoceptive accuracy or attention, after accounting for relevant covariates.

Hypothesis 2 (H2): Autistic participants will show more negative interoceptive evaluation, but comparable interoceptive accuracy and attention when compared to non-autistic participants, after accounting for relevant covariates.

Hypothesis 3 (H3): Autistic participants will have a greater proportion of very high and low scores on both interoceptive accuracy and attention than non-autistic participants.

Method

Participatory Methods

Two autistic non-researchers provided feedback on the initial research design, including whether the research questions addressed what they hoped to see in future autism research, during one-on-one, in-person meetings with the lead author. They are referred to in the acknowledgements by pseudonyms, as per their requests. Yellowfish is a 26-year-old, Black British, bisexual autistic woman. Purplecat is a 26-year-old, Southeast Asian British, autistic, non-binary individual who also has an attention-deficit/hyperactivity disorder (ADHD) diagnosis. Research design was also informed by areas of importance illustrated by participatory qualitative research conducted by the authors in collaboration with a group of 13 autistic adolescents (Adams et al., 2025).

Participants

This article was part of a larger study on autism and mental health. The inclusion criteria for this study were that all participants were 18 years old or older and spoke English fluently. Participants were recruited internationally through social media, existing laboratory databases and adverts on relevant websites. All participants were entered into a prize draw, where 10 participants were randomly selected to win £25 Amazon vouchers. Ethics approval was granted by the Oxford University Medical Science Division's Ethics Committee (reference: R86431/RE003).

G-Power calculations suggested that a total sample size of 128 (64 in each group) would be sufficient to detect a medium effect size (0.25) using an analysis of covariance (ANCOVA) with seven covariates. For the planned linear multiple regressions including interaction terms, a sample size of 77 was recommended to detect an effect size of 0.15 when including six covariates and three predictors. We over-recruited to account for some participants not passing validation checks for group membership. In total, 519 participants were recruited, including 232 with validated autism diagnoses (see the "Procedure" section on diagnosis validation). In total, 143 participants met the criteria to be included in the "not autistic" group.

Materials

For brevity, only the measures used within this study are described. For correlations between each of these measures, see the Supplementary Materials (Supplement 1). Internal reliability (Cronbach's alpha) for each of the measures within the whole sample and only the autistic sub-sample are reported in Supplement 2.

Toronto Alexithymia Scale. The 20-item scale in which participants report how much they agree with statements pertaining to alexithymic symptoms on a five-point Likert-type scale (Bagby et al., 1994). The Toronto Alexithymia Scale (TAS-20) has acceptable internal consistency in autistic (Cronbach's alpha = 0.85, Falter-Wagner et al., 2022) and general population samples (Cronbach's alpha = .81) and good test re-test reliability at 3 weeks (r = .77, Bagby et al., 1994).[1]

Depression, Anxiety, Stress Scale-21 Anxiety Subscale. Participants rate the extent to which they have experienced seven anxiety symptoms over the past week on a four-point severity/frequency scale. This measure was chosen due to its separation of anxiety from depression (Lovibond & Lovibond, 1995). Test–retest reliability was good in a general population sample (r = .79, Brown et al., 1997), and internal consistency was good in general population (Cronbach's alpha = .89, Brown et al., 1997) and autistic samples (Cronbach's alpha = .84, Park et al., 2020).

The Comprehensive Autistic Trait Inventory. In total, 42 five-point Likert-type scale items pertain to the traits of autism, with seven items associated with each subscale: Social Interactions, Sensory Sensitivity, Repetitive Behaviours, Communication Difficulty, Cognitive Rigidity and Social Camouflaging. The Comprehensive Autistic Trait Inventory (CATI) is suggested to be better for capturing autism in females than the AQ (English et al., 2021), has a better predictive ability for classifying autism (Youden's Index = .62 vs. .56–.59) and has a high internal consistency in a general population sample (Cronbach's alpha = .95), although psychometrics are not yet available within autistic populations (English et al., 2021).

AQ-Short. This includes 28 statements pertaining to symptoms of autism, and participants rate their agreement on a four-point Likert-type scale. Internal consistency is acceptable in a general population sample (Cronbach's alpha = .78) and good in an autistic sample (Cronbach's alpha = .86) (Hoekstra et al., 2011). This measure was only used to confirm participants with high autistic traits were not included in the non-autistic control group.

The Interoceptive Accuracy Scale. In total, 21 items pertain to the accuracy of one's perception of somatic signals on a five-point scale. Internal consistency and test–retest reliability are good for this measure [$\alpha = .88$, $r(115) = .754$; Murphy et al., 2020] in general population samples but unknown in autistic samples.

The Interoceptive Attention Scale. In total, 21 items assess attention to interoceptive signals, each rated on a five-point Likert-type scale. Internal consistency is excellent for this measure ($\alpha = .905$), and test–retest reliability is good [$r(144) = .709$; Gabriele et al., 2022] in general population samples but unknown in autistic samples.

The Negative Interoceptive Evaluation Scale. In total, 20 items assess the negative ways in which one might interpret eight different interoceptive signals, each rated on a five-point Likert-type scale. Internal consistency ($\alpha = .848$) and test–retest reliability ($r(147) = .67$) are both good in a general population sample (Adams et al., in press) but unknown in autistic samples.

The International Cognitive Ability Resource Matrix Reasoning. In total, there are 11 matrix reasoning items similar to those used in Raven's Progressive Matrices. The stimuli are three-by-three arrays of geometric shapes with one shape missing. Participants must identify which of six geometric shapes is the missing shape (Condon & Revelle, 2014).

International Cognitive Ability Resource Verbal Reasoning. In total, 16 verbal reasoning items include a variety of logic, vocabulary and general knowledge questions (Condon & Revelle, 2014). Both the International Cognitive Ability Resource (ICAR) matrix and verbal reasoning questionnaires are highly correlated with the current gold standard of measuring cognitive abilities (the Wechsler Adult Intelligence Scale – Fourth Edition; Wechsler, 2012; Young, 2020), although further psychometric information is not available in either the general population or autistic samples.

Procedure

Recruitment materials included either a link or QR code that directed participants to the study, hosted on Qualtrics. Participants were shown an information sheet and then completed a short screening questionnaire to ascertain their eligibility. If eligible, participants were directed to the consent form, followed by the main questionnaire. Completion took around 1 hr. Participants were able to skip any questions.

Participants provided their age and gender before completing the questionnaires outlined in the "Materials" section. They were then asked a series of questions about their physical and mental health, including whether they had ever received a diagnosis of an anxiety disorder or autism. If they indicated "yes," participants were asked to specify the clinic in which they were diagnosed, the clinician who diagnosed them, the year they were diagnosed and, in the case of anxiety disorders, which disorder and whether the diagnosis is still active. A diagnosis was considered verified if the participant provided answers for at least two of the three questions for autistic participants, or four of these five questions for participants with anxiety. They were also asked to report any other current mental health or neurodevelopmental conditions.

Data Cleaning

In total, 1,177 respondents were excluded, as they either failed Qualtrics' reCAPTCHA checks, gibberish had been entered into any of the open text options, response times were under 10 min or they had not completed the questionnaire.

Participants with more than 10% missing responses in the same questionnaire (excluding cognitive tests) or with more than 20 missing responses in total (excluding cognitive tests) were removed to avoid impacting the validity of missing value imputations. This resulted in the removal of eight participants.

Gender was dummy coded as two variables: male (1) and not male (0), and female (1) and not female (0), allowing for three categories of gender: male, female and other. Under the category of other, participants reported the following (reported here verbatim): non-binary, NB, androgynous, agender, demigirl, no gender and fluid.

Cognitive capability was calculated as the total of the ICAR matrix and verbal reasoning scores, providing a proxy measure that can be seen as comparable to intelligence quotient (IQ) scores.

The presence of another current mental health or neurodevelopmental condition was coded in a binary manner. If participants listed any mental health or neurodevelopmental condition (as included in the *Diagnostic and Statistical Manual of Mental Disorders*, Fifth Edition; American Psychiatric Association, 2013) that was not an anxiety disorder or autism, it was coded as 1, if not, it was coded as 0. Anxiety disorders were not included, as trait-level anxiety was controlled for separately.

Interoceptive accuracy was operationalised as the total Interoceptive Accuracy Scale (IAS) score, interoceptive attention as the total Interoceptive Attention Scale (IATS) score, negative interoceptive evaluation as the total Negative Interoceptive Evaluation Scale (NIES) score, alexithymia as the total TAS-20 score, autistic traits as the total CATI score and traits of anxiety as the total Depression, Anxiety, Stress Scale (DASS)-Anxiety score.

Participants were grouped into those with and without a validated autism diagnosis (H2). Participants who did not report an autism diagnosis and scored below 26 on the AQ and 134 on the CATI (both thresholds were used for robustness) were included in the no autism diagnosis group. Those who did not fit into either the validated autism diagnosis or no autism diagnosis group were removed for any analyses that included autism diagnosis as a variable.

Analysis

Our analysis plan was pre-registered after data collection but prior to looking at the data (https://osf.io/cuh98/?view_only=62bd542efd63475fb9192e2ee3f8f318). Any analysis that was not pre-registered is specified. Data are available at: https://osf.io/vnb6m/overview?view_only=450469701a1744398ded151a90a29d39.

There was little missing data, with less than 0.1% of overall responses missing (Supplementary Materials, Supplement 3). Two participants had data missing for age, and five participants for gender. These participants were excluded from analysis, as we did not impute single-item variables.

To avoid questionnaire scores being affected by missing data, data missing at the item level was multiply imputed using the forest function on *r*, and total scores were calculated using these imputed values. Items were coded as factors (proportion of false classification [PFC] value = 0.21). Distributions of both the imputed and non-imputed datasets were compared, and as they were almost identical, this imputation was retained.

For H1, multiple linear regressions were conducted. The predictor variables were autistic traits and the dependent variables for each were interoceptive accuracy, attention and negative interoceptive evaluation. Covariates were age, gender, cognitive ability, presence of other mental health or neurodevelopmental conditions, alexithymia and anxious traits. Supplement 4 in Supplementary Materials shows how the assumptions for the multiple linear regressions were checked.

For H2, ANCOVA tests were conducted. The independent variable was whether participants had a validated autism diagnosis. The dependent variables for each were interoceptive accuracy, interoceptive attention and negative interoceptive evaluation. Covariates in all ANCOVAs included age, gender, cognitive ability, alexithymia, the presence of other mental health or neurodevelopmental conditions and anxious traits. Supplement 5 in Supplementary Materials shows how the assumptions were tested.

For H3, distributions of scores of interoceptive accuracy, attention and negative interoceptive evaluation were compared between the autistic and non-autistic groups using histograms and two-sample Kolmogorov–Smirnov tests.

The Benjamini–Hochberg adjustment was used to correct for multiple comparisons (Benjamini & Hochberg, 1995). All *p*-values for the main analyses and pre-registered and exploratory analyses were included in this. This includes analyses not reported in this article (manuscript in preparation). None of the *p*-values for the demographic information assumption checks or for control variables were included.

The multiple imputations for missing data were performed on R (Version 4.3.2). All other analyses were conducted using SPSS [Version 29.0.2.0 (20)].

Results

Trait-Level Analyses

Demographics. In total, 519 participants were recruited to test H1. In total, 104 (20.0%) were male, 366 (70.5%) were female, and 49 (9.4%) were another gender. In total, 232 (44.7%) had a validated autism diagnosis. In total, 100 (19.3%) had both an anxiety disorder and autism, while 96 (18.5%) had neither an anxiety disorder nor autism. In total, 246 (47.4%) had a mental health or neurodevelopmental condition other than an anxiety disorder or autism (Supplementary Materials, Supplement 6). Table 1 shows the descriptive statistics of the continuous variables.

All the assumptions for the multiple linear regressions were met (Supplementary Materials, Supplement 7).

Negative Interoceptive Evaluation. A multiple regression was conducted to predict NIES scores from autistic traits and covariates (see section "Analysis"). This model significantly predicted negative interoceptive evaluation, $F(8, 510) = 41.180, p < .001, R^2 = .392$. Significant predictors of higher negative interoceptive evaluation were not being male ($\beta = -.199$, $p < .001$), the presence of another mental health condition ($\beta = .085$, $p = .023$), higher autistic traits scores ($\beta = .287$, $p < .001$) and higher trait anxiety ($\beta = .316$, $p < .001$).

Interoceptive Accuracy. A multiple regression was conducted to predict interoceptive accuracy from the same measures as above. This model statistically significantly predicted interoceptive accuracy, $F(8, 510) = 23.439, p < .001, R^2 = .269$. Significant predictors of higher interoceptive accuracy were higher age ($\beta = .129$, $p = .001$),

Table 1. Demographic Information for the Whole Sample.

	M	*SD*	Range	Skewness	Kurtosis	*KS*	*SW*
Age[a]	36.7	15.2	18-82	.727	-.402	.126 (<.001)	.923 (<.001)
IQ[a]	16.7	5.9	2-27	-.489	-.597	.094 (<.001)	.960 (<.001)
TAS-20[a]	59.7	13.8	20-89	-.456	-.294	.080 (<.001)	.979 (<.001)
CATI[a]	154.7	30.2	56-209	-.746	.123	.085 (<.001)	.954 (<.001)
DASS-A[a]	6.9	4.6	0-21	.657	-.084	.117 (<.001)	.954 (<.001)
IATS	50.7	14.4	21-100	.282	-.012	.034 (.200)	.994 (.037)
IAS	71.8	14.0	21-105	-.177	.216	.042 (.027)	.992 (.005)
NIES	67.6	14.9	20-100	-.281	.006	.045 (.013)	.992 (.006)

Note. *N* = 519. *SD* = standard deviation. *KS* = Kolmogorov–Smirnov. *SW* = Shapiro–Wilk. IQ = combined scores from the ICAR Verbal and Matrix Reasoning tests. TAS-20 = Toronto Alexithymia Scale. CATI = Comprehensive Autistic Trait Inventory. DASS-A = Depression Anxiety Stress Scale Anxiety Subscale. IATS = Interoceptive Attention Scale. IAS = Interoceptive Accuracy Scale. NIES = Negative Interoceptive Evaluation Scale.
[a]When histograms were visually inspected, the distribution of these variables was non-normally distributed.

Table 2. Descriptive Statistics for the Autistic Group.

	M	*SD*	Range	Skewness	Kurtosis	*KS*	*SW*
Age[a]	39.5	14.2	18-76	.461	-.729	.103 (<.001)	.954 (<.001)
IQ[a]	16.88	5.9	3-30	-.457	-.588	.095 (<.001)	.962 (<.001)
TAS-20[a]	64.5	11.9	35-89	-.471	-.374	.086 (<.001)	.970 (<.001)
CATI[a]	169.4	20.6	64-205	-1.110	2.626	.096 (<.001)	.941 (<.001)
DASS-A[a]	7.3	4.6	0-21	.572	-.292	.137 (<.001)	.957 (<.001)
IATS	51.0	14.0	21-93	.228	.042	.046 (.200)	.991 (.138)
IAS[a]	69.4	13.7	24-105	.057	.265	.054 (.099)	.990 (.117)
NIES[a]	70.8	15.1	20-100	-.440	.434	.059 (.046)	.983 (.007)

Note. *N* = 232. *SD* = standard deviation. *KS* = Kolmogorov–Smirnov. *SW* = Shapiro–Wilk. IQ = combined scores from the ICAR Verbal and Matrix Reasoning tests. TAS-20 = Toronto Alexithymia Scale. CATI = Comprehensive Autistic Trait Inventory. DASS-A = Depression Anxiety Stress Scale Anxiety Subscale. IATS = Interoceptive Attention Scale. IAS = Interoceptive Accuracy Scale. NIES = Negative Interoceptive Evaluation Scale.
[a]When histograms were visually inspected, the distribution of these variables was non-normally distributed.

being male ($\beta = .132$, $p = .033$), lower autistic traits scores ($\beta = -.133$, $p = .014$) and lower alexithymia ($\beta = -.400$, $p < .001$).

Interoceptive Attention. A multiple regression was conducted to predict interoceptive attention from the same measures. This model statistically significantly predicted interoceptive attention, $F(8, 510) = 27.112, p < .001, R^2 = .298$. Significant predictors of higher interoceptive attention were lower age ($\beta = -.119$, $p = .003$), higher autistic traits ($\beta = .218$, $p < .001$) and higher trait anxiety ($\beta = .398$, $p < .001$).

Autistic Versus Non-Autistic Individuals

The autistic group had a total of 232 participants. Of these, 59 were male (25.4%), 149 were female (64.2%) and 24 (10.3%) were another gender. In total, 100 had a validated anxiety disorder diagnosis (43.1%) and 155 had other mental health or neurodevelopmental conditions (66.8%; Supplementary Materials, Supplement 8). Table 2 shows the descriptive statistics of all continuous variables within the autistic group.

The non-autistic group had a total of 143 participants. Of these, 26 (18.1%) were male, 109 (76.4%) were female, and 8 (5.5%) were another gender. In total, 20 (13.8%) had a validated anxiety disorder diagnosis, and 29 (20.1%) had another mental health or neurodevelopmental condition (Supplementary Materials, Supplement 9). Table 3 shows the descriptive statistics of all continuous variables within the non-autistic group.

Supplementary Materials provide the group differences without adjusting for covariates (Supplementary Materials, Supplement 10). Histograms indicated that although not all the dependent variables were normally distributed, the deviation from normality was not such that ANCOVAs were deemed inappropriate. All other assumptions were met (Supplementary Materials, Supplement 11).

Negative Interoceptive Evaluation. A one-way ANCOVA was conducted to examine the effect of the presence of an autism diagnosis on negative interoceptive evaluation while controlling for covariates (see section "Analysis"). There was a significant difference in negative interoceptive evaluation between participants with and without a validated autism diagnosis when controlling for covariates, $F(1, 366) = 28.41$,

Table 3. Descriptive Information for the Non-Autistic Group.

	Mean	*SD*	Range	Skewness	Kurtosis	*KS*	*SW*
Age[a]	33.0	15.9	18-77	1.252	.574	.180 (<.001)	.829 (<.001)
IQ[a]	17.5	5.6	6-26	-.825	.038	.138 (<.001)	.932 (.001)
TAS-20[a]	48.3	12.2	20-78	-.185	-.504	.053 (.200)	.988 (.235)
CATI[a]	117.7	20.8	56-147	-.833	.124	.148 (<.001)	.930 (<.001)
DASS-A[a]	5.0	4.0	0-19	.950	1.139	.130 (<.001)	.924 (<.001)
IATS[a]	46.2	13.7	21-79	.248	-.548	.067 (.200)	.981 (.049)
IAS	78.1	12.1	47-105	-.221	-.100	.062 (.200)	.988 (.273)
NIES	60.1	13.2	29-91	-.099	-.407	.059 (.200)	.991 (463)

Note. *N* = 143. *SD* = standard deviation. *KS* = Kolmogorov–Smirnov. *SW* = Shapiro–Wilk. IQ = combined scores from the ICAR Verbal and Matrix Reasoning tests. TAS-20 = Toronto Alexithymia Scale. CATI = Comprehensive Autistic Trait Inventory. DASS-A = Depression Anxiety Stress Scale Anxiety Subscale. IATS = Interoceptive Attention Scale. IAS = Interoceptive Accuracy Scale. NIES = Negative Interoceptive Evaluation Scale.
[a]When histograms were visually inspected, the distribution of these variables was non-normally distributed.

$p = .004$, η^2_p (partial eta squared effect size) = .022. Those with a validated autism diagnosis ($M = 70.8$, $SD = 15.1$) had greater negative interoceptive evaluation than those without ($M = 60.1$, $SD = 13.2$). This is a small effect size.

Interoceptive Accuracy. A one-way ANCOVA was conducted to examine the effect of the presence of an autism diagnosis on interoceptive accuracy while controlling for covariates (see section "Analysis"). There was no significant difference in interoceptive accuracy between participants with and without validated autism diagnoses when controlling for covariates, $F(1, 366) = 1.72$, $p = .190$, $\eta^2_p = .005$.

Interoceptive Attention. A one-way ANCOVA was conducted to examine the effect of the presence of an autism diagnosis on interoceptive attention, while controlling for covariates (see section "Analysis"). There was no significant difference in interoceptive attention between participants with and without validated autism diagnoses when controlling for covariates, $F(1, 366) = 0.98$, $p = .323$, $\eta^2_p = .003$.

Distributions Across Groups

Two-sample Kolmogorov–Smirnov tests indicated differences between autistic and non-autistic participants in the distribution of scores across each of the three self-report measures of interoception (NIES: $Z = 3.17$, $p < .001$; IAS: $Z = 3.31$, $p < .001$; IATS: $Z = 1.76$, $p = .004$). However, given the large sample size, even minor differences in distributions could result in significant results. Subsequently, we plotted distributions and compared them visually (Figure 1). All distributions are unimodal. The distribution of IATS scores is similar between autistic and non-autistic participants. IAS scores are slightly more negatively skewed in the non-autistic versus autistic participants. The NIES scores are slightly more negatively skewed in autistic compared to non-autistic participants. None of the differences in histograms are marked.

Exploratory Analyses

Attention to Anxiety-Related and Non-Anxiety-Related Signals and Autism. We wanted to explore whether there was empirical support for Trevisan and colleagues' hypothesis that attention to anxiety-related signals might be heightened in autistic compared to non-autistic individuals, while attention to non-anxiety-related signals would be reduced (Trevisan, Mehling, & McPartland, 2021). We split the IATS into questions pertaining to anxiety-related signals (heart beating fast, breathing fast, feeling nauseated, feeling pain from an injury and feeling pain not from an injury) and all other signals and then created total scores for each. We then compared the 232 autistic and 143 non-autistic participants (Tables 2 and 3).

Histograms indicated that although not all the dependent variables were normally distributed (the attention to anxiety-related signals was positively skewed), the deviation from normality was not such that ANCOVAs were deemed inappropriate. All other assumptions were met (Supplementary Materials, Supplement 12).

There was no significant difference in interoceptive attention to anxiety-related signals between participants with and without validated autism diagnoses when controlling for covariates, $F(1, 366) = 0.24$, $p = .635$, $\eta^2_p = .001$. There was also no significant difference (once multiple comparisons were accounted for) in interoceptive attention to non-anxiety-related signals scores between participants with and without validated autism diagnoses when controlling for covariates, $F(1, 366) = 1.17$, $p = .289$, $\eta^2_p = .003$.

Role of Alexithymia in Group Differences

When unadjusted, differences between the autistic and non-autistic groups were significant for both interoceptive accuracy and attention (Supplementary Materials, Supplement 1). To ascertain whether controlling for alexithymia reduced this association, we conducted further exploratory analysis and found that neither difference in interoceptive accuracy, $F(1, 366) = 1.55$, $p = .214$,

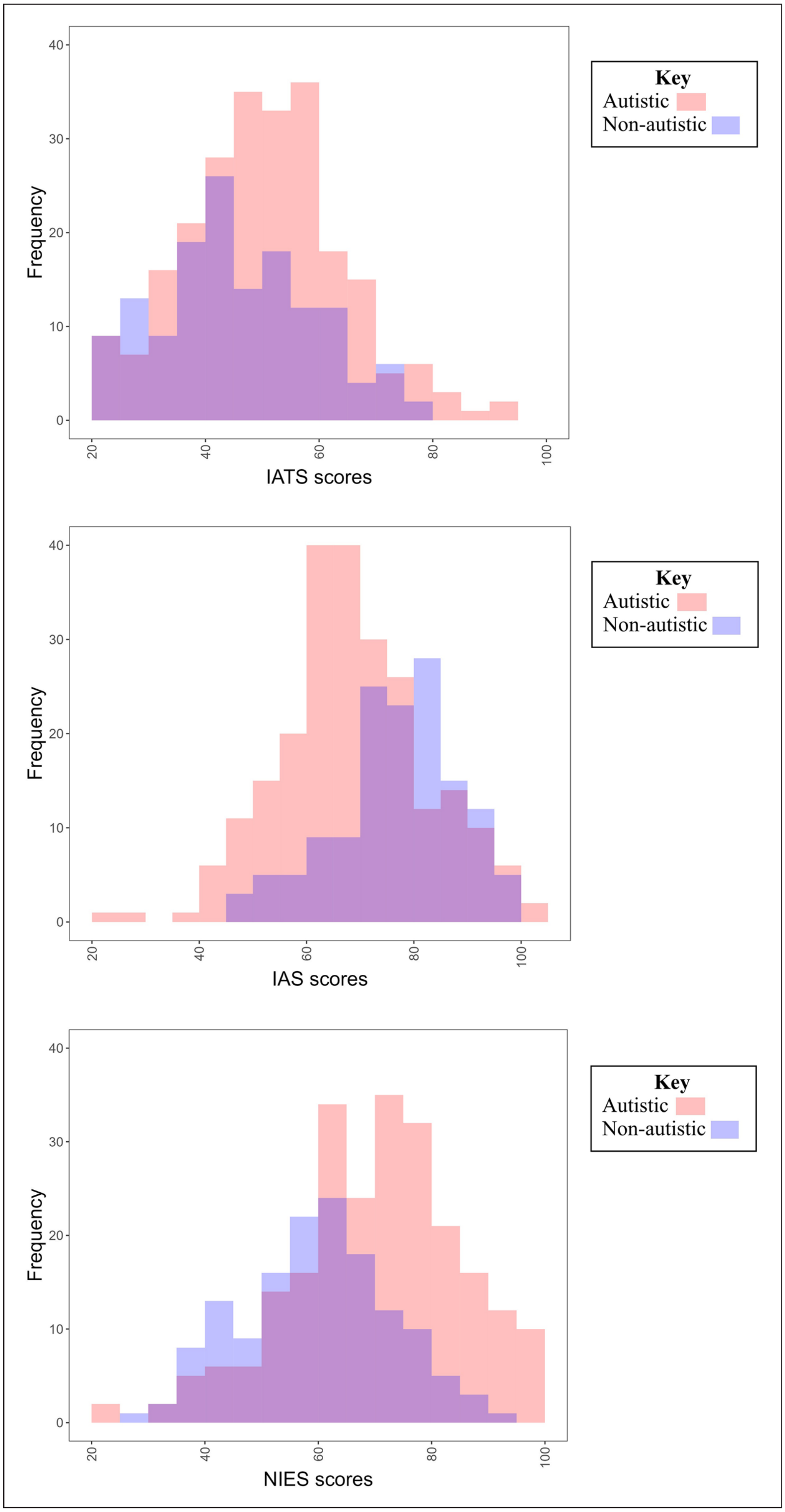

Figure 1. Interoception Score Distributions in Autistic and Non-Autistic Participants.
Note. This figure illustrates the differences in distributions of self-reported interoception dimensions between autistic and non-autistic participants. IATS = Interoceptive Attention Scale. IAS = Interoceptive Accuracy Scale. NIES = Negative Interoceptive Evaluation Scale.

$\eta^2_p = .004$, nor interoceptive attention, $F(1, 366) = 0.94$, $p = .334$, $\eta^2_p = .003$, remained significant when controlling only for alexithymia. Moreover, when controlling for all covariates aside from alexithymia, the difference in interoceptive accuracy, $F(1, 366) = 19.51$, $p < .001$, $\eta^2_p = .050$, but not interoceptive attention, $F(1, 366) = 1.89$, $p = .170$, $\eta^2_p = .005$, remained significant.

Discussion

The aim of this study was to gain a better understanding of how different self-reported dimensions of interoception relate to autism. As predicted in H1, with relevant covariates controlled for, higher autistic traits among our general population sample were predictive of increased negative interoceptive evaluation. This is consistent with the frequent reports of negative interoceptive evaluation in a qualitative study of autistic adolescents (Adams et al., 2025), suggesting increased negative interoceptive evaluation may be applicable across both adolescence and adulthood in autism. However, in contrast to what was predicted in our hypothesis, higher autistic traits were also predictive of reports of lower interoceptive accuracy and higher interoceptive attention. The finding of an association between higher autistic traits and higher interoceptive attention contrasts Yang and colleagues' findings of a negative correlation between autistic traits and interoceptive awareness in the general population (Yang et al., 2023). However, this study used a total score of all the MAIA subscales to calculate interoceptive awareness, conflating multiple independent dimensions of interoception.

H2 was that autistic participants would show more negative interoceptive evaluation, comparable interoceptive attention and comparable interoceptive accuracy when compared to non-autistic participants, after accounting for relevant covariates. Our results supported this hypothesis entirely and suggest an alternative way of interpreting the suggestions that "maladaptive" interoceptive attention to anxiety-related signals may be higher in autism, while "adaptive" attention to neutral signals may be lower (Trevisan, Mehling, & McPartland, 2021). In our exploratory analysis, we did not find direct support for this, as attention to anxiety-related signals was no different between autistic and non-autistic participants when relevant covariates were controlled for. It may be that the questionnaires that Trevisan and colleagues described as capturing "maladaptive attention" captured negative interoceptive evaluation.

There was limited support for H3 that autistic participants would have different distributions of interoceptive accuracy and attention scores when compared to non-autistic participants, driven by a greater frequency of both high and low responses. Although there were significant differences in the distributions for each of the three dimensions of interoception, the significance could have been driven by the large sample size. The histograms did not show greater clustering of scores at each end of the distributions in autistic compared to non-autistic participants, seemingly contrasting what one might expect if interoception was consistent with sensory accounts of autism derived from exteroceptive senses (Proff et al., 2022), which suggest that both hyper- and hypo-sensitivity may be present in autism. However, hyper- and hypo-sensitivity to interoceptive information may still occur in autism, without manifesting in these differences in distributions, if both hyper- and hypo-awareness occur in the same individual but within different contexts or across different interoceptive domains. For example, an autistic individual might experience hypersensitivity to their heart beating in anxiety-inducing situations but feel hyposensitivity to needing to use the bathroom. The high and low scores on these individual items would cancel out in the total score. It would be possible to test this in future research by examining the variance of item-level responses within each participant and then comparing within-person variation between the autistic and non-autistic groups.

While autistic traits predicted all three interoception measures (evaluation, accuracy and attention), the presence or absence of an autism diagnosis only predicted interoceptive evaluation. It is difficult to determine the reason for this discrepancy – alongside wider debates as to whether autism should be considered a dimension (Lord & Jones, 2012), it is worth noting that autistic traits were measured with the CATI. The CATI was used because it is thought to be more sensitive to autistic traits in women (English et al., 2021), but it measures traits (particularly camouflaging) that are not part of the diagnostic criteria for autism. It is possible that these non-diagnostic traits or adaptive coping strategies are associated with interoception, whereas the core traits of autism are not associated with interoceptive accuracy or attention after accounting for covariates. Alternatively, it may be the case that continuous trait measures are simply more sensitive to subtle associations.

Interestingly, the diagnostic group *did* predict scores on all interoceptive measures before accounting for covariates (see Supplementary Materials, Supplement 1). Alexithymia in particular has been considered to account for a number of spurious findings of group differences between autistic and non-autistic individuals (Bird & Cook, 2013; Brewer et al., 2015), and the inclusion of alexithymia as a sole covariate (without any of the other covariates included in the main analysis) was enough to make the presence or absence of an autism diagnosis non-significant for both interoceptive accuracy and attention, while controlling for all covariates aside from alexithymia resulted in a significant difference in accuracy (but not attention). However, this does not explain why an association was found with autistic traits, even when alexithymia was controlled for.

There are some limitations of this study that it would be pertinent to address. Participants were not required to validate diagnoses of mental health and neurodevelopmental conditions other than anxiety disorders and autism, meaning that there was a possibility of participants reporting conditions that they had not received a formal diagnosis for. Moreover, despite the validation checks for anxiety disorders and autism, participants may have still fabricated responses to these questions. However, as all participants were compensated at the same rate, there was no incentive to falsely report a diagnosis.

Moreover, by combining numerous, diverse conditions into a binary covariate for the presence of "other mental health or neurodevelopmental conditions," we were unable to explore the associations that each of these conditions has with autism and interoception. This is especially pertinent when one considers that certain conditions, such as eating disorders, are reported to be associated with both autism and interoception. We did this to avoid overfitting or multicollinearity. However, future research would benefit from a more comprehensive assessment of which mental health and neurodevelopmental conditions play a role in the association between autism and interoception.

Relatedly, our sample had high rates of co-occurring conditions, such as depression, ADHD and post-traumatic stress disorder (PTSD), which may have associations with interoceptive differences. This is often the case in psychology studies, and while it may limit the generalisability of results, as we controlled for co-occurring conditions in our analyses, it should not affect our findings (Ichijo et al., 2025).

There was also some concern about a degree of construct overlap in how interoceptive attention and anxious traits were measured, as the DASS-A includes two questions pertaining to the noticing of anxiety-related bodily signals. Although there were no issues with multicollinearity in any of our checks, it would be useful for further work to be completed using alternative measures of anxious traits that do not include items potentially related to interoception. Similarly, given that one may expect high correlations between negative interoceptive accuracy and interoceptive attention, the NIES and IATS may have reflected the same construct in this study (hypervigilance and negative appraisal process). However, the correlations are not such that it appears there is a complete overlap (see Supplement 1), and conceptually, one might expect a degree of separability between the two (for instance, if one has a high degree of attention in the absence of negative evaluation).

Moreover, the group comparisons in this study do not reflect the considerable heterogeneity one would expect to see within both autistic and non-autistic groups. For example, previous qualitative work has confirmed the heterogeneity of experiences of interoception in autistic adolescents (Adams et al., 2025). While it is useful to understand how groups differ on average, it is important to understand that there is likely a high degree of variability. Relatedly, future research that explores how different autistic traits relate to each dimension of interoception may be useful, following initial research that suggests that there are dissociations between the symptom domains of autism and how they relate to interoceptive functions (Palser et al., 2020).

Finally, in section "Exploratory analyses," we split attention into anxiety- and non-anxiety-related signals. It is important to note factor analyses have not yet confirmed the dissociation between these two signal types when using the IATS, and therefore, our categorisation of these signals may lack validity.

Despite these limitations, our pre-registered study contributes to an underexplored area in the literature by examining the role of subjectively perceived interoceptive accuracy, attention and evaluation in autism at both the trait and diagnosis levels. The study was conducted on a large sample, and several potential confounding variables, such as alexithymia and anxious traits, were controlled for.

In conclusion, our findings support the presence of interoceptive differences in autism. Higher self-reported interoceptive attention was related to higher autistic traits in a general population sample but not an autism diagnosis. Self-reported interoceptive accuracy was unrelated to autism diagnosis, but lower interoceptive accuracy was associated with higher autistic traits in a general population sample. Negative interoceptive evaluation was associated with both trait-level and diagnosed autism, making this dimension of interoception a key focus for further research on the contribution of interoceptive differences to mental health difficulties in autism.

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Ethical considerations

The study was conducted in line with the Declaration of Helsinki (1964), and ethics approval for this study was granted by the University of Oxford's Medical Science Division's Ethics Committee (reference: R86431/RE003).

Consent to participate

Informed consent was obtained from all individual participants included in this study, both for participation and for the publication of these results. Consent was obtained by participants clicking "yes" to all relevant questions in the consent form before the main questionnaire.

Author Contributions

Kiera Louise Adams: Conceptualisation; Data curation; Formal analysis; Investigation; Methodology; Project administration; Visualisation; Writing – original draft.

Caroline Catmur: Conceptualisation; Supervision; Writing – review & editing.

Geoffrey Bird: Conceptualisation; Supervision; Writing – review & editing.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Data Availability Statement

Anonymised data are available at: https://osf.io/vnb6m/?view_only=4a3d3ff381e54707a857135ba88ac540.

Supplemental Material

Supplemental material for this article is available online.

Note

1. Due to human error, the TAS-20 questions were presented out of order, with all the reverse-scored items appearing at the end.

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