Dissociations between self-reported interoceptive accuracy and attention: Evidence from the Interoceptive Attention Scale

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1. Introduction

In recent years there has been a renewed focus on interoception, the perception of one’s own internal bodily states (Khalsa et al., 2018), and its relevance for health and cognition. Such focus has, however, been accompanied by discussions regarding the measurement and conceptualisation of interoception. One influential model proposes a three-dimensional classification framework (Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015) distinguishing between (1) interoceptive accuracy (how objectively accurate an individual is at detecting internal signals using objective measures such as heartbeat counting or detection tasks; see Brener & Ring, 2016); (2) interoceptive sensibility (an individual’s beliefs about their interoceptive ability and the degree to which they feel engaged by interoceptive signals, assessed by self-report measures such as confidence ratings during a task of interoceptive accuracy, or questionnaires e.g. the awareness portion of the Body Perception Questionnaire (BPQ-A); Porges, 1993); (3) interoceptive awareness, a metacognitive measure reflecting the correspondence between objectively measured interoceptive accuracy and interoceptive sensitivity. Note that the term ‘interoceptive awareness’ has also been used as an umbrella term to refer to all aspects of interoceptive ability (Khalsa et al., 2018), though it is used here to refer to one’s metacognitive insight into one’s own interoceptive ability. This framework importantly highlights a need to separate subjective and objective facets of interoception, emphasises the importance of interoceptive awareness, and has been used in numerous investigations (e.g., Forkmann et al., 2016; Garfinkel, Tiley, et al., 2016; Palser, Fotopoulou, Pellicano, & Kilner, 2018). Recent data suggest, however, that there may be additional facets that need to be incorporated within this framework. For example, although this model (and later revisions; Critchley, & Garfinkel, 2017) classifies self-report measures under the umbrella of interoceptive sensibility, differential relationships have been reported to exist within this dimension (e.g., questionnaire measures and confidence ratings do not usually correlate with each other; Garfinkel et al., 2015). Likewise, whilst this model highlights separation of interoceptive sensibility and objective interoceptive accuracy, subjective confidence ratings sometimes correlate with objective interoceptive accuracy, whilst questionnaire measures usually do not (Ferentzi, Drew, Tihanyi, & Köteles, 2018; Garfinkel et al., 2015; Murphy et al., 2020; though this may vary across interoceptive accuracy tasks; e.g., Forkmann et al., 2016; Schulz, Lass-Hennemann, Sütterlin, Schächinger, & Vögele, 2013).

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Murphy, Catmur, and Bird (2019) proposed that the aforementioned discrepancies may be understood by considering not only *how* interoception is measured (e.g., the level of measurement: objective vs. subjective) but also *what* is measured (Fig. 1). Whilst their 2 × 2 factorial model of interoception, like the tripartite model, highlights a need to separate objective and self-report measures, it also highlights a need to separate measures according to whether they assess interoceptive accuracy or attention (see Fig. 1). Importantly, this framework may explain discrepancies between facets of interoception; the lack of a relationship between confidence ratings (self-reported interoceptive accuracy) and questionnaires such as the BPQ-A (self-reported interoceptive attention; Garfinkel et al., 2015) may be explained by these measures assessing different aspects of interoception. Likewise, objective measures of accuracy may correlate with confidence ratings (self-reported accuracy), but not questionnaires such as the BPQ-A (self-reported attention), because they assess similar and different aspects of interoception, respectively, despite differences in the level of measurement (Garfinkel et al., 2015; Murphy et al., 2019). Supporting this model, across a number of studies it was found that whilst self-reported accuracy measures were generally correlated (e.g., confidence ratings collected during an objective interoceptive accuracy task, the Interoceptive Accuracy Scale (Accuracy Scale: IAS; Murphy et al., 2020), and the Interoceptive Confusion Questionnaire (ICQ); Brewer, Cook, & Bird, 2016) these measures were uncorrelated with a measure of self-reported interoceptive attention (the BPQ-A; Porges, 1993). Furthermore, relationships between objective interoceptive accuracy and self-reported interoception were only found when self-report measures assessed accuracy (e.g., the IAS or confidence ratings) and not attention (e.g., the BPQ-A).

Notably, however, whilst dissociations may be due to differences in the facet of interoception assessed, in line with the 2 × 2 model, it is also possible that they are due to differences in the interoceptive sensations rated across questionnaires. Such an alternative explanation is plausible given evidence that objectively measured interoceptive accuracy may dissociate across domains (e.g., Ferentzi, Bogdány, et al., 2018; Garfinkel, Manassei, et al., 2016; Steptoe & Vogele, 1992; but see Herbert, Muth, Pollatos, & Herbert, 2012; Whitehead & Drescher, 1980). As such, the aim of the present set of studies was to assess the relationship between self-report measures of interoceptive attention and accuracy. To test these competing hypotheses, in Study 1 we constructed a novel self-report measure of interoceptive attention – the Interoceptive Attention Scale (IATS; hereafter ‘Attention Scale’) – designed such that the signals were matched to the IAS (hereafter ‘Accuracy Scale’). Given this design, observing a relationship between the newly developed Attention Scale and Accuracy Scale, but not between the BPQ-A and Accuracy Scale, would indicate that previous reports of a lack of a relationship between self-reported interoceptive accuracy and attention were driven by differences in the sensations examined by each questionnaire. Conversely, a lack of relationship between the Attention and Accuracy Scales would indicate a genuine dissociation between self-reported interoceptive attention and accuracy, providing crucial support for the 2 × 2 model of interoception. In Study 2, we examined whether participants’ interpretation of the questionnaires varies, and whether interpretation alters associations between self-report measures of interoception.

### 2. The Interoceptive Attention Scale (IATS)

The Attention Scale was constructed to quantify the extent to which internal signals are the object of one’s attention. Where possible, the signals exactly matched the signals included in the Accuracy Scale. If this resulted in unusual wording (e.g., for affective touch or for bruising) the items were reworded for clarity, but focus was retained on the same signal (Fig. 2). Given that attention to internal signals may be a product of both 1) monitoring of the signal (e.g., checking whether one needs to urinate) and 2) the presence of the signal (e.g., the objective activation of stretch receptors in the bladder when full, inducing the urge to urinate), the instructions for the Attention Scale explicitly outlined that individuals should rate the extent to which attentional focus is on these signals regardless of whether the signal is present. The wording of individual items was also used to emphasise this (e.g., whether I need to urinate rather than e.g. ‘when’ or ‘that’ I need to) and for further clarity specific examples of what would, and would not, constitute attention to internal signals were given in the instructions (Fig. 2). For consistency with the Accuracy Scale, the Attention Scale comprises 21-items rated from strongly agree (5) to strongly disagree (1), with scores ranging...
from 21 to 105. Higher scores indicate greater self-reported attention to internal signals.

2.1. Ethical approval, pre-registration, and data availability

For all studies, ethical approval was granted by the local ethics committee. Participants provided informed consent and were fully debriefed upon study completion. Data and pre-registrations of predictions for all studies can be found at https://osf.io/3v9ea/.

2.2. General methods and analytic strategy

For all studies, participants were recruited via social-media and databases of individuals who had expressed an interest in research participation. Participation was incentivised by a prize draw for Amazon vouchers. In all studies, the order of questionnaire completion was randomised across participants.

For all studies, prior to assessing the relationship between measures, assumptions of normality were checked using histograms and Kolmogorov-Smirnov tests and the data were checked for outliers. No outliers (>3 × the interquartile range) were detected. In terms of normality, although visual inspection of the histograms suggested little deviation from normality, Kolmogorov-Smirnov tests were significant for all questionnaire variables across all studies (all \( p < .05 \)). As such, Spearman correlations are reported in the main text, with Pearson correlations reported in the Supplement (though results were broadly

Fig. 2. Interoceptive Attention Scale (IATS).
consistent). All reported correlations are two-tailed. Given that the overall aim of this study was to assess the relationship between questionnaire measures of interoceptive attention and accuracy when measures assess the same internal signals, total scores derived from all items were employed for correlational analyses as detailed in the pre-registration. Additional analyses examining factor scores were consistent with total scores and are reported in the Supplement [S1].

To compare the size of correlations, R-to-Z tests were employed (Steiger, 1980; Cohen & Cohen, 1983; conducted using the quantpsy web implementations; Lee & Preacher, 2013a, 2013b; Preacher, 2002). Given that directional predictions were made, one-tailed tests were utilised as pre-registered.

As English language proficiency was not assessed, and the relationship between different facets of interoception may vary across clinical and typical groups, for completeness all correlational analyses were repeated removing those reporting (or declining to report on) mental health conditions and individuals reporting English as an additional language. In unplanned analyses, individuals reporting (or declining to report on) physical health conditions were removed in addition to the aforementioned subgroups.

2.3. Additional analyses

For brevity, the psychometric properties of the Attention Scale and the test-retest reliability of the measures are reported in the Supplement [S1–3; S15].

3. Study 1: the relationship between the Attention Scale (IATS) and existing measures

Study 1 assessed the relationship between the Attention Scale and existing self-report measures of accuracy and attention.

3.1. Methods

Participants completed the Attention Scale alongside the Accuracy Scale (Murphy et al., 2020), the Interoceptive Confusion Questionnaire (ICQ; Brewer et al., 2016) and the awareness scale of the Body Perception Questionnaire (BPQ-A; Porges, 1993) via Qualtrics (Provo, UT). A minimum sample size of 350 was determined a-priori based on the sample required for factor analysis (Field, 2005), and recruitment was set to continue until 31st July 2020 (see pre-registration). After the removal of duplicates (assessed on the basis of duplicate email addresses) and incomplete responses, the final sample comprised 596 individuals ($M_{age} = 30.97$ years, $SD_{age} = 12.57$ years, age-range = 18–93 years, 143 male, 443 female, 10 other). 25.3% reported pre-existing psychiatric conditions (2.5% declined to answer this question), 22.5% reported pre-existing physical health conditions (1.7% declined to answer this question) and 26.7% reported having English as an additional language.

3.2. Results

3.2.1. Correlations between measures

As predicted, questionnaire measures of interoceptive accuracy (the Accuracy Scale and ICQ) were correlated with each other ($r(594) = -0.610, p < .001$); as self-reported interoceptive accuracy increased, self-reported interoceptive confusion decreased. Likewise, measures of self-reported interoceptive attention (the BPQ-A and Attention Scale) were positively correlated with each other ($r(594) = 0.354, p < .001$), suggesting that as self-reported attention on one measure increased, self-reported attention on the other measure also increased. In terms of the relationship across facets, the Accuracy Scale was not significantly correlated with the BPQ-A ($r(594) = -0.023, p > .250$) or the Attention Scale ($r(594) = -0.072, p = .077$). Contrary to predictions, the ICQ showed a positive relationship with the BPQ-A ($r(594) = 0.130, p = .002$) and the ICQ was correlated with the Attention Scale ($r(594) = 0.197, p < .001$). In both cases, greater self-reported attention to internal signals was associated with increased interoceptive confusion (Fig. 3).

For ease of comparison with the Accuracy Scale, ICQ scores were reversed prior to comparing correlation sizes, so that higher scores reflect greater, rather than lower, self-reported accuracy. The size of the correlation between the two accuracy measures (Accuracy Scale and ICQ) was significantly larger than the size of the correlation between measures assessing different facets of interoception (Accuracy Scale with BPQ-A; Accuracy Scale with Attention Scale; ICQ with BPQ-A and; ICQ with Attention Scale; all $p < .001$), in line with predictions. Likewise, the size of the correlation between the two attention measures (BPQ-A and Attention Scale) was significantly larger than the size of the correlation between measures assessing different facets (Accuracy Scale with BPQ-A; Accuracy Scale with Attention Scale; ICQ with BPQ-A and; ICQ with Attention Scale); all $p < .001$; for details and Pearson correlations see Supplement [S4].

3.2.2. Planned exploratory analyses

3.2.2.1. Exclusion of individuals reporting mental health conditions and English as an additional language and those who declined to report. The removal of these individuals had little effect on the relationships reported above (Supplement [S5]) except a significant negative correlation between the Attention Scale and Accuracy Scale was observed, with self-reported interoceptive attention increasing as self-reported interoceptive accuracy decreased ($r(303) = -0.180, p = .002$). As in the total sample, correlations between measures assessing the same facet of interoception (self-reported accuracy or attention) were significantly larger than those between measures assessing different facets (all $p < .001$).

3.2.3. Unplanned exploratory analyses

3.2.3.1. Exclusion of individuals reporting mental health conditions, physical health conditions and English as an additional language and those who declined to report. Exclusion of these individuals had no substantial impact on the pattern of significance reported above, though no association between the ICQ and BPQ-A was observed in this subsample (Supplement [S6]). As before, correlations between measures assessing the same facet were greater than measures assessing different facets (all $p < .01$).

3.2.3.2. Comparison of the size of correlations between measures of self-reported accuracy and measures of self-reported attention. Comparison of the size of correlations between measures of self-reported accuracy (Accuracy Scale and ICQ) and self-reported interoceptive attention (Attention Scale and BPQ-A) in the total sample indicated that the correlation between the Accuracy Scale and ICQ was significantly stronger than the correlation between the Attention Scale and BPQ-A ($Z = 5.82, p < .001$). This pattern was consistent in the first ($Z = 3.44, p < .001$) and second ($Z = 2.46, p < .01$) sub-samples.

3.2.3.3. Non-linear associations. Given recent suggestions (Campos et al., 2020, in prep) that there may be a quadratic association between self-reported attention and self-reported accuracy, non-linear associations were explored. As in Campos et al. (2020, in prep), in regression models accuracy was treated as the dependent variable and attention as the independent variable. The linear term was included in Step 1, the quadratic term at Step 2, and the cubic term at Step 3. R squared change values and their associated F change values were used to identify significant quadratic and cubic relationships. We found some evidence for a quadratic association between self-reported accuracy and attention measures, whereby both lower and higher levels of self-reported...
interoceptive attention were associated with greater self-reported interoceptive accuracy than mid-levels of self-reported interoceptive attention. However, some evidence of cubic associations was also observed (see Supplement [S7]).

3.3. Discussion

The results of Study 1 support the proposed separation between self-reported interoceptive accuracy and attention (Murphy et al., 2020). Relationships within facets were more likely to be observed than relationships across facets, and in all cases relationships within facets were stronger than relationships across facets. Where relationships were observed across facets, these were often in an unexpected direction, with greater self-reported attention to internal signals relating to lower self-reported accuracy.

It is notable, however, that unplanned exploratory analyses demonstrated a stronger relationship between the measures of self-reported interoceptive accuracy than between the measures of self-reported interoceptive attention. In interpreting this finding, it is of relevance that the BPQ-A requires participants to report their level of ‘awareness’ of internal bodily signals rather than explicitly assessing the extent to which signals are the object of their attention. It is possible, therefore, that individual differences in the interpretation of the term ‘awareness’ (where some participants interpret the term awareness as referring to attention and others interpret the term as referring to accuracy, the extent to which these signals occur in one’s body, or otherwise) may underlie the smaller relationship observed between the attention measures. This possibility was examined in Study 2.

4. Study 2 (interpretation of the questionnaires)

Study 2 aimed to assess further the relationship between self-reported attention and accuracy and examine whether participants’ interpretations of the questionnaires alter associations. It was predicted that within a sub-sample of individuals who interpret the BPQ-A as assessing self-reported accuracy, a positive relationship would be observed between the BPQ-A and the Accuracy Scale, and no relationship would be observed between the BPQ-A and the Attention Scale, with the former predicted to be significantly larger than the latter. Conversely, in a sub-sample of individuals who interpret the BPQ-A as assessing self-reported attention, a positive relationship was predicted between the Attention Scale and BPQ-A, while no relationship was predicted between the BPQ-A and the Accuracy Scale, with the former predicted to be significantly larger than the latter. In the total sample, predictions were the same as in Study 1.

4.1. Methods

Participants completed the Attention Scale, Accuracy Scale and BPQ-A via Qualtrics (Provo, UT). Following each questionnaire, participants were asked how they interpreted the questionnaire and a free text box was given for further comments (e.g. Attention Scale: ‘In this questionnaire we asked you to tell us how much attention you pay to specific bodily sensations. While you were completing the questionnaire, what did you think the term ‘attention’ meant in this context? A) How much attention you pay to these sensations, B) How accurate you are at perceiving these sensations, C) How often (frequently) or intensely these sensations actually occur in your body’; see Supplement [S8]). As pre-registered, data collection continued until there were either 123 participants in each group (123 who believed the BPQ-A was assessing accuracy and 123 who believed the BPQ-A was assessing attention, providing > 80% power to detect an effect size of r = .25) or at least 500 participants had completed the survey. Having removed duplicate completions and incomplete responses, the final sample comprised 500 individuals (M_{age} = 33.60 years, SD_{age} = 15.16 years, Age range = 18–89 years, 121 Males, 374 Females, 5 Other). 24% reported pre-existing psychiatric conditions (2% declined to answer this question), 25.2% reported pre-existing physical health conditions (0.4% declined to answer this question) and 22.6%...
4.2. Results and discussion

4.2.1. Planned analyses

4.2.1.1. Interpretation responses. In the total sample, most participants interpreted the Attention Scale as a measure of self-reported attention (79%), followed by how often the signal objectively occurs (10.8%), accuracy (9.6%) and otherwise (0.6%; Fig. 4). Of these three ‘other’ responses, one individual interpreted the Attention Scale as measuring ‘all of the above’ with the other two individuals providing no further clarification. For the Accuracy Scale, the majority interpreted the measure as assessing self-reported accuracy (84.6%), followed by attention (10.2%), how often the signal objectively occurs (4.6%) and other (0.6%). Of the three individuals answering ‘other’, one individual declined to provide specification, one reported ‘all of the above’ and one reported the measure as assessing how often they remember or notice signals during or after they have occurred. For the BPQ-A, there was less consensus across responses; the most common interpretation was self-reported attention (36.4%), followed by how often the signal objectively occurs (30.8%), accuracy (30.4%) and other (2.4%). Content analysis of other responses suggested the individuals interpreted the BPQ-A as assessing either ‘all of the above’, a combination of accuracy and attention or how often they are aware of/notice/feel/are conscious of the sensation regardless of/or dependent on the presence of the term ‘interoceptive’ (see Supplement [S9]).

4.2.1.2. Correlations in the total sample. Correlations were first assessed in the total sample. Consistent with Study 1, the Attention Scale and BPQ-A were significantly correlated ($r(498) = 0.337, p < .001$). No correlation was observed between the Accuracy Scale and the Attention Scale ($r(498) = 0.036, p > .250$) or the Accuracy Scale and BPQ-A ($r(498) = 0.087, p = .053$).

4.2.1.3. Correlations as a function of BPQ-A interpretations: accuracy and attention. To examine whether relationships between the BPQ-A and the Attention Scale and Accuracy Scale vary according to interpretations, the relationships between the measures were examined as a function of interpretation. As pre-registered, we excluded individuals who did not interpret the Accuracy Scale as assessing self-reported accuracy, and the Attention Scale as assessing self-reported attention from all interpretation analyses, given that these terms are explicitly used in these questionnaires. In the sub-sample who interpreted the BPQ-A as assessing self-reported attention, a significant association was observed between the BPQ-A and the Attention Scale ($r(121) = .459, p < .001$). No relationship was observed between the BPQ-A and the Accuracy Scale ($r(121) = −0.121, p = .181$) or the Accuracy Scale and the Attention Scale ($r(121) = 0.004, p > .250$) (Fig. 5) in this sub-sample, as expected.

In contrast, in the sub-sample who interpreted the BPQ-A as assessing self-reported accuracy, no significant association was observed between the BPQ-A and the Accuracy Scale, though a trend was observed ($r(95) = 0.187, p = .067$). No association was observed between the BPQ-A and the Attention Scale ($r(95) = 0.090, p > .250$) or the Attention Scale and the Accuracy Scale ($r(95) = −0.083, p > .250$) in this sub-sample, again as predicted.

As predicted, the size of the correlation between the BPQ-A and Attention Scale was significantly larger in the sub-sample who interpreted the BPQ-A as assessing attention, than the sub-sample who interpreted the BPQ-A as assessing accuracy ($Z = 2.95, p = .002$). Similarly, the size of the correlation between the BPQ-A and Accuracy Scale was significantly larger in the sub-sample who interpreted the BPQ-A as assessing accuracy, than in the sub-sample who interpreted the BPQ-A as assessing attention ($Z = −2.26, p = .012$).

4.2.2. Planned exploratory analyses

4.2.2.1. Exclusion of individuals reporting mental health conditions and English as an additional language and those who declined to report. Exclusion of these individuals did not notably change the pattern of significance in comparison to the total sample correlations (Supplement [S11]).

4.2.2.2. Correlations as a function of BPQ-A interpretations: how often the signal objectively occurs. In the total sample of individuals who interpreted the BPQ-A as assessing how often the signal objectively occurs within their body, a significant association was observed between the Attention Scale and BPQ-A ($r(115) = 0.353, p < .001$). No association was observed between the Accuracy Scale and BPQ-A ($p > .250$) or the Accuracy Scale and the Attention Scale ($p > .250$). This pattern of significance was the same after excluding individuals reporting mental health conditions (and those who declined to specify) or English as an additional language.
additional language; an association was observed between the Attention Scale and BPQ-A ($p < .001$) and no association was observed between the Accuracy Scale and BPQ-A ($p > .250$) or the Attention Scale and Accuracy Scale ($p > .250$). Given that few individuals interpreted the BPQ-A as assessing ‘other’ ($N = 12$), relationships between measures were not examined in this sample.

4.2.3. Unplanned exploratory analyses

4.2.3.1. Exclusion of individuals reporting mental health conditions, physical health conditions and English as an additional language and those who declined to report. Sub-sample correlations were similar to those reported above (Supplement [S12]).

4.2.3.2. Content analysis of feedback. Content analysis of free-text responses (Supplement [S13]) suggested that for the Attention Scale, some participants felt the phrase ‘most of the time’ lacked clarity and that it was difficult to distinguish between the extent to which the signals objectively occurred and how much attention was focused on these signals. For the Accuracy Scale, less consistent feedback was observed though participants generally commented on difficulty assessing their accuracy for some items. For the BPQ-A, participants commented on lack of clarity regarding the term ‘awareness’ as well as some instructional terms (e.g., focus, most situations) and response options (e.g., the similarity of occasionally and sometimes).

4.2.3.3. Non-linear associations. Whilst non-linear associations were observed in Study 2, these associations were not all consistent with Study 1; in the total sample, both quadratic and cubic trends were observed in the Accuracy Scale and BPQ-A model. A quadratic (as in Study 1), but not cubic, trend was observed between the Accuracy Scale and Attention Scale. Where sub-samples are concerned, whilst a quadratic trend was observed between the Accuracy Scale and Attention Scale across sub-samples (though this was a non-significant trend in the group who interpreted the BPQ-A as assessing accuracy), for the BPQ-A an inconsistent pattern was observed; no non-linear trends were observed when individuals interpreted the BPQ-A as assessing self-reported attention, though significant quadratic trends were observed when individuals interpreted the BPQ-A as assessing self-reported accuracy or how often the signal objectively occurs (Supplement [S14]).

4.3. Discussion

Wide variation in participants’ interpretations of the BPQ-A measure of self-reported interoception was observed in Study 2, which altered associations between the BPQ-A and other measures. Such results highlight lack of clarity regarding the BPQ-A, and suggest that discrepancies in the literature may result from differences in the interpretation of this measure across samples or individuals.

5. General discussion

The results of these studies are consistent with the proposed distinction between self-reported accuracy and self-reported attention (Murphy et al., 2020, 2019). As the interoceptive signals included in the Attention Scale were specifically designed to match those in the Accuracy Scale, the lack of a linear association between these measures suggests that previous reports of a lack of an association between the Accuracy Scale and BPQ-A are not simply due to differences in the sensations rated across these questionnaires (Murphy et al., 2020). Given previous evidence that measures of self-reported interoceptive attention and self-reported interoceptive accuracy may be differentially associated with psychopathology (Murphy et al., 2020) these results underscore the importance of considering which specific facet of interoception is quantified by interoceptive measures. Such consideration may be particularly important in light of new data suggesting little correspondence across multiple self-report measures of interoception (Desmedt, Heeren, Corneille, & Luminet, 2021). Future research
examining whether this dissociation extends to objectively measured facets of interoception, or indeed other aspects of interoception (e.g., propensity to utilise signals, magnitude of signals; Khalsa et al., 2018; Murphy, Catmur, & Bird, 2018), is warranted. Whilst we highlight a need to consider whether measures assess accuracy or attention, further subdivision may also be useful, for example distinguishing attentional focus (e.g., moment-by-moment perception) from attentional ruminati-
on (e.g., thought content) and attentional control (e.g., ability to direct attention when required). Likewise, it may be useful to distinguish within-channel accuracy (e.g., accuracy of perceiving a specific sensation) from across-channel accuracy (e.g., accuracy of distinguishing between channels; e.g., hunger from thirst). Whether participants are able to make such fine-grained distinctions, particularly for self-report, remains a question for further research. Further understanding of the complexity of interoception and the measurement of multiple facets, however, is likely to be important for research in clinical groups (where different facets of interoception may relate differentially to mental health), developmental research (as different facets of interoception may follow different developmental trajectories), and work on typical cognition (where different interoceptive facets may relate differently to abilities such as social and emotional abilities and decision-making).

Results from Study 2 raise concerns regarding the interpretation of measures of self-reported interoception. For the BPQ-A in particular, no consensus interpretation of the term ‘awareness’ was observed. While the most common interpretation (~36% of participants) was that the BPQ-A assessed self-reported interoceptive attention, a high number of participants endorsed self-reported interoceptive accuracy, the objective frequency of interoceptive signals, or otherwise. Importantly, the interpretation of the BPQ-A altered associations between the BPQ-A and other questionnaire measures of interoception; where individuals interpreted the BPQ-A as assessing self-reported attention or accuracy, relationships were observed with the Attention and Accuracy Scales, respectively. It should be noted, however, that the relationship was less reliable when considering the accuracy scale. Whilst it is unclear why this may be, in light of evidence that objective interoceptive accuracy may dissociate across domains (Ferentzi, Bogdány, et al., 2018; Garfinkel, Manassei, et al., 2016; Steptoe & Vögle, 1992; but see Herbert et al., 2012; Whitehead & Drescher, 1980), and the fact that the BPQ-A examines different interoceptive signals than the Accuracy Scale and Attention Scale, it is possible that self-reported interoceptive accuracy differs depending on the interoceptive signals assessed within questionnaires, whereas self-reported interoceptive attention generalises across domains. Regardless of this, given frequent use of the BPQ-A in the literature as a measure of self-reported interoception and for the calculation of other facets of interoception (e.g., Garfinkel, Tiley, et al., 2016; Palser et al., 2018), these data hold important implications suggesting that differential results may be observed across studies due to differences in the interpretation of measures across samples. It is of note that the BPQ-A is often used as a general measure of interoceptive sensibility (self-reported interoception, not specifying self-reported accuracy or attention), but the current and previous findings (Murphy et al., 2020) suggest that this is an important distinction. Utilising tools that are less ambiguous in their interpretation, and can be seen as pure measures of self-reported interoceptive accuracy or interoceptive attention, is therefore likely to aid interpretation of findings. However, it is important to acknowledge that not all individuals interpreted the Accuracy Scale and Attention Scale as measures of self-reported accuracy or interoceptive attention, respectively; as Study 3 (Supplementary) suggests, some evidence of differences within individuals was observed. Future research examining self-reported interoception should therefore assess individuals’ interpretations of these questionnaires, and efforts should be made to improve clarity of instructions in further revisions of these questionnaires.

Given concerns over the BPQ-A as a measure of self-reported interoceptive attention, the Attention Scale may be a useful tool for examining self-reported interoceptive attention once refined further to ensure clarity of instructions and confidence regarding psychometrics. Initial evidence suggests that this measure is more likely to be interpreted as assessing self-reported attention than the BPQ-A, with an additional advantage being that the interoceptive signals included are directly matched with the Accuracy Scale. The use of these two questionnaires in combination would, therefore, allow for specific investigation of self-reported abilities across two facets of self-reported interoception without discrepancies between the measures being potentially attributed to different interoceptive signals. Preliminary validation results suggest that the Attention Scale has good internal consistency and convergent and discriminate validity, and its test-retest reliability is comparable to existing measures. Whilst more research is required to further examine the factor structure of the measure, and further refinements to improve clarity are necessary, for investigations requiring separate assessment of self-reported interoceptive accuracy and attention, total scores from the Accuracy Scale and Attention Scale would allow comparisons using measures that assess the same interoceptive signals.

Whilst the above results were in line with pre-registered predictions, it should be noted that for some comparisons greater self-reported attention was associated with lower self-reported accuracy. Whilst these associations were often inconsistent across samples, such an association is perhaps unsurprising, as individuals who believe their interoceptive accuracy to be low may pay more attention to internal signals in an attempt to compensate for poor accuracy and recognise the sensation. Alternatively, greater attention to internal sensations may provide more opportunities for individuals to notice difficulties perceiving interoceptive signals accurately. Although this inverse relationship supports dissociation of these constructs (i.e., that they are not interchangeable), further examination of the relationship between self-reported interoceptive accuracy and self-reported interoceptive attention is required to understand whether such a pattern is reliably observed and clinically meaningful. Similarly, future research should examine possible non-linear associations between these constructs further. Although some evidence of a quadratic association between self-reported accuracy and attention was observed, the observation of no quadratic association in individuals who interpreted the BPQ-A as assessing attention requires further scrutiny to establish the reliability of these effects and understand what is driving this association. To investigate these relationships accurately, it is essential that pure measures of self-reported interoceptive accuracy and attention are utilised.

Despite the utility of these data for understanding the relationship between measures of self-reported interoception, limitations must be acknowledged. First, although online testing is increasingly common in psychological research, there are inherent limitations to this approach (e.g., generalisability, control of environment). Second, as these data were collected during the COVID-19 pandemic, which may impact self-reported interoception (Biotti et al., in prep), it is not possible to rule out a contribution of the present climate to these results. Third, whilst efforts were made to construct the Attention Scale instructions to ensure separation of self-reported interoceptive attention and how often the signal objectively occurs, such a separation may not always be applicable. For example, whilst an individual may often pay attention to whether they need to urinate (regardless of whether the sensation objectively occurs), for some individuals attention may be strictly bound to the presence of these signals. The role of the presence of the signal on attention may also depend on the signal, for example attention to pain being more closely associated with the presence of a painful stimulus, but the attention to heart rate being more consistent across contexts, and again these attentional profiles may differ across individuals. Further research is therefore required to understand the extent to which these aspects of interoception are linked or dissociate across individuals, and dissociate across interoceptive signals. Finally, although issues with the measurement of objective interoceptive accuracy has received much focus (see Brener & Ring, 2016), it is worth acknowledging the limitations of self-report measures of interoception. First, though a consensus
interpretation was observed for the Accuracy and Attention Scales which far exceeded the BPQ-A (a commonly used measure of self-reported interoception), further refinements of these measures will be required. Second, as the extent to which self-report measures of interoception can be used as a proxy of objective indices remains unclear, these data cannot be used to infer the relationship between interoceptive attention and accuracy when measured objectively. Furthermore, the extent to which measures assess beliefs in interoceptive abilities specifically, or also tap negative affect or anxiety, remains debated and further research examining psychometric overlap between such measures is required. As this concern has been raised for the BPQ-A specifically (Mehling, 2016), future research should seek to examine whether such concerns should be shared for the Attention Scale. However, given the dissociations between measures of self-reported accuracy and attention observed here and dissociations noted by other research (Desmedt et al., 2021), coupled with previous evidence that these facets differentially relate to psychopathology (Murphy et al., 2020), it appears unlikely that the Attention and Accuracy scales tap the same psychological constructs. Overall, despite limitations associated with self-report, beliefs regarding one’s interoceptive abilities remain a key element in all models of interoception (e.g., Garfinkel et al., 2015; Murphy et al., 2020; Khalsa et al., 2018) and these results hold important implications for refining the measurement of self-reported interoceptive abilities.

In conclusion, the current results suggest dissociations between self-reported interoceptive accuracy and self-reported interoceptive attention, which remain even when the to-be-rated interoceptive signals are matched across questionnaires. Variation in participants’ interpretation of the BPQ-A caution against reliance on the BPQ-A as a measure of self-reported interoceptive attention, and suggest a need for greater consideration of the interpretation of questionnaire measures of interoception. The current study also provides initial support for the use of the novel Attention Scale, which appears to be a valid measure of self-reported interoceptive attention based on its convergent and discriminant validity, and is matched in interoceptive signals to the existing Accuracy Scale, allowing for comparison of these two distinct facets of interoception.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.biopsycho.2021.108243.

References

Biotti, F., Barker, M., Carr, L., Brewer, R., & Murphy, J.(2021). The impact of COVID-19 on self-reported interoception and mental health. (in preparation).

Brener, J., & Ring, C. (2016). Towards a psychophysics of interoceptive processes: The measurement of heartbeat detection. Philosophical Transactions of the Royal Society B: Biological Sciences, 371(1708), Article 20160015.

Brewer, R., Cook, R., & Bird, G. (2016). Alexithymia: A general deficit of interoception. Royal Society Open Science, 3(10), Article 150664. https://doi.org/10.1098/ rsos.150664

Campos, C., Murphy, J., Brewer, R., Gabriele, E., Rocha, N., & Barbosa, F. (2020) (in prep). Quadratic Association Between Self-Reported Interoceptive Accuracy and Attention. Retrieved from ⟨https://osf.io/v632y⟩.

Cohen, J., & Cohen, P. (1983). Applied multiple regression/correlation analysis for the behavioral sciences. Hillsdale, N.J: Erlbaum, Critchley, H. D., & Garfinkel, S. N. (2017). Interoception and emotion. Current opinion in psychology, 17, 7-14.

Desmedt, O., Heeren, A., Cornille, O., & Luminet, O. (2021). What do measures of self-report interoception measure? Insights from a systematic review, latent factor analysis, and network approach. ⟨https://doi.org/10.11234/osi.8mp9⟩.

Ferentzi, E., Bogdány, T., Szabolcs, Z., Csaba, B., Horváth, Á., & Köteles, F. (2018). Multichannel investigations of interoception: Sensitivity is not a generalizable feature. Frontiers in Human Neuroscience, 12, 223. https://doi.org/10.3389/fnhum.2018.00223

Ferentzi, E., Drew, R., Tilhaný, B. T., & Köteles, F. (2018). Interoceptive accuracy and body awareness – Temporal and topographical associations in a non-clinical sample. Physiology & Behavior, 184, 100–107. https://doi.org/10.1016/j.physbeh.2017.11.015

Field, A. (2005). Discovering statistics with SPSS.

Forkmann, T., Scherer, A., Meesen, J., Michal, M., Schachinger, H., Vogele, C., & Schulz, A. (2016). Making sense of what you sense: Disentangling interoceptive awareness, sensitivity and accuracy. International Journal ofPsychophysiology, 109, 71–80. https://doi.org/10.1016/j.ijpsycho.2016.09.019

Garfinkel, S. N., Manassar, M. F., Hamilton-Fletcher, G., In den Bosch, Y., Critchley, H. D., & Engels, M. (2016). Interoceptive dimensions across cardiac and respiratory axes. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 371(1708). https://doi.org/10.1098/rstb.2016.0014

Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (2015). Knowing your own heart: Distinguishing interoceptive accuracy from interoceptive awareness. Biological Psychology, 104, 65–74. https://doi.org/10.1016/j.biopsycho.2014.11.004

Garfinkel, S. N., Tiley, C., O’Keeffe, S., Harrison, N. A., Seth, A. K., & Critchley, H. D. (2016). Discrepancies between dimensions of interoception in autism: Implications for emotion and anxiety. Biological Psychology, 114, 117–126. https://doi.org/10.1016/j.biopsycho.2015.12.005

Herbert, B. M., Muth, E. R., Pollatos, O., & Herbert, C. (2012). Interoception across modalities: On the relationship between cardiac awareness and the sensitivity for gastric functions. PloS One, 7(5), Article e36646. https://doi.org/10.1371/journal. pone.0036646

Khalsa, S. S., Adolphs, R., Cameron, O. G., Critchley, H. D., Davenport, P. W., Feinstein, J. S., … Interoception Summit 2016 participants. (2018). Interoception and mental health: A roadmap. Biological Psychiatry: Cognitive Neuroscience and Neuroimaging, 3(6), 501–513. https://doi.org/10.1016/j.xbcp.2017.12.004

Lee, L. A., & Preacher, K. J. (2013a). Calculation for the test of the difference between two dependent correlations with no variable in common [Computer software]. Available from ⟨http://quantpsy.org⟩.

Lee, L. A., & Preacher, K. J. (2013b). Calculation for the test of the difference between two dependent correlations with one variable in common [Computer software]. Available from ⟨http://quantpsy.org⟩.

Mehling, W. (2016). Differentiating attention styles and regulatory aspects of self-reported interoceptive sensitivity. Philosophical Transactions of the Royal Society B: Biological Sciences, 371(1708), Article 20160013.

Murphy, J., Brewer, R., Plans, D., Khalsa, S. S., Catmur, C., & Bird, G. (2020). Testing the independence of self-reported interoceptive accuracy and attention. Quarterly Journal of Experimental Psychology, 73(1), 115–133.

Murphy, J., Catmur, C., & Bird, G. (2018). Alexithymia is associated with a multidomain, multidimensional failure of interoception: Evidence from novel tests. Journal of Experimental Psychology: General, 147(3), 398–408. https://doi.org/10.1037/xge0000366

Murphy, J., Catmur, C., & Bird, G. (2019). Classifying individual differences in body awareness, sensibility and accuracy. Frontiers in Human Neuroscience, 13, 167. https://doi.org/10.3389/fnhum.2019.01673

Murphy, J., Catmur, C., & Bird, G. (2017). Distinguishing individual differences in interoception: Implications for the measurement of interoceptive awareness. Psychonomic Bulletin & Review, 24(5), 1467–1471. https://doi.org/10.3758/s13423-019-01632-7

Palser, E. R., Fotopoulou, A., Pellicano, E., & Kihlér, J. M. (2018). The link between interoceptive processing and anxiety in children diagnosed with autism spectrum disorder: Extending adults findings into a developmental sample. Biological Psychology, 136, 13–21. https://doi.org/10.1016/j.biopsycho.2018.05.003

Porges, S. (1993). Body perception questionnaire. Laboratory of Developmental Assessment, University of Maryland.

Preacher, K. J. (2002). Calculation for the test of the difference between two independent correlation coefficients [Computer software]. Available from ⟨http://quantpsy.org⟩.

Schulz, A., Lass-Hennemann, J., Sütterlin, S., Schachinger, H., & Vogele, C. (2013). Cold pressor stress induces opposite effects on cardiovascular accuracy dependent on assessment paradigm. Biological Psychology, 90(1), 167–174. https://doi.org/10.1016/j.biopsycho.2013.01.007

Steiger, J. H. (1980). Tests for comparing elements of a correlation matrix. Psychological Bulletin, 87(2), 245–251. https://doi.org/10.1037/0033-2909.87.2.245

Stepnoe, A., & Vogele, C. (1992). Individual differences in the perception of bodily sensations: The role of trait anxiety and coping style. Behaviour Research and Therapy, 30(6), 597–607. https://doi.org/10.1016/0005-7967(92)00005-2

Whitehead, W. E., & Drescher, V. M. (1980). Perception of gastric contractions and self-control of gastric motility. Physiologist, 17(6), 552–558. https://doi.org/10.1111/j.1469-8986.1980.tb02296.x