Meta-analysis of the Interoceptive Accuracy Scale (IAS) Structure and its Subjective Correlates

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Abstract

Blabla the abstract blabla.

Keywords: keyword1, keyword2, keyword3

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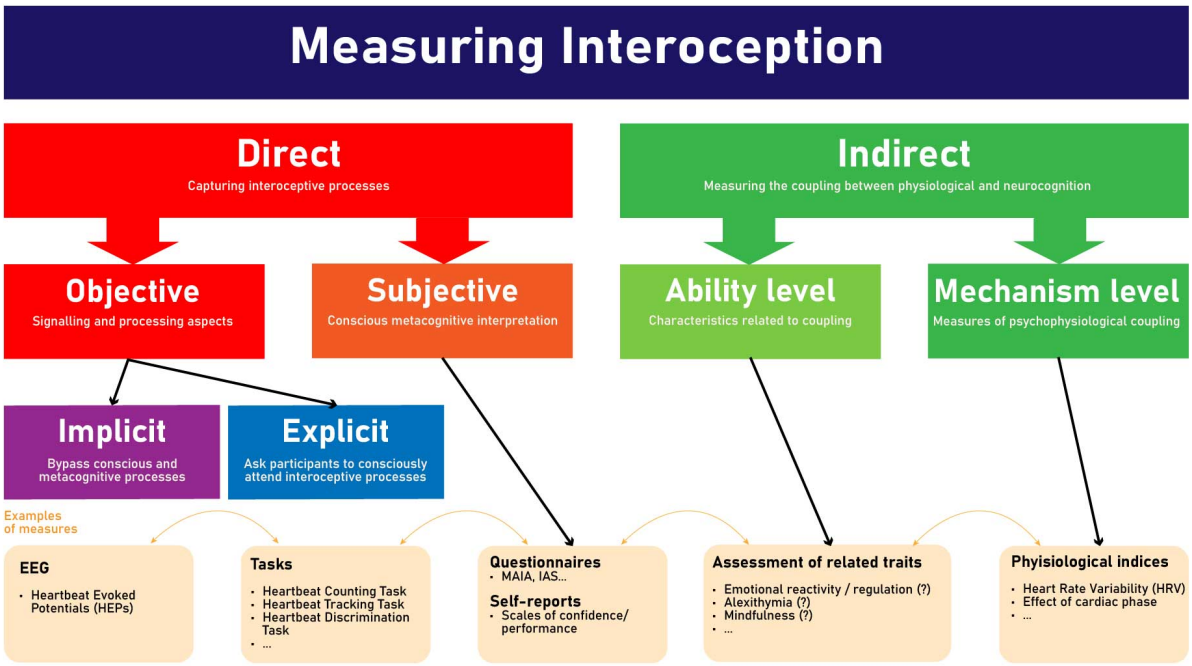
Interoception is referred to the process of sensing, interpreting and integrating information pertaining to internal organs, such as the heart, the lungs or the gut (Khalsa, Adolphs, Cameron, Critchley, Davenport, Feinstein, Feusner, Garfinkel, Lane, Mehling, Meuret, et al., 2018). While recent research emphasizes a key role of interoception in a variety of processes (e.g., emotion regulation, decision making) and of outcomes (physical and psychological well being), the field remains clouded by concerns about how interoception is assessed.

Various measures of interoception have been developed (see Figure 1), forming a combination of "objective" and "subjective" assessments (i.e., physiological tasks such as the heart beat counting or tracking vs. questionnaires and subjective scales involving a metacognitive reflection), "explicit" and "implicit" paradigms (i.e., directing participants' awareness and attention to interoceptive processes *vs.* measuring interoception unbeknownst to them), various interoceptive modalities (e.g., cardioception, respiroception, gastroception) and theoretical dimensions (e.g., accuracy, sensitivity, awareness). While there is no consensus as to which particular approach provides the most accurate and "pure" measure of interoception and interoceptive abilities (assuming it is a unidimensional construct), it is instead plausible that each measure has strengths and limitations, and a utility dependent on the context and goal at hand (Jahedi & Méndez, 2014).

The use of subjective self-report questionnaires to measure deeply embodied functions might seem paradoxical. However, recent redefinitions of interoception emphasize the role of high-level and metacognitive elaboration of interoceptive information. These redefinitions provide theoretical grounding to support the idea that some facets of interoception, including participants' metacognitive beliefs, can be assessed subjectively (Khalsa, Adolphs, Cameron, Critchley, Davenport, Feinstein, Feusner, Garfinkel, Lane, Mehling, & others, 2018; Suksasilp & Garfinkel, 2022). This approach offers useful and interesting measures (Lin et al., 2023; Murphy et al., 2019).

Figure 1

Different ways in which interoception can be measured.



The notion that self-reports might not reflect the same processes as other interoception measures is important to contextualize the apparent lack of convergence between measures in the field (Desmedt et al., 2022). While few studies have explored the correlation between objective interoceptive measures, such as the Heartbeat Counting Task (HCT, Schandry, 1981) and the Heartbeat Detection Task (HDT, Kleckner et al., 2015), and correspondent self-report measures, existing findings typically show weak or no correlations (Brand et al., 2023; e.g., task-based accuracy vs. self-reported accuracy, Murphy et al., 2019).

Even among self-report measures low correlations have been observed, suggesting that these measures, while group in the same umbrella term of self-report assess different facets of interoception. A recent systematic review by Desmedt et al. (2022) examined whether various questionnaires designed to assess "interoceptive sensibility" truly measure the same construct. Notably, Garfinkel et al. (2015) defines interoceptive sensibility as the self-reported tendency to focus on and detect internal sensations, whereas Khalsa, Adolphs, Cameron, Critchley, Davenport,

Feinstein, Feusner, Garfinkel, Lane, Mehling, and others (2018) defines it more narrowly, excluding the ability to detect these signals. According to Desmedt et al. (2022), most authors adopt the latter definition. The review found that these questionnaires measure related but distinct constructs, leading researchers to mistakenly treating them as equivalent measures of interoceptive sensibility. A better understanding of what is being measured with different questionnaires and dimensions, as well as their potential overlaps with other constructs (e.g., alexithymia, body awareness), is thus needed to clarify the role of self-reports in the assessment of interoception.

A recently developed scale with a rapidly growing popularity is the Interoceptive Accuracy Scale (IAS, Murphy et al., 2019). The IAS consists of 21 Likert-scale items that query how accurately one can perceive different bodily signals, with one item per physiological modality such as respiration (*"I can always accurately perceive when I am breathing fast"*), heart (e.g *"I can always accurately perceive when my heart is beating fast"*), skin (e.g *"I can always accurately perceive when something is going to be ticklish"*), arousal or bodily functions like coughing (e.g *"I can always accurately perceive when I am going to cough"*) or urinating (e.g. *"I can always accurately perceive when I need to urinate"*). Interestingly, the IAS' statements are about specific interoceptive behaviours, which is a notable difference with other popular interoception questionnaires, such as the Multidimensional Assessment of Interoceptive Awareness scale (MAIA, Mehling et al., 2012; MAIA-2, Mehling et al., 2018), which contains more general and metacognitive items (e.g., *"I trust my body sensations"*, *"I can notice an unpleasant body sensation without worrying about it"*).

Although the original validation study suggested a two-factor structure for the IAS, the authors underline its acceptable but imperfect fit (Murphy et al., 2019, p. 127), calling on further investigation of the scale's factor structure. Notably, the authors did not define these factors, as no clear explanations were evident. They suggested that the first factor reflects the perception of interoceptive signals, while the second pertains to signals that may be difficult to perceive solely through interoceptive information.

note to dom:Morin et al. (2015) is a methodological paper on ESEM

Other follow-up studies using confirmatory factor analysis (CFA) and structural modeling have identified different optimal solutions. Some studies, like Brand et al. (2023), reported a 1-factor solution, while Lin et al. (2023) and Campos et al. (2021) found bifactor solutions - one general factor and a set of lower-level factors (Rodriguez et al., 2016) - to be the best fit. Notably, the only other study to report a 2-factor solution was conducted by Koike and Nomura (2023), who performed an Exploratory Factor Analysis (EFA) assuming 2 factors to align with the findings from the original validation paper.

Discussions have also been focused on specific items. For instance, Murphy et al. (2019) notes that some items might measure direct interoceptive signals such as cardioception, while others might capture phenomena not perceivable through interoceptive signals alone (e.g., "bruising"; p. 119). Lin et al. (2023) also highlights their correlation analysis, showing five locally dependent pairs and three items (touch, blood sugar, bruise) with exceptionally high difficulty and low discrimination. Additionally, Campos et al. (2021) reported "tickle" to be the only item that reflected more specific factors than the general factor. Interestingly, Lin et al. (2023) reported that all items of the IAS grouped together using a new approach, Exploratory Graph Analysis (EGA, Golino & Epskamp, 2017), to assess convergent and discriminant validity, providing further evidence for unidimensionality.

The IAS has naturally been compared to other interoception-related scales, and shows a positive correlations with most facets of the MAIA (Mehling et al., 2018), except for the Non-Distracting and Not-Worrying subscales (Brand et al., 2023). Interestingly, findings on the correlation between the IAS and the body awareness dimension of the Body Perception Questionnaire (BPQ-A, Porges, 1993) have been mixed: some studies report small positive correlations (Brand et al., 2023; Campos et al., 2021; Koike & Nomura, 2023), while others find small negative correlations (Lin et al., 2023) or no correlation at all (Murphy et al., 2019). Small positive correlations have also been observed with the "observation" and "description" subscales of the Five Facet Mindfulness Questionnaire (FFMQ, Baer et al., 2006; Brand et al., 2023; Koike & Nomura, 2023), as well as with the "non-reactivity" and "acting with awareness" subscales

(Koike & Nomura, 2023). Additionally, the IAS has shown a positive correlation with the interoceptive awareness subscale of the Eating Disorder Inventory (Lin et al., 2023) and a negative correlation with the Interoceptive Confusion Questionnaire (Brand et al., 2023; ICQ, Brewer et al., 2016; Murphy et al., 2019). Lastly, small positive correlations have also been reported with the Interoceptive Attention Scale (Koike & Nomura, 2023; IATS, Lin et al., 2023), though studies have also found no correlation between these measures (Gabriele et al., 2022). Interestingly, the IAS and the IATS supposedly measure two different interoceptive processes (i.e., accuracy and attention, respectively) which contradict Murphy et al. (2019) proposed 2x2 framework.

While assessing the validity of an interoception scale can be conceived as theoretically challenging, several measures have been used to assess convergent validity for the the IAS, including expected negative associations with alexithymia (Brand et al., 2023; Campos et al., 2021; Koike & Nomura, 2023; Lin et al., 2023; Murphy et al., 2019), somatic symptoms (Brand et al., 2023; Koike & Nomura, 2023; Lin et al., 2023), depressive symptoms (Brand et al., 2023; Koike & Nomura, 2023; Lin et al., 2023), anxiety (Brand et al., 2023), neuroticism (Brand et al., 2023) and self-esteem (Murphy et al., 2019).

The current study aims at 1) clarifying the structure of the IAS with a meta-analytic approach that leverages existing data and contrast the traditional CFA/SEM factor-based analyses with network-based ones such as EGA; 2) the second part will provide an overview of the dispositional correlates of the IAS, clarifying the pattern of associations which is key to better understand the nature, place and role of interoception questionnaires within a larger context.

Study 1

The goal of study 1 is to re-analyse and assess the factor structure of the IAS by taking advantage of the large number of open-access datasets (Arslanova et al., 2022; Brand et al., 2022; Brand et al., 2023; Campos et al., 2021; Gaggero et al., 2021; Lin et al., 2023; Murphy et al., 2019; Todd et al., 2022; Von Mohr et al., 2023). While combining these studies might provide a more robust and generalizable understanding of the IAS' factor structure, we also additionally provide an individual analysis (i.e., on all samples separately) to add nuance to the general picture,

as all studies differ in their sample sizes, demographics, language, and procedure.

Methods

Datasets. Our search focused on studies citing the original IAS validation paper (Murphy et al., 2019), identifying 136 papers (as of 01/05/2024). To qualify for inclusion, papers needed to (1) provide accessible data in open-access, (2) employ the IAS as a measure, and (3) report individual IAS items scores. We also included the data of two unpublished (but already open-access) studies. A total of 10 studies was included (see **Table 1**).

The total number of participants was 32,214 participants (Mean = 48.6 ± 13.1, 71.6% Female).

Sample	Subsample	Language	N	Difference	Age (Mean ± SD)	Range	Female %	Availability
Murphy et al., (2020)								osf.io/3m5nh
	Sample 1	English	451		25.8 ± 8.4	18-69	69.4%	
	Sample 2	English	375		35.3 ± 16.9	18-91	70.1%	
Gaggero et al., (2021)		English and Italian	814		24.9 ± 5.3	18-58	60.3%	osf.io/5x9sg
Campos et al., (2022)		Portuguese	515		30.7 ± 10.5	18-72	59.6%	osf.io/j6ef3
Todd et al., (2022)		English	802		48.6.6 ± 14.1*	18-92*	50%*	osf.io/ms354
Arslanova et al., (2022)		English	143		28.5 ± 7.6	18-73	46.8%	osf.io/mp3cy
Brand et al., (2022)		German	619		43.9 ± 14.5	18-78	78.7%	osf.io/xwz6g
Brand et al., (2023)								osf.io/3f2h6
	Sample 1	German	522		23.4 ± 6.7	18-79	79.5%	
	Sample 2	German	1993		32.0 ± 12.6	16-81	77.7%	
	Sample 3	German	802		27.3 ± 9.3	18-72	68.9%	
Lin et al., (2023)								osf.io/3eztd
	Sample 1	Chinese	1166	Collapsed ”Itch” and ”Tingling”	32.5 ± 8.4	16-60	57.0%	
	Sample 2	Chinese	500	Collapsed ”Itch” and ”Tingling”	37.4 ± 7.4	20-60	56.2%	
VonMohr et al., (2023)		English	21843		56.5 ± 14.4	18-93	73.2%	osf.io/7p9u5
Makowski et al., (2023a)		English	485	Analog scales	30.1 ± 10.1	18-73	50.3%	github.com/RealityBending/IllusionGameReliability
Makowski et al., (2023b)		English	836	Analog scales	25.1 ± 11.3	17-76	53.0%	github.com/DominiqueMakowski/PHQ4R
Makowski et al., (2023c)		English	104	Analog scales	21.6 ± 5.0	18-50	76%	github.com/RealityBending/InteroceptionPrimals
Poreiro et al., (2024)		English	107		26.8 ± 9.2	18-57	74.8%	osf.io/49wbv
Poreiro et al., unpublished		English	131		30.9 ± 12.0	18-60	75.9%	
Total			32214		48.6 ± 13.1	17-93	71.6%	

* Information taken from the sample description of relevant paper rather than recomputed.

Statistical Analysis. To examine the factor structure of the IAS, a two-steps approach was employed. First, Exploratory Graph Analysis (EGA), was used to estimate the dimensions via network estimation and community detection, alongside assessing the stability of dimensions and items using the bootstrapping techniques (Golino & Epskamp, 2017). The selection of EGA was motivated by its capability to handle complex, multidimensional data and provide robust dimension estimates. A novel network psychometrics - Unique variable analysis (UVA, Christensen et al., 2023) - approach based on the weighted topological overlap will be computed to evaluate which items have substantial local dependence (> 0.25). Subsequently, exploratory factor analysis (EFA) was employed followed by confirmatory factor analysis (CFA).

Results

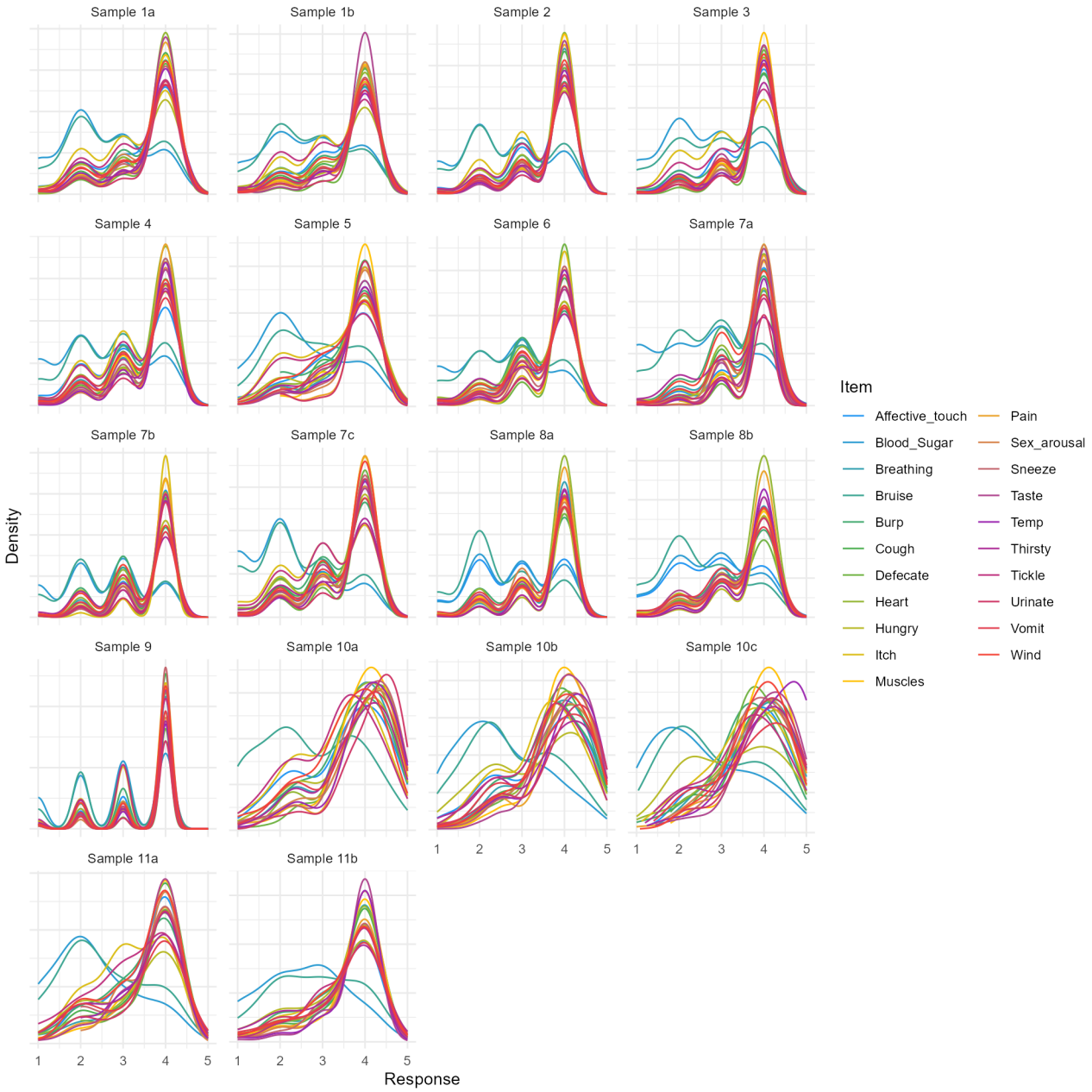
Visualizing the distribution of the items for all samples suggests the presence of a consistent modal value (Figure 2). In other words, participants are most likely to answer 4/5 (i.e., agree) on most items (but "affective touch", "blood sugar", and "bruise" that exhibit a different distributional pattern). Additionally, one can note the low density on extreme values (1 and 5), meaning that the bulk of answers (i.e., 99%) varies between 3 values. The interindividual variability seems improved in the samples using an analogue scale, displaying a more continuous and progressive spread of answers.

Correlations. The correlation analysis revealed that the items overall have positive intercorrelation patterns with no clear structure emerging. This remains the same across all samples. However, there are possibly some higher-order groupings emerging for the 2 analog-scale samples.

EGA.. The UVA revealed that there are two large to very large redundant variables when taking all samples into account. Namely, "itch" and "tickle", where "tickle" should be removed, and "itch" should be kept. There are several more items that are moderately to largely redundant, namely, "wind" and "burp", and "urinate" and "defecate". On top of that, "sneeze" and "cough", "heart" and "breathing", and "hungry" and "thirsty" seem to have small to moderate redundancy. These findings are rather consistent across the samples with minor differences, such as that when

Figure 2

Distribution of responses for all items across various datasets.



the questionnaire had an analog scale, there seems to be no large to very large redundant items but "itch" and "tickle" remain moderately to largely redundant and "heart" and "breathing" small to moderately redundant in one sample.

According to the network analysis, using the Walktrap and Louvain algorithms applied to Glasso networks, a 4-factor structure fits the questionnaire best across all data sets. This is rather consistent within the data sets, where some samples indicate 3-factor structure, and some a 5-factor structure would fit well too. The 4-factor structure model with the best fit entails the following items per group: 1) itch, tickle, bruise, blood sugar; 2) burp, wind, cough, sneeze, vomit; 3) affective touch, sexual arousal, muscles, temperature, pain, and taste; 4) Heart, breathing, hungry, thirsty, urinate, and defecate.

Stability analysis, employing 500 bootstrap iterations, also favoured the 4-factor solution for its greater stability. Most items, except for 'affective touch,' demonstrated stability levels exceeding 0.90, indicating structural consistency and reliability (Christensen & Golino, 2021). These findings underscore the robustness of the identified 4-dimensional structure.

When accounting for all samples, the factor analysis reveals that a 4-factor structure fits best. The exploratory factor analysis revealed that 4 latent factors (oblimin rotation) accounted for 41.58% of the total variance of the original data (MR1 = 14.45%, MR3 = 11.76%, MR2 = 8.09%, MR4 = 7.28%). Since UVA identified "tickle" as the item to be removed—and it also had the lowest uniqueness value in factor analysis with a similar loading to "itch"—" it was excluded from subsequent analyses.

CFA was computed with the removal of the item "tickle" as it was constantly flagged as redundant. This analysis compared 5 models: a single-factor solution, a 4-factor solution, a 5-factor solution, a 6-factor solution and a 7-factor solution. The latter was preferred in most datasets, including with indices that penalise increased number of parameters (such as BIC). There was no evidence for higher order factors.

Discussion

In this study, several datasets were analyzed for a meta analysis of the structure of the IAS. The findings reveal that a 4-factor model fits the IAS best. Additionally, the lowest level structure (pairs of items) seem to be the most robust, especially for samples using Likert scales (some higher-order groupings might emerge for the 2 analog-scale samples). There was no clear evidence for higher-order factors.

These findings contrast with previous research, which all found that 2-factor model (Koike & Nomura, 2023; Murphy et al., 2019), 1-factor model (Brand et al., 2023) and bifactor model (Campos et al., 2021; Lin et al., 2023) fits the data best. While this analysis also revealed an okay fit for the 1-factor model, the 4-factor model was superior. The 4-factor structure reveals different 'hubs' of items that are related, not only in this structure analysis, but also in underlying mechanisms. The 'wind-burp-cough-sneeze-vomit' category, for example, only entails items that are linked to excretion through the mouth. The other categories are organized similarly. This organization and structure is useful for further analysis, as the data can be analyzed and interpreted according to a grouping that is coherent in result, as well as underlying mechanisms.

note to dom: what stats do you mean here? the UVA one?

There are several items that show redundancy suggesting that adapting the IAS would be beneficial for validity. Based on the given results, we suggest removing the tickle, while keeping the itch item [**todo**: stats?]. Other items with slight redundancy were "hungry" and "thirsty", "urinate" and "defecate", and "sneeze" and "cough".

Interestingly, Lin et al. (2023) also found that "tickle" and "itch" were redundant, which led them to excludw one of them. Although, the reason being that the character for both words is the same in the Chinese language. On top of that, they came up with a shortened version of the IAS, excluding further items, resulting in a 12-item IAS, which aligns with our findings, suggesting that further items are ambiguous as to whether they should be removed. Their 12-item IAS included the "hunger", "breath", "urinate", "taste", "vomit", "cough", "temperature", "sexual arousa", "wind", "muscle", "pain", "itch" items.

In contrast, other findings also found “tickle” to be redundant but did not suggest excluding items (Campos et al., 2021).

The findings indicate a high proportion of answers at 4 (see Figure 1), especially when using a 5-step scale. The analogue scale shows a more dispersed distribution, with some answers indicating the highest 5/5, which was not the case in Likert-scales. Therefore, we recommend using an analog scale for the IAS.

Before this paper, the IAS had not yet been used or analyzed with an analog scale, rather than a five-step scale. Therefore, this study provides a novel approach to improving the IAS in a simple manner.

Limitations and Future Directions

There are several limitations to the IAS. There are some redundant items, the 5-point scale does not provide great variability, and the structure could be improved. Therefore, improving the IAS, or creating a new questionnaire investigating interoception could be useful to achieving reliable and accurate indication of interoceptive awareness.

Study 2

Study 2 aims to investigate correlates of the IAS. Correlations of the IAS will be computed to assess the relationship between subjective interoceptive accuracy and other subjective measures of interoception, mood, psychopathology, personality, and beliefs. Investigating correlates will help validate the IAS, as well as other interoceptive measures in the future.

Methods

Materials. The questionnaires used for the IAS correlates are listed in **Table 2** (**TODO: add the rest of the questionnaires, sample items and references**).

Statistical analysis. Correlations will be computed using the correlation package under a Bayesian framework (Ben-Shachar et al., 2020).

Questionnaire	Number of Dimensions	Assessment	Number of Items	Scoring
Interoceptive Related				
MAIA-2	8	Interoception	37	6-point Likert scale
BPQ	2	Body awareness and autonomic reactivity	49	5-point Likert scale
TAS-20	3	Alexithymia	20	5-point Likert scale
BVAQ	2	Alexithymia	40	5-point Likert scale
Mood				
BDI-II	1	Severity of depressive symptoms	21	0-to-3-point values
PHQ-4	2	Anxiety and depressive symptoms	4	5-point Likert scale
STAI-T	1	Trait anxiety	20	4-point Likert scale
GAD-2	1	General Anxiety	2	4-point Likert scale
Personality				
NEO-FFI	1	Neuroticism	12	5-point Likert scale
Mini IPIP6	6	Personality	24	Analogue scales
BFI	5	Personality	44	5-point Likert scale
PID-5-SF	5	Dysfunctional personality traits	25	4-point Likert scale
Psychopathology				
SPQ-BRU	4	Schizotypy	32	5-point Likert scale
MSI-BPD	1	Borderline personality disorder	10	Analogue scales
ASQ - Short	5	Autistic Traits	28	4-point Likert scale
Beliefs and Misbeliefs				
GCB	5	Conspiracy beliefs	15	5-point Likert scale
PI-18	1	Beliefs about the world	99	6-point Likert scale
LIE scale	4	Lying tendencies	16	Visual analogue scales

Results

Average correlations

The EGA components captured grouping of items such as ‘wind’ and ‘burp, ’cough’ and ‘sneeze’, ‘muscle’ and ‘pain’. These groupings were used in correlational analysis to analyse how much each pairing is associated with other factor such as Alexithymia and with Mood disorders (see figure 2).

notecompute internal consistency

Correlations with body measures. Alexithymia was assessed in the samples with the Bermond–Vorst Alexithymia Questionnaire [BVAQ; Vorst and Bermond (2001)] and the Toronto Alexithymia Scale[TAS; Bagby et al. (1994)].

The BVAQ consists of 5 subscales - fantasising, idenitying, analysing; verbalising and emotionalising - assessed with 40 items on a 5-point Likert scale, from ‘defnitely applies to me’ to

'in no way applies to me'. Additionally, the BVAQ reduces these subscales into two high order factors, an affective component and a cognitive one, with high scores being indicative of high proneness to alexithymia.

On average, the cognitive component of the BVAQ was weakly and negatively correlated with all IAS pairs of items with the biggest correlation being with the Itch/Bruise pair (r = -0.112) and the lowest correlation beeing with the Muscle/Pain pair (r = -0.244). The affective component of the BVAQ was positively, but very weak, correlated with all pairs, with the biggest correlation being with the Itch/Bruise pair (r = 0.107). The only exception was a negative correlation with the Urinate/Defecate pair (r = -0.036).

The TAS contains 20-items rated on a 5-point forced scale, from 'strongly disagree' to 'strongly afree', divided into 3 dimensions - difficulty identiying feelings, difficulty describing feelings, and externally thinking. High scores on this scale also reflect higher alexithymia.

All the three dimensions assessed with the TAS were on average negatively correlated with all pairs of IAS items. The difficulty describing feelings had its strongest correlation with Hungry/Thirsty (r = -0.179) and weakest with the Wind/Burp (r = -0.117). while, the difficulty describing feelings had its strongest correlation with Muscle/Pain (r = -0.247) and weakest with Itch/Bruise (r = -0.157). Lastly, the external thinking dimension was more correlated with the Cough/Sneeze pair (r = -0.138) and less correlated with the Hungry/Thirsty (r = -0.018).

The studies within our sample used the Body Perception Questionnaire short-form (BPQ-SF) and the very-short form (BPQ-VSF) to assess interoception (Cabrera et al., 2018). The BPQ-SF comprised of 46 items on a 5-point Likert scale assessing body awareness (26 items) and autonomic reactivity (21 items). The BPQ-VSF comprises of 12 items from the body awareness subscale of the BPQ-SF. In this study, all scores assessing these two dimensions were grouped together, hence no disitintion is made between awareness measured with the BPQ-SF and the BPQ-VSF, or eith scores obtained only using the awareness subscale.

note to add: discuss later

In general, all pairs of the IAS were positively,and weakily, associated with the body

awareness subscales, while negative and weakily correlated with the autonomic reactivity subscale. The strongest correlation identified between the IAS pairs and the body awereness subscale was with the

Heart/Breathing pair (r = 0.151) whilst the strongest correlation with the autonomic reactivity was with the Urinate/Defecate pair (r = -0.235). The weakest correlation between the body awareness and the IAS was with the Hungry/Thirsty pair (r = 0.055) and between the autonomic reactivity and the IAS was with the Heart/Breathing pair (r = -0.106).

The MAIA was one of the most commonly used measures of interoception in our study, with nine samples reporting its use. This 37-item questionnaire assesses eight state-trait dimensions of interoception: Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trust. Responses are rated on a scale from 0 (Never) to 5 (Always).

On average, all MAIA dimensions were positively and weakly to moderately correlated with IAS pairings. Notably, the strongest correlations were observed between the Noticing dimension and the Heart/Breathing pairing (r = 0.394), Trusting and Hungry/Thirsty (r = 0.347), and Attention Regulation and Heart/Breathing (r = 0.334). The Not-Distracting and Not-Worrying subscales were generally positively correlated with IAS pairings, with a few exceptions: Not-Distracting showed minimal correlation with Cough/Sneeze (r = 0.0206) and Heart/Breathing (r = -0.007), while Not-Worrying had a low correlation with Itch/Bruise (r = 0.031).

The Interoceptive Confusion Questionnaire (ICQ; Brewer et al. (2016)) was used to assess individuals' difficulties in interpreting non-affective physiological states, such as pain and hunger. The ICQ consists of 20 items rated on a scale from 1 ("Does not describe me") to 5 ("Describes me very well"), with higher scores indicating greater interoceptive confusion.

The ICQ showed weak to moderate negative correlations with all IAS pairings. The strongest correlation was observed with the Hunger/Thirsty pairing (r = 0.348), while the weakest was with the Itch/Bruise pairing (r = 0.207).

Correlations with mood measures. Mood disorders were assessed using several standardized measures, including the General Anxiety Disorder-2 [GAD-2; Kroenke et al. (2007)], the State-Trait Anxiety Inventory [STAI; Spielberger (1970)] and its shorter version, the STAI-5 (Zsido et al., 2020), Beck's Depression Inventory [BDI; Beck et al. (1996)], and the Mood and Feelings Questionnaire [MFQ; Messer et al. (1995)]. Additionally, the Patient Health Questionnaire (PHQ) was administered in its 2-item [PHQ-2; Kroenke et al. (2003)], 9-item [PHQ-9; Kroenke et al. (2001)], and 15-item [PHQ-15; Kroenke et al. (2002)] versions. Finally, borderline personality traits were assessed using the McLean Screening Instrument for Borderline Personality Disorder [MSI-BPD; Zanarini (2003)].

The GAD-2, a brief screening tool for generalized anxiety disorder, consists of two items rated on a scale from 0 (not at all) to 3 (nearly every day). The STAI, a 40-item questionnaire rated on a 4-point Likert scale (0 to 3), measures both state and trait anxiety. However, in our study, most participants primarily completed the trait anxiety subscale. In some samples, a shorter 5-item version (STAI-5) was used to assess both state and trait anxiety.

On average, anxiety measures showed weak negative correlations with all IAS pairs. Notably, the strongest correlations between the IAS pairings and the GAD-2, STAI-T and STAIT-5 were observed with the Hungry/Thirsty pair (r = -0.168, r = -0.270 and r = -0.248, respectively).

The BDI consists of 21 items measuring the severity of depressive symptoms on a scale from 0 to 3. The total score is calculated by summing the highest responses, which are then compared to six depression severity levels, ranging from 1–10 (normal fluctuations in mood) to over 40 (extreme depression). The PHQ-2 includes two items assessing the frequency of depressive symptoms and anhedonia. The PHQ-2 is derived from the PHQ-9, a nine-item screening tool used to assess depression severity and monitor treatment response. Both questionnaires are measured on on a scale from 0 (not at all) to 3 (nearly every day)

Depression measures showed weak to moderate negative correlations with IAS pairings. The BDI (r = -0.372), PHQ-2 (r = -0.148), and PHQ-9 (r = -0.241) correlated most with the Hungry/Thirsty pair, while the MFQ correlated most with Heart/Breathing (r = -0.345) pair.

The PHQ-15 is a 15-item questionnaire that assesses somatic symptoms on a 3-point scale (e.g., back pain). It exhibited its strongest correlation with the Hungry/Thirsty pair (r = -0.241) and, on average, showed weak negative correlations with all other IAS pairings.

Lastly, the MSI-BPD is a 10-item questionnaire used to assess personality disorder, where items are rated on a dichotomous scale of 1 (present) and 0 (absent). The MSI-BPD also showed its strongest negative correlation with the Hungry/Thirsty pair (r = -0.140) and was negatively correlated with all other pairings, except for Cough/Sneeze, which showed a slight positive correlation (r = 0.0219).

Correlations with psychopathology measures. Maladaptive personality traits were assessed using the Personality Inventory for DSM-5 Short Form [PID-5-SF; Thimm et al. (2016)], which measures five domains: disinhibition, antagonism, detachment, negative affect, and psychoticism. The scale consists of 25 items rated on a 4-point Likert scale, ranging from 0 (very false or often false) to 3 (very true or often true).

On average, all maladaptive personality traits assessed by the PID-5-SF were weakly and negatively correlated with IAS pairings. The strongest correlation was observed between the psychoticism dimension and the Muscle/Pain pairing (r = -0.173).

Schizotypy was assessed using the Schizotypal Personality Questionnaire – Brief Revised Updated (SPQ-BRU; Davidson et al. (2016)), which consists of 32 items rated on a 5-point Likert scale ranging from strongly agree to strongly disagree. This questionnaire evaluates four primary dimensions: cognitive-perceptual (positive), interpersonal (negative), disorganized, and social anxiety. These dimensions are further divided into nine secondary factors: constricted affect, eccentricity, magical thinking, lack of close friends, odd speech, referential thinking, social anxiety, suspiciousness, and unusual perceptions.

On average, all nine factors were weakly and negatively correlated with IAS pairings, with correlations ranging from r = -0.170 (between lack of close friends and Muscles/Pain) to r = 0.102 (between magical thinking and Itch/Bruise).

The short version of the Autism-Spectrum Quotient (ASQ-Short; Hoekstra et al., 2011)

was used to assess five autistic traits: social skills, adherence to routines, cognitive flexibility (switching), imagination, and patterns/numbers. The questionnaire consists of 28 items rated on a 4-point Likert scale, ranging from 1 (definitely agree) to 4 (definitely disagree).

Overall, all pairings were weakly and negatively correlated with the ASQ dimensions, except for the Itch/Bruise and Heart/Breathing pairings, which showed weak positive correlations with the patterns/numbers trait (r = 0.184 and r = 0.038, respectively). The strongest correlation was observed between the imagination trait and the Wind/Burp pairing (r = -0.218).

Correlations with personality measures. The Big Five Inventory-Short Form [BFI-S; Lang et al. (2011)] and the Mini International Personality Item Pool [Mini-IPIP6; Sibley et al. (2011)] were used to assess general personality traits. The BFI-S consists of 15 items rated on a 7-point Likert scale, ranging from 1 (strongly disagree) to 7 (strongly agree), measuring five personality factors: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. The Mini-IPIP6 assesses six personality traits—Extraversion, Agreeableness, Conscientiousness, Neuroticism, Openness, and Honesty-Humility—using 24 items. While this questionnaire is typically scored on a 7-point Likert scale from 1 (very inaccurate) to 7 (very accurate), an analogous scale was used in the respective sample. Lastly, the Neuroticism subscale of the NEO Five-Factor Inventory [Neo-FFI; Costa and McCrae (1992)] was used to assess Neuroticism, consisting of 12 items rated on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

To assess correlations with the IAS pairings, scores were grouped across personality dimensions due to the overlap among these traits (with the exception of Honesty-Humility). On average, IAS pairings were positively associated with most personality dimensions, though these correlations were generally weak. The strongest correlation was observed between Conscientiousness and the Hungry/Thirsty pairing (r = 0.164). Both Honesty-Humility and Neuroticism were weakly and negatively correlated with the IAS pairings, with the highest correlations observed for the Hungry/Thirsty pairing (r = -0.217 and r = -0.200, respectively).

Correlations with other measures. The IAS was also correlated with primal world beliefs, as measured by the Primal Inventory [PI-18; J. D. Clifton and Yaden (2021)], which assesses beliefs about the world being alive, good, safe, and enticing. Items that evaluate neutral beliefs about the hierarchical order of importance in the world (i.e., hierarchical), as well as beliefs about the comprehensibility of most things and situations (i.e., understandable), and the belief that the world is characterized by flux (i.e., changing) were added as well. The scale contains 18 items ranging from 5 (Strongly agree) to 0 (strongly disagree).

Overall, most primal beliefs show weak positive correlations with all pairings of the IAS. The strongest correlation is between the hierarchical belief and the Hungry/Thirsty pairing (r = 0.181). Some beliefs, however, exhibit negative correlations with certain pairings. These negative correlations range from r = -0.0940 between the changing belief and the Hungry/Thirsty pairing, to r = -0.00490 between the Enticing belief and the Itch/Bruise pairing.

The Generic Conspiracist Beliefs Scale [GCBS; Brotherton et al. (2013)] was used to assess five facets of conspiracy beliefs: Extraterrestrial, Global Conspiracies, Government Malfeasance, Information Control, and Personal Wellbeing. The scale comprises 15 items rated on a 5-point Likert scale, ranging from definitely not true (1) to definitely true (5).

Overall, the GCBS showed a weak but positive correlation with all facets of the IAS, with the strongest correlation observed between Global Conspiracies and Hungry/Thirsty (r = 0.140). Negative correlations were found within the Global Conspiracies, Extraterrestrial, and Information Control facets, though these were small, ranging from r = -0.0101 to r = -0.0167.

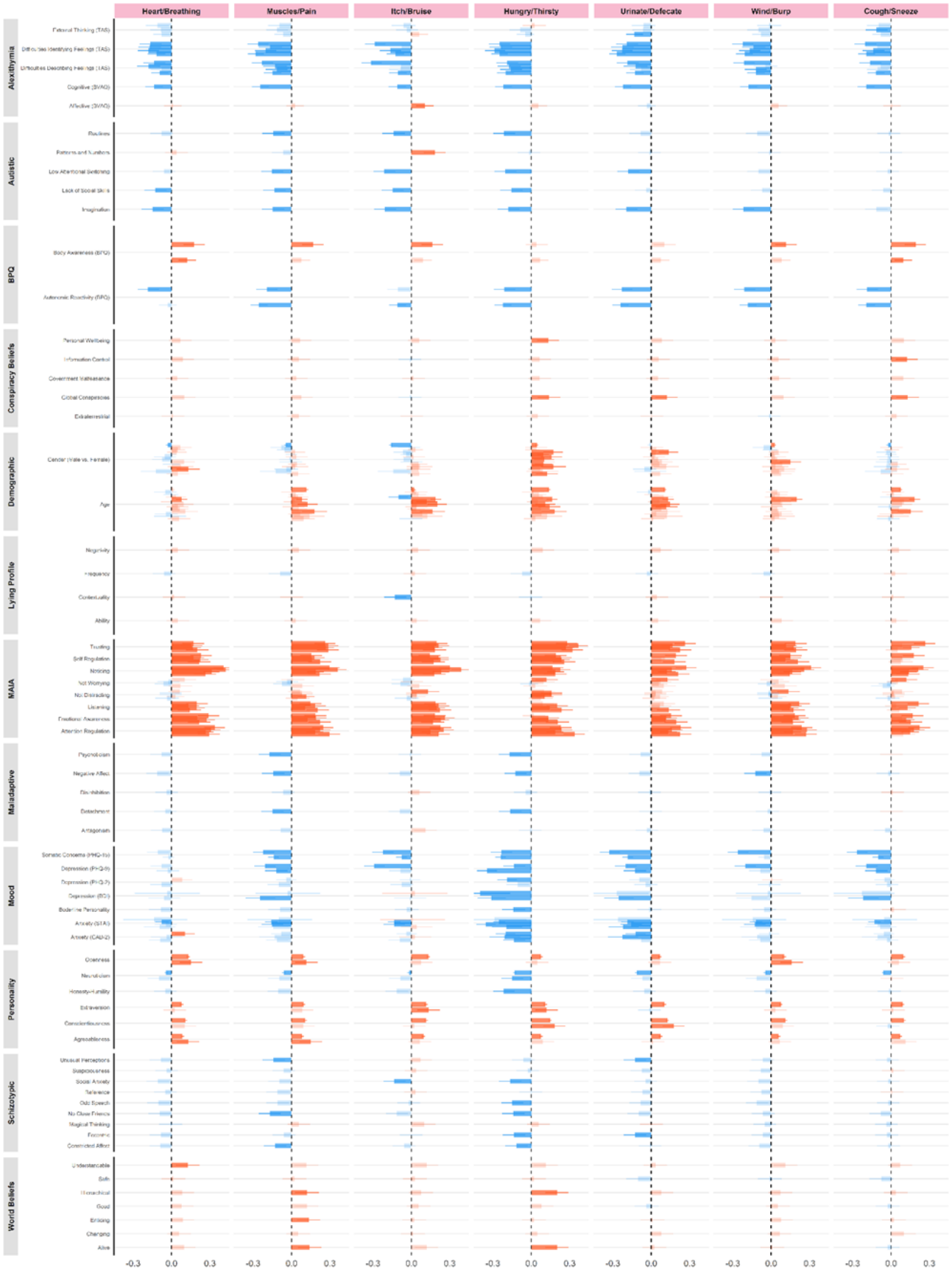
Lastly, the Lying Profile Questionnaire [LIE; Makowski, Pham, et al. (2023)] a 16 item visual analog scale was used to assess 4 dispositional lying simensions: ability; negativity, contextuality, and frequency.

Overall, most lying profile dimensions show weak correlations with IAS pairings. Ability exhibits primarily weak positive correlations, with the strongest observed for Wind/Burp (r = 0.082). In contrast, Frequency tends to show weak negative correlations, ranging from Wind/Burp (r = -0.062) to Muscles/Pain (r = -0.088). Contextuality displays mixed correlations, with

Itch/Bruise showing the strongest negative association (r = -0.127), while Urinate/Defecate has a small positive correlation (r = 0.045). Finally, Negativity is consistently positively correlated with all pairings, with the strongest relationship found for Hungry/Thirsty (r = 0.090).

Figure 3

Figure 2. *Correlates of the IAS*



Discussion

Our findings confirm that interoception exists within a complex network of correlates. Among these, alexithymia exhibits the strongest negative correlation with the IAS, whereas the MAIA questionnaire shows the strongest positive correlation. These correlates not only help explain different aspects of interoception but also serve as valuable tools for validating interoceptive measures.

While our results reveal various correlations with the IAS, they are limited to the scope of the given questionnaire. Nonetheless, they provide valuable insights into how interoception may relate to different psychological and personality traits. The results show a consistent pattern of correlations with other measures and highlight interesting exploratory results, such as correlations between primal world beliefs with the IAS.

Our analysis found a strong negative correlation between alexithymia and IAS scores, aligning with previous research (Brand et al., 2023; Herbert et al., 2011; Murphy et al., 2019). Similarly, a negative correlation between autism and interoceptive awareness was observed in our sample, consistent with prior findings (DuBois et al., 2016).

Conspiracy beliefs did not strongly correlate with IAS scores, though a slight positive correlation was present. To our knowledge, this relationship has not been previously explored. However, prior studies have suggested connections between interoception and (political) beliefs, potentially pointing to shared underlying mechanisms (Ruisch et al., 2022a).

The relationship between interoception and lying profiles was also weak. This contrasts with previous research suggesting associations between interoception and deception (Makowski, Lau, et al., 2023), warranting further investigation.

Mood and IAS scores exhibited a strong negative correlation, consistent with prior studies that have documented similar findings (Solano López & Moore, 2018). Additionally, personality traits correlated with interoceptive accuracy scores, reinforcing existing research linking personality and interoception (Erle et al., 2021).

We also observed negative correlations between schizotypy and interoception, in line with

previous studies that identified a similar relationship with interoceptive awareness, particularly in individuals at risk for psychosis (Torregrossa et al., 2022).

Interestingly, world beliefs demonstrated significant positive correlations with interoception. While this relationship has not been previously documented, other forms of belief, such as political ideology, have been linked to interoception (Ruisch et al., 2022b). Further research is needed to determine whether world beliefs, which shape our perception of reality (J. D. W. Clifton, 2020), are meaningfully connected to interoception.

Overall, our findings highlight the broad relevance of interoception across various cognitive and affective traits, underscoring its significance in both research and clinical contexts. By identifying numerous correlates of the IAS, we contribute not only to a deeper understanding of interoception's role in daily life but also to the ongoing validation of the IAS and other interoceptive measures. This analysis lays an important foundation for the development of new interoceptive assessment tools, further advancing our comprehension of interoception and its impact on human experience.

General Discussion

Our analyses revealed that the IAS follows a four-factor structure with an uneven distribution. While the findings indicate that the IAS measures interoception adequately, there is room for improvement. Additionally, different correlation measures with the IAS suggest opportunities for further exploration of how interoception is assessed. In the following section, we discuss the strengths and shortcomings of the IAS, followed by proposed steps to enhance interoception measurement.

Overall, the IAS is straightforward in its sensation-centered items. However, several areas for improvement emerge from this study. Firstly, redundant items should be removed, such as the "itch" item, as highlighted in our analysis. Previous research also suggests redundancy between itch and tickle items Campos et al. (2021). Interestingly, while Campos et al. (2021) does not recommend the removal of either, Lin et al. (2023) argues for removing the itch item due to their overlapping character representation.

Furthermore, this study recommends using analog scales instead of 5-point scales. The limited variability of the 5-point scale often results in most responses clustering around 3 or 4. As shown in Figure 2, adopting an analog scale significantly increases variability. However, even with an analog scale, IAS variability remains constrained. Greater variability allows for better differentiation among participants, making dispersion an essential factor for obtaining meaningful results. Enhancing variability would therefore be beneficial for the IAS.

Despite these improvements, certain limitations persist in the IAS that affect its accuracy. Notably, some modalities are underrepresented—for instance, heart perception is measured by only one item. Expanding modality coverage would enhance variability within each category, leading to more nuanced results. Moreover, the IAS lacks a clear theoretical or empirical structure, with only small item groupings. Ideally, a scale should allow for clear groupings that support meaningful data analysis. In this study, each group contained only two items, resulting in low scores and limited variability. Additionally, some IAS items are ambiguous, with their interpretation depending on context. For example, an item about perceiving heartbeats and another about vomiting could both relate to anxiety, leading to results that may differ from initial expectations. Thus, the grouping and structure of the IAS require refinement.

Another concern is that all IAS items are phrased positively, which may influence participant responses. While positive phrasing has advantages, it can also introduce response bias, leading to unidimensional results. A more balanced phrasing approach, incorporating both positively and negatively framed items, could yield more accurate responses.

Given these considerations, it is clear that context-specific, cross-modal items—such as integrating cardioception and respiroception—are needed. Recognizing the necessity for a refined interoception scale, this study proposes the development of the Multidimensional Interoceptive Inventory (MInt). This new scale will be designed to align with recent findings on the IAS and interoception research while allowing for direct comparison with IAS correlates.

[**TO DO**: add - previous work suggests the importance of physiological contexts (Vlemincx et al., 2021)] **I would rather put that in the discussion in the suggestions for better**

scales

Conclusion

The IAS is a valuable tool for measuring interoception compared to existing questionnaires and methods. However, refining or even redesigning the questionnaire could lead to a more precise and comprehensive assessment. This study highlights the need for a new interoception scale to advance research in the field. By identifying various correlates of the IAS, this work paves the way for future investigations into optimal interoceptive measures, ultimately laying the foundation for the development of a more effective interoception survey.

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