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

Ana Neves[1], Giulia Poerio[2], Magdalena Pfaff[1], Robyn Scharte[1], Raquel Nogueira Arjona[1,3], and Dominique Makowski[1,4]

[1]School of Psychology, University of Sussex

[2]Sussex Addictions Research and Intervention Centre, University of Sussex

[3]Sussex Centre for Consciousness Science, University of Sussex

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Introduction

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 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.

The Interoceptive Assessment Puzzle

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 metacognitive judgments), "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 (Desmedt et al., 2023; Jahedi & Méndez, 2014).

Although the use of subjective self-report questionnaires to measure deeply embodied functions might seem paradoxical at first, 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 et al., 2018; Suksasilp & Garfinkel, 2022). Moreover, the notion that self-reports might not reflect the same processes as other interoception tasks might be important to contextualize the apparent lack of convergence between measures in the field (Desmedt et al., 2022). For instance, existing findings typically show weak or no correlations between questionnaires and objective measures, such as the Heartbeat Counting Task (HCT, Schandry, 1981) and the Heartbeat Detection Task (HDT, Kleckner et

Ana Neves
Giulia Poerio
Magdalena Pfaff
Robyn Scharte
Raquel Nogueira Arjona
Dominique Makowski

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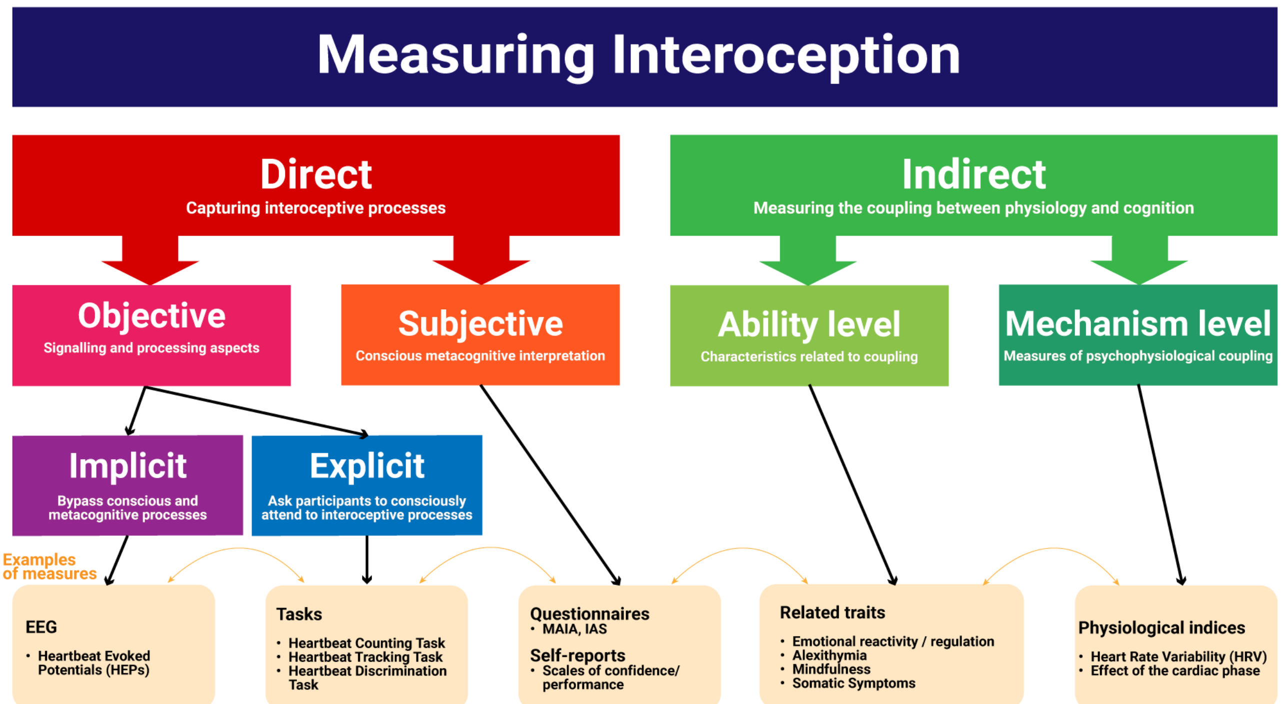
Correspondence concerning this article should be addressed to Dominique Makowski, Email: D.Makowski@sussex.ac.uk

Figure 1

The Interoceptive Assessment Puzzle. The different modalities of interoception (e.g., cardioception) can be assessed directly or indirectly. Direct assessments can further be subjective or objective, depending on whether they involve conscious metacognitive appraisals or more performance-based indices. Interoceptive tasks can be explicit (the participant is aware of the interoceptive nature of the task and must consciously attend to interoceptive signals; e.g., the heartbeat counting task) or implicit (measurements of interoception done unbeknowst to the participant; e.g., heartbeat evoked potentials measured during resting state). Indirect assessments evaluate constructs typically related (and ideally dependent on) to interoceptive processes or ability (or its deficit).



al., 2015), including for measures of the same theoretical dimensions (Arslanova et al., 2022; Brand et al., 2023; e.g., task-based accuracy vs. self-reported accuracy, Murphy et al., 2019). Additionally, even various objective measures assessing in theory the same interoceptive dimension, such as accuracy, either show no or weak correlation (respectively, Brand et al., 2023; Hickman et al., 2020). Perhaps more surprisingly, low correlations have been observed even among questionnaires, suggesting (in parallel to major validity concerns) the potential targeting of different facets related to interoception.

One striking example concerns the assessment of interoceptive sensibility, which is broadly defined as the self-reported tendency to focus on and detect internal sensations (Garfinkel et al., 2015), but more narrowly as the subjective tendency to focus on interoceptive signals, without necessarily implying detection ability (Khalsa et al., 2018). A recent systematic review suggested that various questionnaires designed to assess interoceptive sensibility may, in fact, measure distinct constructs, with the risk of researchers treating them as equivalent despite overall low convergence (Desmedt et al., 2022). Notably, this review adopted a broad definition of sensibility, incorporating both interoceptive sensibility and interoceptive self-report scales, following the eight-facet model by Khalsa et al. (2018). Several widely used questionnaires were included in the review, such as the Multidimensional Assessment of Interoceptive Awareness (MAIA, Mehling et al., 2012; MAIA-2, Mehling et al., 2018), the Body Perception Questionnaire (BPQ, Porges, 1993), the Private subscale of the Body Consciousness Questionnaire (PBCS, Miller et al., 1981), the Body Awareness Questionnaire (BAQ, Shields et al., 1989), and the Eating Disorder Inventory (Garner et al., 1983; EDI, Garner, 1991). The lack of correlations to moderate correlations among these questionnaires highlight the need for greater conceptual clarity regarding what each measure captures, how they relate to different dimensions of interoception, and their potential overlaps with other constructs, such as alexithymia and body awareness.

The Interoceptive Accuracy Scale (IAS)

Focusing on another dimension 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 (*"I can always accurately perceive when my heart is beating fast"*), skin (*"I can always accurately perceive when something is going to be ticklish"*), arousal or bodily functions like coughing (*"I can always accurately perceive when I am going to cough"*) or urinating (*"I can always accurately perceive when I need to urinate"*). Appealingly, the IAS' statements are about specific interoceptive behaviours, which is a distinct difference with other popular interoception questionnaires, such as the MAIA-2, 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"*), as well as dimensions related to attention regulation (e.g., Not-distracting) or emotion regulation (e.g., Not-worrying).

[**NOTES**: todd 2022 found no correlation for MAIA and IAS except with the non-worrying facet + Gaggero found positive correlations with IAS and MAIA (general)]

The original validation study suggested a two-factor structure for the IAS, one reflecting the perception of general interoceptive signals (urinate, hungry, defecate, thirsty, pain, heart, taste, breathing, temperature, muscles, affective touch, vomit, sexual arousal), and other relating to signals that may be difficult to perceive solely through interoceptive information (itch, tickle, cough, burp, bruise, blood sugar, sneeze, wind). The authors however underlined its acceptable but imperfect fit (Murphy et al., 2019, p. 127), and several follow-up studies have indeed identified different optimal solutions. For instance, Brand et al. (2023) reported a 1-factor solution, while Lin et al. (2023) - using Exploratory Graph Analysis (EGA, H. F. Golino & Epskamp, 2017) - and Campos et al. (2021) found bifactor solutions (i.e., one general factor above a set of lower-level factors, Rodriguez et al., 2016) to be the best fit. Using a 2-factors Exploratory Factor Analysis (EFA), Koike and Nomura (2023) suggested that the items could be grouped into cutaneous (itching, tickling, coughing, burping, affective touch, bruising, passing gas, sneezing, muscle sensations, sexual arousal, and taste) and visceral sensations (urination, defecation, hunger, thirst, pain, breathing, fatigue/blood sugar, temperature, vomiting, and heartbeat).

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) additionally highlights five locally dependent pairs and three items (touch, blood sugar, bruise) with exceptionally high difficulty and low discrimination, and Campos et al. (2021) reported "tickle" to be the only item that reflected more specific factors than the general factor. Furthermore, localization issues also arose, with both "itch" and "tickle" corresponding to the same Chinese character, leading to their collapse into a single item (Lin et al., 2023).

Regarding its validity, the IAS has naturally been compared to other interoception-related measures, and shows a positive correlations with most facets of the MAIA (Mehling et al., 2018), except for the Not-Distracting and Not-Worrying subscales (Brand et al., 2023) - which were previously highlighted as related to non-interoceptive abilities (Ferentzi et al., 2021). Interestingly, findings on the correlation between the IAS and the body awareness dimension of the BPQ (i.e., BPQ-A) 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 (EDI-IA, Lin et al., 2023) and a negative correlation with the Interoceptive Confusion Questionnaire (ICQ, Brewer et al., 2016), as reported by Brand et al. (2023) and Murphy et al. (2019). Lastly, the correlation with the Interoceptive Attention Scale (IATS, Gabriele et al., 2022) appears rather small (Koike & Nomura, 2023; Lin et al., 2023).

While assessing the predictive validity of an interoception scale can be conceived as theoretically challenging, expected negative associations were observed between the IAS and 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). Taken together, these findings support the IAS as measuring an adaptive aspect of interoception, although its pattern of associations with other interoception (or interoception-related) questionnaires points towards some overlap across various theoretical dimensions, casting some doubt on the orthogonal models of interoception and the possibility of its faithful capture by questionnaires.

The current study aims at 1) clarifying the structure of the IAS with a mega-analytic (which involves a re-analysis at the raw data level by aggregating datasets) approach that leverages existing data and contrast the traditional CFA/SEM factor-based analyses with network-based ones (Exploratory Graph Analysis); 1) provide an overview of the dispositional correlates of the IAS, clarifying its general pattern of associations, which is key to better understand the nature, place and role of interoception questionnaires within a larger context.

Study 1

Study 1 will 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; Makowski et al., 2025; Murphy et al., 2019; Poerio et al., 2024; 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., applying the same method on all samples separately) to add nuance to the general picture, as all studies differ in their sample size, demographic characteristics, 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 five unpublished studies. A total of 16 datasets was included (see **Table 1**).

The total number of participants was 33,272 participants (Mean = 48.09 ± 13.1, 71.3% Female).

Data Analysis

Psychometrically good items should exhibit various qualities, such as validity, reliability and discrimination, to which one of the contributing factors is the amount of inter-individual variability captured by an item. Items to which all participants' answers are concentrated around one option - i.e., exhibiting a narrow distribution - will be flagged as potentially problematic.

After examining the distributions and correlations of all IAS items, we will test for "redundant" items (e.g., due to multicollinearity or local dependency) using Unique Variable Analysis (UVA, Christensen et al., 2023), a novel method derived from network psychometric designed to identify and merge items that share substantial variance (which can distort the structure estimation). We will use a threshold of 0.30 that detects large to very large overlap.

Following the analysis of items, we will analyze the factor structure of the IAS using three different approaches, each with particular trade-offs and assumptions, to provide a multi-verse picture of likely solutions. Namely, we will apply traditional exploratory and confirmatory Factor Analysis (EFA/CFA), hierarchical clustering (HCA), and Exploratory Graph Analysis (EGA), to the whole sample, as well as to each dataset separately (details being available in the analysis document at https://github.com/RealityBending/InteroceptionIAS), and our decisions and conclusions will try to take into account both levels of analysis.

By combining network analysis with psychometric methods, the recently-developed EGA framework allows to jointly estimate the number of dimensions (i.e., groups of items), the structure as well as its stability (H. Golino et al., 2020; H. F. Golino & Epskamp, 2017). Evidence has underlined its suitability as an alternative to traditional factor analysis, addressing some of its limitations such as the assumption of a "latent" source of variability, possible biasing in the estimation of the optimal factor numbers depending on sample size, and the poor performance of other methods in complex population structures, while remaining comparable and interpretable (Christensen & Golino, 2021b; Jiménez et al., 2023). At a fundamental level, EGA conceptualizes variables as nodes in a network, with connections (edges) reflecting associations between them. Clustering these nodes reveals distinct communities of related items, in practice akin to traditional latent factors - but without explicitly assuming their presence (Christensen & Golino, 2021b). We used the EGAnet package (Christensen & Golino, 2021a) to fit a hierachical EGA with the Leiden community detection algorithm.

While EGA offers a robust alternative to traditional factor analysis, factor analysis remains a widely used method for dimensionality assessment. As our goal is to provide a general - yet nuanced - picture, with room to show potential discrepancies emerging from the methods used, we will also include it in the present study. Unlike EGA, factor analysis assumes that a latent source of variability — a common latent variable — underlies the observed set of manifest variables (Cosemans et al., 2022). A critical step in factor analysis is determining the optimal number of factors, for which we will used the Method Agreement Procedure (Lüdecke et al., 2021), which involves a consensus-based decision based on multiple factor estimation methods applied concurrently.

Finally, we will also apply Hierarchical Clustering Analysis (HCA, Murtagh & Legendre, 2014), which differs from factor analysis in that it does not assume any latent source of variability, but instead iteratively groups items based on their similarity (e.g., correlation) into a hierarchy of clusters. The benefits of HCA include its interpretability and ability to capture complex relationships among items without relying on strict assumptions about data distribution or latent variables.

In a typical 2-step fashion, this first analysis run will be followed by a structure refinement with a further selection of items, and the final pool of items will be tested again. Additionally, various solutions (e.g., adding general factors) will

Table 1

Description of the samples used in the study.

Sample	Reference	Language	N	Difference	Age (Mean ± SD)	Range	Female %	Availability
	Murphy et al., (2020)							osf.io/3m5nh
Sample 1a		English	451		25.8 ± 8.4	18-69	69.4%	
Sample 1b		English	375		35.3 ± 16.9	18-91	70.1%	
Sample 2	Gaggero et al., (2021)	English and Italian	814		24.9 ± 5.3	18-58	60.3%	osf.io/5x9sg
Sample 3	Campos et al., (2022)	Portuguese	515		30.7 ± 10.5	18-72	59.6%	osf.io/j6ef3
Sample 4	Todd et al., (2022)	English	802		48.6.6 ± 14.1*	18-92*	50%*	osf.io/ms354
Sample 5	Arslanova et al., (2022)	English	143		28.5 ± 7.6	18-73	46.8%	osf.io/mp3cy
Sample 6	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 7a		German	522		23.4 ± 6.7	18-79	79.5%	
Sample 7b		German	1993		32.0 ± 12.6	16-81	77.7%	
Sample 7c		German	802		27.3 ± 9.3	18-72	68.9%	
	Lin et al., (2023)							osf.io/3eztd
Sample 8a		Chinese	1166	Collapsed "Itch" and "Tickling"	32.5 ± 8.4	16-60	57.0%	
Sample 8b		Chinese	500	Collapsed "Itch" and "Tickling"	37.4 ± 7.4	20-60	56.2%	
Sample 9	VonMohr et al., (2023)	English	21843		56.5 ± 14.4	18-93	73.2%	osf.io/7p9u5
Sample 10	Makowski et al., (2023a)	English	485	Analog scales. No Temperature, Blood sugar and Cough items	30.1 ± 10.1	18-73	50.3%	github.com/RealityBending/IllusionGameReliability
Sample 11	Makowski et al., (2023b)	English	836	Analog scales	25.1 ± 11.3	17-76	53.0%	github.com/DominiqueMakowski/PHQ4R
Sample 12	Makowski et al., (2023c)	English	146	Analog scales	21.1 ± 4.3	18-50	76%	github.com/RealityBending/InteroceptionPrimals
Sample 13	Makowski et al., (2024)	English	737		36.8 ± 14.9	17, 87	57.3%	github.com/RealityBending/InteroceptionScale
Sample 14	Poerio et al., (2024)	English	107		26.8 ± 9.2	18-57	74.8%	osf.io/49wbv
Sample 15	Poerio et al., unpublished	English	131		30.9 ± 12.0	18-60	75.9%	
Sample 16	Arjona et al., unpublished	English	279		26.4 ± 13.2	18-79	67.7%	
Sample 17	Total		33272		48.09 ± 13.1	17-93	71.3%	

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

be statistically compared using Confirmatory Factor Analysis (CFA).

Results

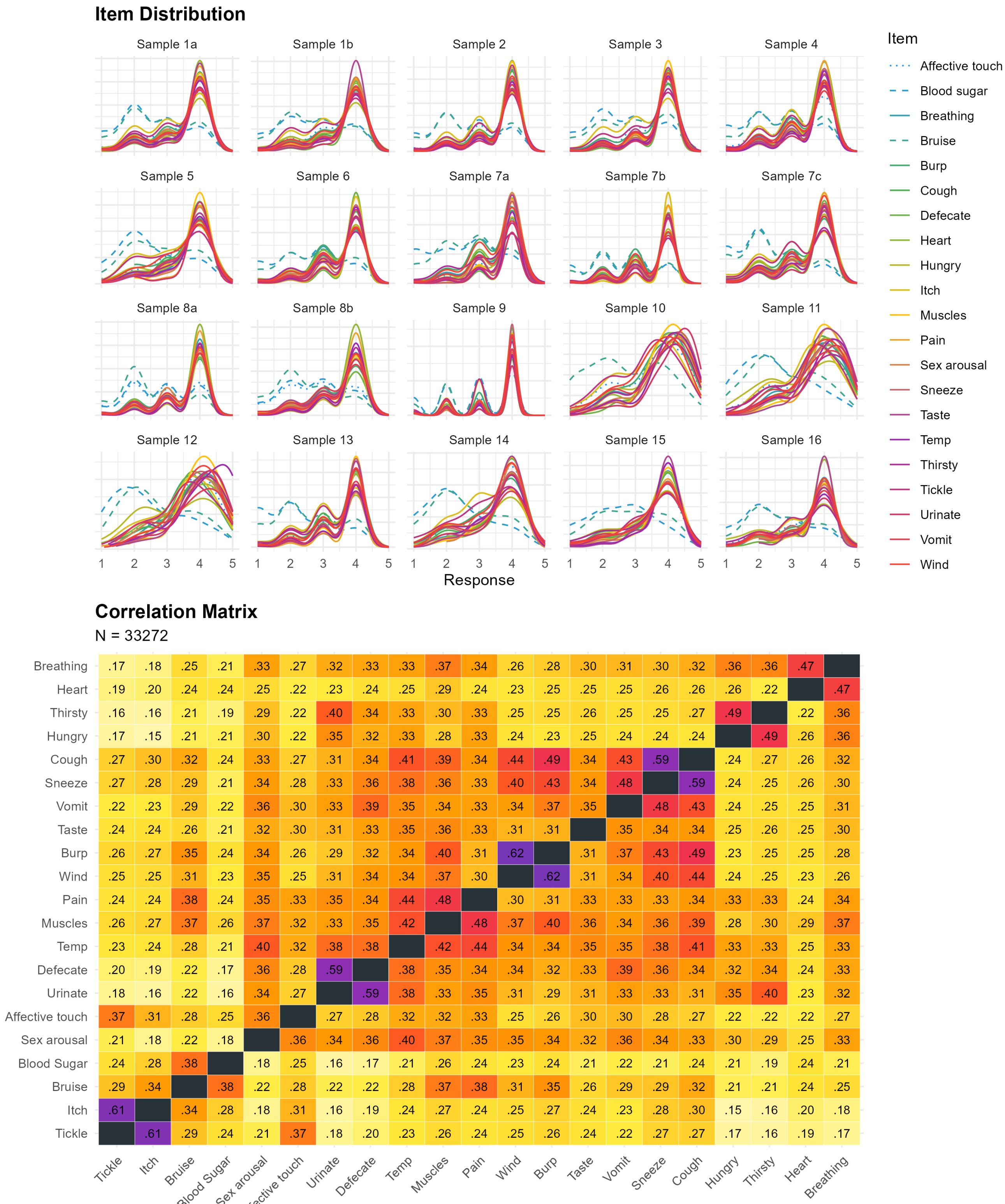
The distribution of the items across samples suggests the presence of a consistent modal value (Figure 2). In other words, participants are most likely to answer 4/5 (i.e., agree) on most items, with the exception of “blood sugar” and “bruise”, which exhibit a different distributional pattern with a lower mode (~2/5). While it is not a problem *per se*, the contrasting distribution might be indicative of items with non-homogeneous psychometric “difficulty”. This is also the case for “affective touch” in samples 8a and 8b (the Chinese validation samples), which might indicate localisation issues. Additionally, one can note the low occurrence of extreme values (1 and 5), meaning that the bulk of answers varies between 3 values (assuming the IAS is implemented as a 5-point Likert scale following its validation). The samples using an analogue scale (samples 10a, 10b and 10c in the figure) display a more continuous and progressive spread of answers, seemingly improving the interindividual variability, although potentially displaying a secondary lower mode at ~2 (which might be suggesting the existence of potential clusters of participants). The correlation matrix between all items shows an overall positive correlation pattern, with highly correlated pairs of items (e.g., Tickle-Itch, Urinate-Defecate, Pain-Wind, Hungry-Thursty) or triplets (Vomit-Sneeze-Cough, Temperature-Muscles-Pain).

UVA flagged two strongly redundant variables, “itch” and “tickle” - suggesting to remove the latter. Several more pairs of items were flagged as moderately redundant (“wind” and “burp”; “urinate” and “defecate”) and mildly redundant (“sneeze” and “cough”; “heart” and “breathing”; “hungry” and “thirsty”). These patterns consistently appeared in most samples when considered individually. We removed “tickle” from further analysis due to its high redundancy (and because it is absent from some datasets due to translation issues).

The HCA highlighted pairs and triplets of items consistently grouped together across samples, such as “wind” and “burp”, “sneeze” and “cough”, “itch” and “bruise”, “urinate” and “defecate”, and “pain”, “muscles”, and “temperature”.

Figure 2

Top: Distribution of responses across datasets reveals a consistent modal value, typically around 4 or 5 (indicating agreement), except for 'blood sugar' and 'bruise' - in dashed lines - and 'affective touch' (dotted lines) in the Chinese validation sample, which have lower modes. Most responses cluster around the middle values, with few extreme scores (1 and 5). Samples using an analogue scale (10a, 10b, 10c) show a more continuous distribution and increased interindividual variability. Since most samples use Likert scales (discrete), density plots may not be the most accurate representation but were chosen to clearly highlight variability patterns in the data. Bottom: The correlation matrix between all items shows an overall positive correlation pattern, with correlated pairs (e.g., Wind, Burp) of items or triplets (e.g., Vomit, Sneeze and Cough).



This pattern was largely replicated by the EGA, with the additional presence of a unique cluster comprising "Sex arousal", "Affective touch", "Temperature", "Pain", "Muscles", and "Taste". EFA suggested the optimal number of factors to be 3, yielding one dimension with expulsion-related items ("burp", "wind", "cough", "sneeze", and "vomit"), a second dimension with visceroceptive items ("heart", "breathing", "hungry", "thirsty", "urinate", and "defecate"), and a third dimension with skin-related items ("bruise" and "blood sugar").

Importantly, this initial structure analysis run highlighted some problematic items: "taste" typically displayed a lone or unstable pattern of associations, "affective touch" exhibited cross-loadings and instability, "vomit" was less strongly associated with other items, and "itch" did not form a consistent cluster. Finally, "temperature" and "sexual arousal" showed redundant patterns of associations but were less reliable. These 6 items were thus removed, and a second run of structure analysis was performed on the remaining 14 items.

HCA and EGA yielded highly consistent results, emphasizing pairs of items, namely Hungry-Thirsty, Bruise-Blood sugar, Urinate-Defecate, Muscles-Pain, Breathing-Heart, Cough-Sneeze, Wind-Burp. HCA also significantly grouped the Urinate-Defecate and Muscles-Pain pairs, as well as expulsion items (Wind-Burp and Cough-Sneeze). EFA suggested once again 3 factors as the optimal solution, with the first factor including expulsion-related items ("burp", "wind", "cough", "sneeze"), the second factor being related to the Urinate-Defecate pair, and the third factor comprising the remaining items.

We then fitted and compared using CFA various candidate structures emerging from the previous analyses, including a 1-factor model (the G-model), a 3-factor model (EFA), a 3+1 model (EFA + general factor), a 5-factor model (HCA), a 5+1 model (HCA + general factor), a 7-factor model (EGA), and a 7+1 model (EGA + general factor). The EGA model with 7 factors of item pairs provided the best fit with the lowest RMSEA (0.035), lowest χ^2 (2306.30), highest CFI (0.984). It was followed by the EGA + general factor model (RMSEA = 0.054, χ^2 = 6842.38, CFI = 0.952), and the HCA model with 5 factors (RMSEA = 0.078, χ^2 = 13296.33, CFI = 0.907). The other models performed poorly, with RMSEA > 0.08 and CFI < 0.90. The unique-factor model yielded the lowest BIC (which takes into account the number of factors), followed by the EGA model. All the other models displayed significantly (BIC-based Bayes Factor < 1/100) lower evidence compared to the EGA model.

This result was relatively consistent across unique datasets with the EGA model providing the best fit. In all samples where CFA converged, it showed excellent performance with low RMSEA (≈ 0.025–0.046), high CFI (≥ 0.97), and substantially lower χ^2 compared to alternative models. Adding a general factor systematically worsened fit, while hierarchical clustering and EFA-based models showed poorer performance (RMSEA > 0.06, CFI < 0.93). Although BIC values occasionally favored alternative specifications, Bayes factor comparisons overwhelmingly supported the EGA solution, confirming its robustness across datasets.

Discussion

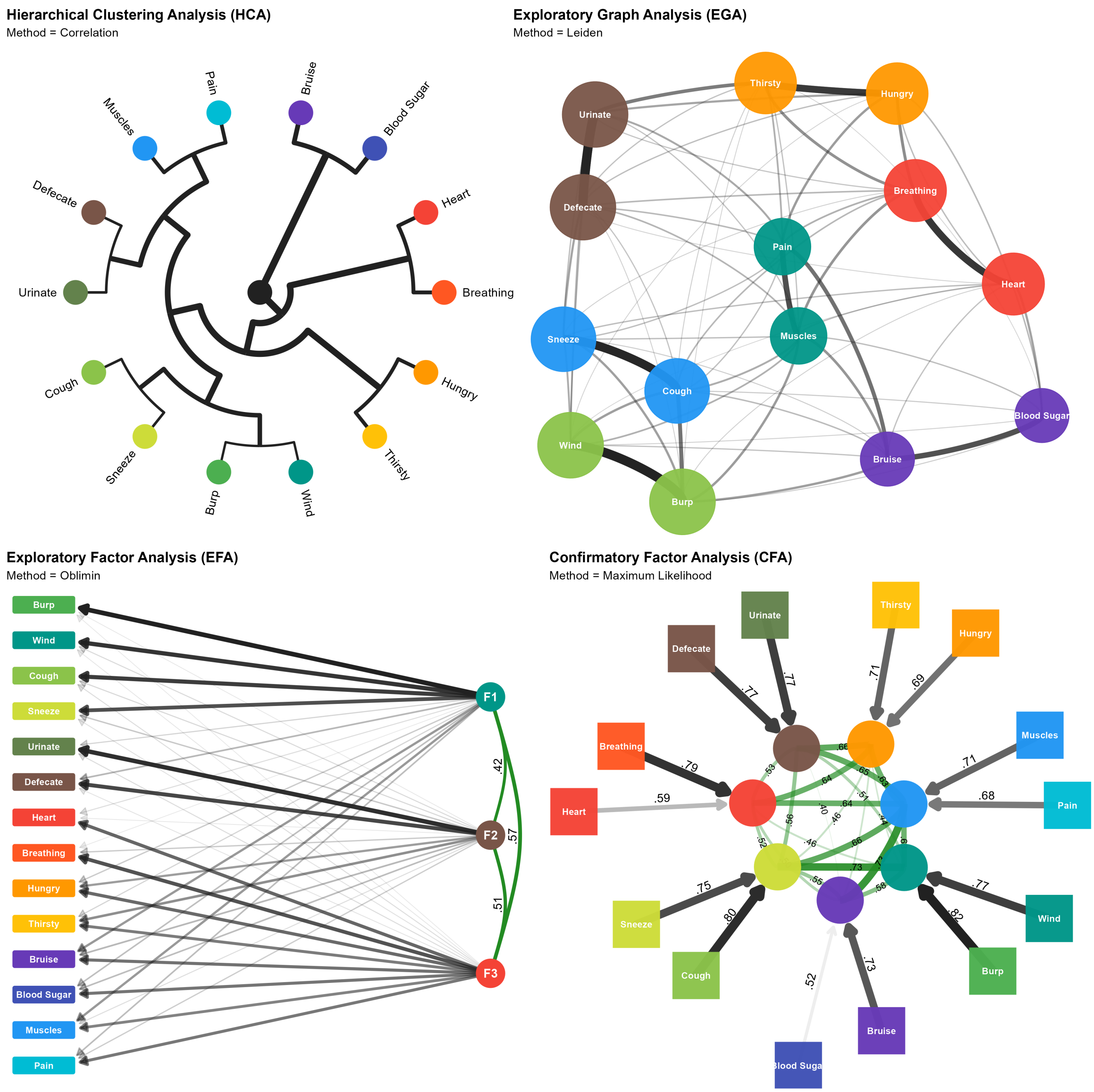
The first study aimed to provide the most systematic test of the IAS structure to date. Previous work has produced conflicting models, ranging from a single general factor (Brand et al., 2023), to bifactor solutions (Campos et al., 2021; Lin et al., 2023), and two-factor models (Koike & Nomura, 2023; Murphy et al., 2019). Alongside these structural discrepancies, several studies have questioned the quality of specific items. Murphy et al. (2019) distinguished between items tapping direct interoceptive signals (e.g., heartbeat) and others reflecting phenomena less accessible to interoception (e.g., bruising). Additionally, Lin et al. (2023) identified locally dependent pairs and low-discrimination items with Network-based methods, while Campos et al. (2021) found that "tickle" did not load on the general factor. To address these open questions, we reanalyzed multiple open-access datasets using a mega-analytic framework, contrasting traditional factor-analytic approaches with network-based methods.

Overall, the findings converge on a robust yet novel picture. Initial analysis revealed issues in 7 items (e.g., instability, redudancy, low associations, less reliable) which led to the formation of a 14-item IAS. Exploratory and confirmatory analyses indicated that the IAS is best characterized by seven pairs of closely related items, consistently identified by EGA and supported by HCA. These pairs (e.g., hunger–thirst, urinate–defecate, cough–sneeze) were highly replicable across independent samples and yielded superior fit indices in CFA compared to other solutions. Although the one-factor model occasionally achieved lower BIC, Bayes factor comparisons overwhelmingly supported the EGA structure, underlining its empirical robustness.

This pattern has several important implications. First, it suggests that the IAS does not capture a broad latent construct of interoceptive accuracy as originally intended, but rather reflects a set of tightly coupled item clusters tied to specific bodily sensations. In other words, the IAS may function more as a checklist of bodily signal detection items than as a scale measuring a coherent higher-order dimension. This stands in contrast to the original two-factor proposal (Murphy et al., 2019), where the factors were highly correlated and collapsed into a unidimensional score, and helps explain why subsequent studies diverged in their conclusions: the psychometric structure of the IAS appears to be driven more by local dependencies than by robust latent factors. Second, the presence of redundant or unstable items (e.g., tickle, taste, affective touch), already highlighted in prior validation studies (Campos et al., 2021; Lin et al., 2023), undermines the

Figure 3

TODO.



interpretability of the scale, as their contributions appear inconsistent or overlapping. Together, these findings help explain why previous research has struggled to converge on a stable factor structure: the IAS lacks the psychometric properties required for strong latent modeling and may overstate its dimensionality by conflating redundancy with structure.

At the same time, the results do not render the IAS unusable. The consistent emergence of item pairs highlights intuitive bodily domains (e.g., visceral, expulsion, musculoskeletal) that align with everyday interoceptive experiences, supporting its ecological validity. However, the limited breadth of these pairings, the redundancy across items, and the reliance on a narrow 5-point scale all restrict the scale's ability to differentiate between individuals and to capture the multidimensional nature of interoception (Desmedt et al., 2022). These findings therefore call for refinement, either through targeted revisions of the IAS (e.g., removing redundant items, addition of context-specific items, adopting analogue response formats) or through the development of a new questionnaire that better balances theoretical coherence with empirical validity.

In sum, Study 1 demonstrates that the IAS structure is best described by clusters of tightly coupled item pairs reflecting local dependencies, rather than by a broad latent dimension. While this solution is replicable and statistically robust, it highlights the conceptual and psychometric limitations of the IAS in its current form. These insights help contextualize the mixed findings on the scale's validity and provide a crucial foundation for Study 2, where we do the dispositional correlates of the IAS to further evaluate its construct validity and situate it within the broader network of interoceptive and psychological traits.

Study 2

Study 2

Building on the structural findings from Study 1, the second study turns to the validity of the IAS by examining its dispositional correlates. Although the IAS has been widely used, evidence regarding its associations with personality traits, affective dispositions, and related psychological constructs remains scattered and inconsiste (Brand et al., 2023; Lin et al., 2023; Murphy et al., 2019; Todd et al., 2022). Study 2 therefore had two primary goals. First, to provide a robust overview of the dispositional correlates of the IAS by leveraging the large number of available datasets. Second, to evaluate the practical benefits of using the refined 14-item version of the scale identified in Study 1, compared to the original 21-item unidimensional version, in order to assess whether structural improvements translate into clearer and more reliable external associations.

Methods

Materials

We selected measures that appeared in multiple datasets from Study 1 and/or were relevant given the scope of the study, merging scores of regular and abridged versions for conciseness where applicable. The measures include constructs related to interoception, mood, personality, psychopathology, and beliefs and misbeliefs.

Interoception Related. The Multidimensional Assessment of Interoceptive Awareness Version-2 (MAIA-2, Mehling et al., 2018) is a 37-item questionnaire assessing eight dimensions of interoception: Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trust. Responses are rated on a 6-point Likert scale (e.g., "I notice when I am uncomfortable in my body").

The Body Perception Questionnaire Short Form (BPQ-SF, Cabrera et al., 2018) contains 46 items measuring body awareness and autonomic reactivity on a 5-point Likert scale (e.g., "My heart often beats irregularly"). The very-short form (BPQ-VSF) contains 12 items from the body awareness subscale. For this study, scores from both versions were combined.

The Interoceptive Confusion Questionnaire (ICQ, Brewer et al., 2016) consists of 20 items rated on a 5-point Likert scale (e.g., "I cannot tell when my muscles are sore or tight") assessing difficulties in interpreting non-affective physiological states, such as pain or hunger.

The Toronto Alexithymia Scale (TAS-20, Bagby et al., 1994) contains 20 items rated on a 5-point forced-choice scale (e.g., "I have feelings I can't quite identify"), divided into three dimensions: difficulty identifying feelings, difficulty describing feelings, and externally oriented thinking.

The Bermond–Vorst Alexithymia Questionnaire (BVAQ, Vorst & Bermond, 2001) consists of 40 items across five subscales: fantasising, identifying, analysing, verbalising, and emotionalising. Items are rated on a 5-point Likert scale. The BVAQ also provides two higher-order factors, namely affective and cognitive (e.g., "I like to tell others how I feel").

Mood and Anxiety Related. The Beck Depression Inventory-II (BDI-II, Beck et al., 1996) is a 21-item measure of depressive symptom severity, including psychological (e.g., guilt) and physiological (e.g., loss of energy) components. Items are rated on a 4-point scale (e.g., "I feel sad much of the time").

The Patient Health Questionnaire-4 (PHQ-4, Kroenke et al., 2009) is a 4-item screening tool for depression and anxiety, rated on a 4-point Likert scale (e.g., "Little interest or pleasure in doing things"; "Not being able to stop or control worrying"). The PHQ-2 (PHQ-2, Kroenke et al., 2003) and General Anxiety Disorder-2 (GAD-2, Kroenke et al., 2007) scores were combined with the PHQ-4 scores.

The Patient Health Questionnaire-9 (PHQ-9, Kroenke et al., 2001) includes 9 items assessing depressive symptoms on a 4-point Likert scale (e.g., "Feeling tired or having little energy?").

The Patient Health Questionnaire-15 (PHQ-15, Kroenke et al., 2002) assesses somatic symptom distress with 15 items rated on a 3-point scale (e.g., "Over the last week, how often have you been bothered by back pain?").

The Short Mood and Feelings Questionnaire (SMFQ, Angold et al., 1995) is a 13-item measure of recent depressive symptoms in children aged 6–17, rated on a 3-point scale (e.g., "I felt miserable or unhappy").

The State–Trait Anxiety Inventory Trait Version (STAI-T, Spielberger, 1970) is a 20-item trait anxiety questionnaire rated on a 4-point Likert scale (e.g., "I worry too much about something that really doesn't matter"). Scores from the shorter version of the STAIT-5 (Zsido et al., 2020) were combined with the STAI-T.

The Generalized Anxiety Disorder Scale (GAD-7, Spitzer et al., 2006) is a 7-item measure of generalized anxiety symptoms rated on a 4-point Likert scale (e.g., "Not being able to stop or control worrying").

Personality. The NEO Five-Factor Inventory, neuroticism subscale (NEO-FFI, Costa & McCrae, 1992) is a 12-item measure of neuroticism, assessing the general tendency to experience negative emotions such as fear, sadness, or disgust. Items are rated on a 5-point Likert scale (e.g., "I often feel inferior to others").

The Mini International Personality Item Pool (MINI-IPIP6, Sibley et al., 2011) includes 24 items measuring six broad traits: Agreeableness, Conscientiousness, Neuroticism, Openness, Extraversion, and Honesty-Humility. Items were scored on visual analogue scales in our samples (originally 7-point Likert scales; e.g., "Have a vivid imagination").

The Big Five Inventory Short Form (BFI-S, Rammstedt & John, 2007) is a 10-item measure of the Big Five traits, rated on a 7-point Likert scale (e.g., "I see myself as someone who … is considerate and kind to almost everyone").

Psychopathology. The Personality Inventory for DSM-5 Short Form (PID-5-SF, Thimm et al., 2016) consists of 25 items rated on a 4-point Likert scale, measuring five domains: disinhibition, antagonism, detachment, negative affect, and psychoticism (e.g., "Plenty of people are out to get me").

The Schizotypal Personality Questionnaire – Brief Revised (SPQ-BR, Davidson et al., 2016) contains 32 items rated on a 5-point Likert scale, assessing four primary dimensions: cognitive-perceptual, interpersonal, disorganized, and social anxiety. These are subdivided into nine secondary factors, including constricted affect, eccentricity, magical thinking, lack of close friends, odd speech, referential thinking, social anxiety, suspiciousness, and unusual perceptions (e.g., "Plenty of people are out to get me").

The McLean Screening Instrument for Borderline Personality Disorder (MSI-BPD, Zanarini, 2003) is a 10-item dichotomous screening measure for borderline personality disorder (present/absent; e.g., "Have any of your closest relationships been troubled by a lot of arguments or repeated breakups?").

The Autism Spectrum Quotient Short Form (ASQ-S, Hoekstra et al., 2011) is a 28-item measure of five autistic traits: social skills, adherence to routines, cognitive flexibility, imagination, and patterns/numbers. Items are rated on a 4-point Likert scale (e.g., "I find it difficult to work out people's intentions").

Beliefs and Misbeliefs. The Generic Conspiracist Beliefs Scale (GCBS, Brotherton et al., 2013) is a 15-item measure assessing five dimensions of conspiracy beliefs: government malfeasance, extraterrestrial cover-up, malevolent global conspiracies, personal wellbeing, and control of information. Items are scored on a 5-point Likert scale (e.g., "Secret organizations communicate with extraterrestrials, but keep this fact from the public").

The Primal World Beliefs Inventory (PI-99, Clifton et al., 2019) is a 99-item measure assessing 26 high-order beliefs about the world. Items are scored on a 5-point Likert scale (e.g., "Nearly everything in the world is beautiful") The PI-18 (Clifton & Yaden, 2021) is a short form of the orginal questionnaire assessing the 4 main world beliefs: the world is Good (vs. Bad) and its three dimensions: Safe (vs. Dangerous), Enticing (vs. Dull), and Alive (vs. Mechanistic). Scores from the PI-18 scores were combined with the PI-99.

The Lie Scale (LIE, Makowski et al., 2023) is a 16-item measure of lying tendencies across four components: Ability, Frequency, Negativity, and Contextuality. Items are scored on visual analogue scales (e.g., "I am a good liar").

Data Analysis

All variables from the 16 open-access datasets will be extracted and standardized (z-scored). For continuous predictors, we will first ensure consistent ranges across datasets; when necessary, ranges will be rescaled to achieve comparability. In cases where scales of different lengths measure the same construct, scores will be harmonized: when possible, means will be computed from overlapping items, while in other cases total scores will be normalized by the number of items. We will collapse redundant subscales (e.g., PHQ-2 and GAD-2 within PHQ-4) into unified composite scores. Similarly, short forms of trait anxiety (e.g., STAI-5-trait) will be collapsed with their longer counterpart (STAI-T), with scores computed as the mean to ensure comparable ranges. Shorter formats of the PI (PI-18) will be combined with scores of its longer version (PI-99). Missing data will be handled via listwise deletion on a per-model basis prior to fitting.

Associations will be estimated using multilevel regression models implemented in the glmmTMB package (McGillycuddy et al., 2025). Each predictor will be entered separately, with the seven IAS item pairs identified in Study 1 ("Hungry–Thirsty", "Muscles–Pain", "Wind–Burp", "Urinate–Defecate", "Breathing–Heart", "Bruise–Blood", "Cough–Sneeze") and the original IAS scale serving as outcomes. Models will include random intercepts and slopes by sample to account for between-study heterogeneity; when models fail to converge, a reduced structure with random intercepts only will be used. This approach will treat datasets as clusters, thereby providing pooled estimates of the associations while accounting for both within- and between-sample variability, akin to a meta-analytic framework.

From each fitted model, we will extract standardized regression coefficients (β), 95% confidence intervals, p-values, convergence status, and effective sample size. Participants identifying as "Other" will be excluded from analyses due to limited representation.

Results

Age was positively associated across Ias correlates (mean r = .12), with all correlations significant. Gender showed near-zero effects (mean r = −.01), with 63% reaching significance.

Several MAIA subscales showed consistent positive associations with the IAS: Noticing, Attention Regulation, Trusting, Emotional Awareness, Listening, and Self-Regulation (βs ≈ .18–.26). These effects were generally strongest for the full IAS, but often replicated with Hungry/Thirsty or Bruise/Blood pairings. By contrast, Autonomic Reactivity (BPQ; β = −.17) was reliably negative across most pairings, while Body Awareness (BPQ; β = .12) was weak and only reliable for Hungry/Thirsty and Bruise/Blood. Alexithymia measures were consistently negative, with robust effects across both the full IAS and pairings, except for the Affective dimension of the BVAQ which showed only a positive association with the Bruise/Blood sugar pairing (β = .04).

Depression (BDI; β = −.20) and anxiety (STAI-T; β = −.19) were consistently negative across the IAS and most pairings, with Hungry/Thirsty again emerging as a particularly sensitive correlate. Broader symptom indices (PHQ-15, PHQ-4, GAD-7) showed weaker but often reliable effects, although some were restricted to certain pairings (e.g., PHQ-15 with Hungry/Thirsty, Bruise/Blood). By contrast, PHQ-9 and MFQ averaged negatively but were largely nonsignificant, even with the full scale. Autistic traits were generally negative, especially Imagination (β = −.18), which showed broad consistency across pairings except Cough/Sneeze.

Within the Big Five, Openness (β = .14), Agreeableness (β = .05), and Conscientiousness (β = .03) showed small but consistent positive associations, most reliably captured by the full IAS but also evident in pairings. Honesty–Humility was uniquely negative, with significant associations for both the full scale and Hungry/Thirsty. Worldview measures were generally null, though belief in a comprehensible world (β = .11) and an "alive" world (β = .09) showed small but consistent positive associations, mainly with the full IAS and Hungry/Thirsty.

Overall, the full IAS yielded the largest number of significant associations (25), but the Hungry/Thirsty (16) and Bruise/Blood sugar (11) pairings frequently showed equally strong or stronger effects. These item-level pairings often captured variance that the full scale did not, particularly for interoceptive and mood measures. In contrast, other pairings (e.g., Cough/Sneeze, Wind/Burp, Urinate/Defecate) contributed little unique variance. Together, these results suggest that while the full IAS captures broad dispositional tendencies, select pairings may provide more fine-grained sensitivity to specific domains, particularly interoception and affect.

[**NOTE** justify the choice of those specific primals ? higehr correlations with the IAS?]

Discussion

The second study set out to provide a comprehensive overview of the dispositional correlates of the IAS by pooling data across multiple datasets, while also testing whether the refined 14-item version identified in Study 1 confers practical advantages over the original 21-item scale.

Consistent with prior research, the IAS showed strong positive associations with other interoceptive self-report measures, particularly the MAIA, with the exception of the Not Distracting and Not Worrying facets (Brand et al., 2023). This pattern replicates earlier findings while contradicting (Todd et al., 2022), who reported only a near-zero correlation with Not Worrying. Similarly, while previous evidence on the BPQ was mixed, our results indicate more robust associations with the Autonomic Reactivity dimension compared to body awareness (Brand et al., 2023; Campos et al., 2021; Todd et al., 2022). This pattern diverges from earlier findings that consistently reported significant positive associations with Body Awareness (Brand et al., 2023; Campos et al., 2021; Gaggero et al., 2021), while at the same time complementing reports of significant negative correlations with Autonomic Reactivity (Gaggero et al., 2021). The replication of negative associations with interoceptive confusion (Brand et al., 2023; Gaggero et al., 2021; Murphy et al., 2019) further supports the convergent and discriminant validity of the IAS.

Robust negative correlations were observed between the IAS and alexithymia, in line with prior studies (Brand et al., 2023; Campos et al., 2021; Koike & Nomura, 2023; Lin et al., 2023; Murphy et al., 2019). Similarly, negative associations with depression and anxiety, as measured by the BDI and STAI-T, reinforce the clinical relevance of interoceptive accuracy (Brand et al., 2023; Lin et al., 2023). Somatic symptoms were also negatively related to the IAS, although effect sizes were small, echoing earlier findings (Brand et al., 2023; Koike & Nomura, 2023; Lin et al., 2023). At the same time, more recent studies have reported null or inconsistent associations between interoceptive sensitivity and mental-health symptomatology, suggesting that such links may not generalize across all interoceptive domains and could be contingent on measurement approaches or sample characteristics [**REF PRE_PRINT?**].

Clear negative associations also emerged with autism-related traits such as imagination, low attentional switching, and reduced social skills. These findings resonate with DuBois et al. (2016) review reporting interoceptive abnormalities in autism. Nonetheless, our findings are limited to a single dataset employing the ASQ, which constrains the generalisability of conclusions regarding the relationship between interoception and autistic traits.

The associations between interoception and personality traits were more nuanced. Whereas prior work suggested a negative link with neuroticism (Brand et al., 2023), we found this relationship to be inconsistent and even slightly positive, though near zero. By contrast, openness and agreeableness were consistently positively associated with the IAS, albeit with small effect sizes. These findings are consistent with emerging evidence linking openness to interoception as measured by the MAIA-2 (Simkute et al., 2025), and complement reports of associations between interoceptive sensitivity (i.e., the accuracy of reported heartbeat counts relative to actual heartbeats) and extraversion (Haustein et al., 2024). Personality effects more broadly were modest in size, and as such, warrant replication before firm conclusions can be drawn. In contrast, maladaptive personality dimensions and schizotypal traits showed only weak and inconsistent associations with the IAS, indicating that interoceptive accuracy may not play a central role in these domains.

Beyond established correlates, exploratory analyses revealed weak but positive associations between the IAS and primal world beliefs, specifically perceiving the world as alive and understandable. The inclusion of primal world beliefs was exploratory, motivated by their potential theoretical link to embodied cognition and meaning-making processes. Although effect sizes were small, the emergence of consistent associations with perceiving the world as alive and understandable suggests an intriguing avenue for future work at the intersection of interoception and worldview formation.

A central aim of Study 2 was to assess whether the refined 14-item IAS identified in Study 1 provides practical benefits over the original 21-item scale. While the full version most often emerged as the strongest correlate, the refined 14-item IAS performed largely comparably across dispositional measures. Importantly, specific item pairings — particularly Hungry/Thirsty and Bruise/Blood sugar — frequently captured associations as strong as, or occasionally stronger than, the full scale. This suggests that beyond efficiency, the refined IAS may offer more fine-grained sensitivity to certain dispositional domains, highlighting that interoceptive self-report is not unidimensional but may be differentially expressed across bodily contexts.

Overall, these findings provide converging evidence for the construct validity of the IAS, most strongly in relation to interoceptive self-report, alexithymia, mood, and autism-related traits. Other associations, particularly with personality and belief systems, were weaker and more exploratory, highlighting both the breadth and the limits of interoceptive accuracy as captured by the IAS. Taken together, Study 2 advances our understanding of the dispositional landscape of interoception. The findings provide strong support for the construct validity of the IAS, while also demonstrating that the refined version can capture comparable patterns of association. Moreover, the sensitivity of specific item pairings points to the possibility that different bodily contexts (e.g., hunger vs. pain) may differentially align with psychological traits, suggesting a promising direction for future research on the contextual dimensions of interoceptive accuracy.

General Discussion

The present study aimed… [always start with a description of the study].

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**

This suggests that the 14-item IAS constitutes a more efficient tool without substantial loss of predictive power. In practice, the refined scale offers advantages for researchers and clinicians alike: it reduces participant burden, avoids problematic items flagged in Study 1 (e.g., "tickle," "taste," "vomit"), and provides a more coherent representation of interoceptive domains.

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.

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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