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

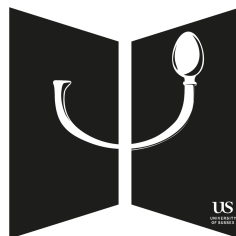**Correlates**

Ana Neves

School of Psychology, University of Sussex

**Author Note**

Ana Neves ⓘD https://orcid.org/0009-0006-0020-7599

This preprint is a non-peer-reviewed work from the **Reality Bending Lab**.

**Abstract**

Blabla the abstract blabla.

*Keywords:* keyword1, keyword2, keyword3

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

**Correlates**

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 3), 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).

26    The notion that self-reports might not reflect the same processes as other interoception

27    measures is important to contextualize the apparent lack of convergence between measures in the

28    field (Desmedt et al., 2022). While few studies have explored the correlation between objective

29    interoceptive measures, such as the Heartbeat Counting Task (HCT, Schandry, 1981) and the

30    Heartbeat Detection Task (HDT, Kleckner et al., 2015), and correspondent self-report measures,

31    existing findings typically show weak or no correlations (Brand et al., 2023; e.g., task-based

32    accuracy vs. self-reported accuracy, Murphy et al., 2019).

33    Even among self-report measures low correlations have been observed, suggesting that

34    these measures, while group in the same umbrella term of self-report assess different facets of

35    interoception. A recent systematic review by Desmedt et al. (2022) examined whether various

36    questionnaires designed to assess "interoceptive sensibility" truly measure the same construct.

37    Notably, Garfinkel et al. (2015) defines interoceptive sensibility as the self-reported tendency to

38    focus on and detect internal sensations, whereas Khalsa, Adolphs, Cameron, Critchley, Davenport,

39    Feinstein, Feusner, Garfinkel, Lane, Mehling, and others (2018) defines it more narrowly,

40    excluding the ability to detect these signals. According to Desmedt et al. (2022), most authors

41    adopt the latter definition. The review found that these questionnaires measure related but distinct

42    constructs, leading researchers to mistakenly treating them as equivalent measures of interoceptive

43    sensibility. A better understanding of what is being measured with different questionnaires and

44    dimensions, as well as their potential overlaps with other constructs (e.g., alexithymia, body

45    awareness), is thus needed to clarify the role of self-reports in the assessment of interoception.

46    A recently developed scale with a rapidly growing popularity is the Interoceptive

47    Accuracy Scale (IAS, Murphy et al., 2019). The IAS consists of 21 Likert-scale items that query

48    how accurately one can perceive different bodily signals, with one item per physiological modality

49    such as respiration (*"I can always accurately perceive when I am breathing fast"*), heart (e.g *"I*

50    *can always accurately perceive when my heart is beating fast"*), skin (e.g *"I can always*

51    *accurately perceive when something is going to be ticklish"*), arousal or bodily functions like

52    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. A total of 10 studies was included (see **Table 1**). We also included the data of two unpublished (but already open-access) studies from the authors and one from another researcher. The total N participants was 32,214 participants (*Mean* = 48.6 years, *SD* = 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 ± 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/3cztd |
| | 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.

129        **Statistical Analysis.**  To examine the factor structure of the IAS, a two-step approach was

130    employed. First, Exploratory Graph Analysis (EGA), was used to estimate the dimensions via

131    network estimation and community detection, alongside assessing the stability of dimensions and

132    items using the bootstrapping techniques (Golino & Epskamp, 2017). The selection of EGA was

133    motivated by its capability to handle complex, multidimensional data and provide robust

134    dimension estimates. A novel network psychometrics - Unique variable analysis (UVA,

135    Christensen et al., 2023) - approach based on the weighted topological overlap will be computed

136    to evaluate which items have substantial local dependence (> 0.25). Subsequently, exploratory

137    factor analysis (EFA) was employed followed by confirmatory factor analysis (CFA).

138    *Results*

139        Visualizing the distribution of the items for all samples suggests the presence of a

140    consistent modal value (Figure 1). In other words, participants are most likely to answer 4/5 (i.e.,

141    agree) on most items (but "affective touch", "blood sugar", and "bruise" that exhibit a different

142    distributional pattern). Additionally, one can note the low density on extreme values (1 and 5),

143    meaning that the bulk of answers (i.e., 99%) varies between 3 values. The interindividual

144    variability seems improved in the samples using an analogue scale, displaying a more continuous

145    and progressive spread of answers.

146        **Correlations.**  The correlation analysis revealed that the items overall have positive

147    intercorrelation patterns with no clear structure emerging. This remains the same across all

148    samples. However, there are possibly some higher-order groupings emerging for the 2

149    analog-scale samples.

150        **EGA..**  The UVA revealed that there are two large to very large redundant variables when

151    taking all samples into account. Namely, "itch" and "tickle", where "tickle" should be removed,

152    and "itch" should be kept. There are several more items that are moderately to largely redundant,

153    namely, "wind" and "burp", and "urinate" and "defecate". On top of that, "sneeze" and "cough",

154    "heart" and "breathing", and "hungry" and "thirsty" seem to have small to moderate redundancy.

155    These findings are rather consistent across the samples with minor differences, such as that when

**Figure 1**

*Distribution of responses for all items across various datasets.*
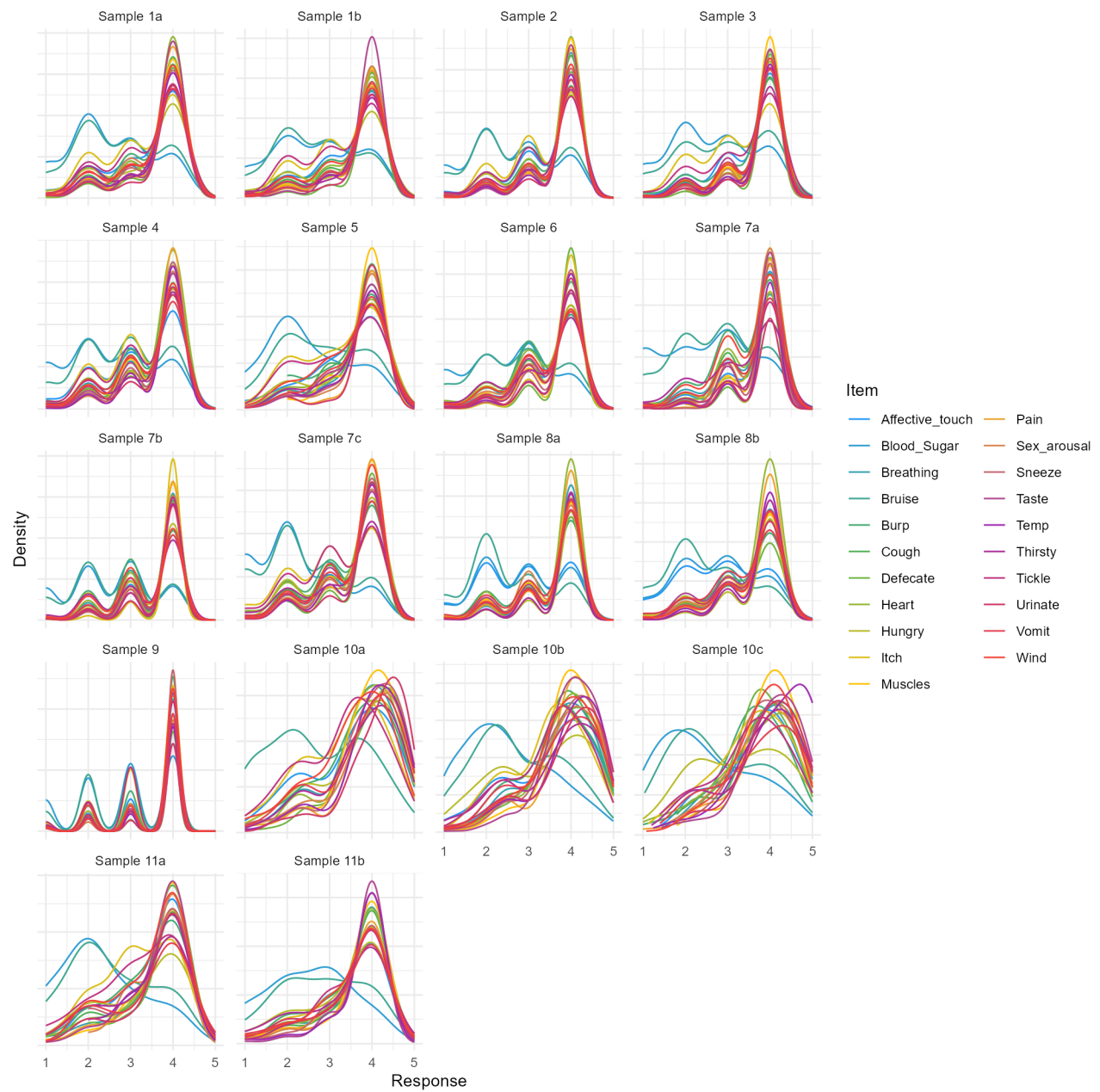
the questionnaire had an analog scale, there seems to be no large to very large redundant items but "itch" and "tickle" remain moderately to largely redundant and "heart" and "breathing" small to moderately redundant in one sample.

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. note to dom** how do you want to present the questionnaires? in text format or in the table with their references on a footnote?

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

***Interoceptive Measures.***

**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*

**todo: compute average correlations**

The EGA components capture groupings of pairs of items, such as "wind" and "burp", "cough" and "sneeze", and "muscle" and "pain". These groupings were used in the correlational analysis, to observe how much each group/pair correlates with other factors, such as Alexithymia, or the MAIA (see Figure 2).

Alexithymia is negatively correlated with all interoceptive groups. Autistic traits are mostly negatively correlated with IAS measure, except for patterns and numbers (as an autistic trait), which is significantly and positively correlated with the "itch/bruise" pairing.

The BPQ Body Awareness part is positively correlated with all IAS pairs, whereas the Autonomic Reactivity part is negatively correlated with all IAS groupings. Conspiracy Beliefs were all positively correlated with the IAS pairs, however, only Global Conspiracy with

"hungry/thirsty", "urinate/defecate" and "cough/sneeze", as well as personal wellbeing with

"hungry/thirsty", and Information Control with "cough/sneeze" were significantly positively

correlated.

Demographic data is also mostly positively correlated with the IAS findings, where gender

and age more strongly correlated with "hungry/thirsty".

In this analysis, lying profile is not strongly correlated with the IAS, except for

contextuality which shows a significant negative correlation with "itch/bruise". The MAIA has a

strong positive correlation with most IAS pairings, except for the Not Worrying and Not

Distracting items of the MAIA, which show less strong, or even negative correlations with all IAS

item pairings.

Maladaptiveness had mostly negative correlations with the IAS, with only a few

significant correlations, namely "psychoticism", "negative affect", and "detachment" with

"muscle/pain" and "hungry/thirsty", as well as "negative affect" with "wind/burp".

Overall, mood was mostly negatively correlated with the IAS, where "hungry/thirsty" had

the strongest negative correlation of all mood measures. Except for "neuroticism" and

"honesty-humility", personality traits, such as "openness" and "extraversion" were positively

correlated with the IAS groupings. Shizotypic traits were mostly negatively correlated with the

IAS, with "hungry/thirsty" showing the strongest negative correlation between schizotypic and the

IAS.

World beliefs were mostly positively correlated with the IAS, however, only a few were

significant: "hierarchical", "enticing", and "alive" correlates significantly with "muscle/pain";

"Understandable" has a significant positive correlation with "heart/breathing"; And "hierarchical"

and "alive" has a significant positive correlation with "hungry/thirsty".

**Figure 2**

*Figure 2.* Correlates of the IAS
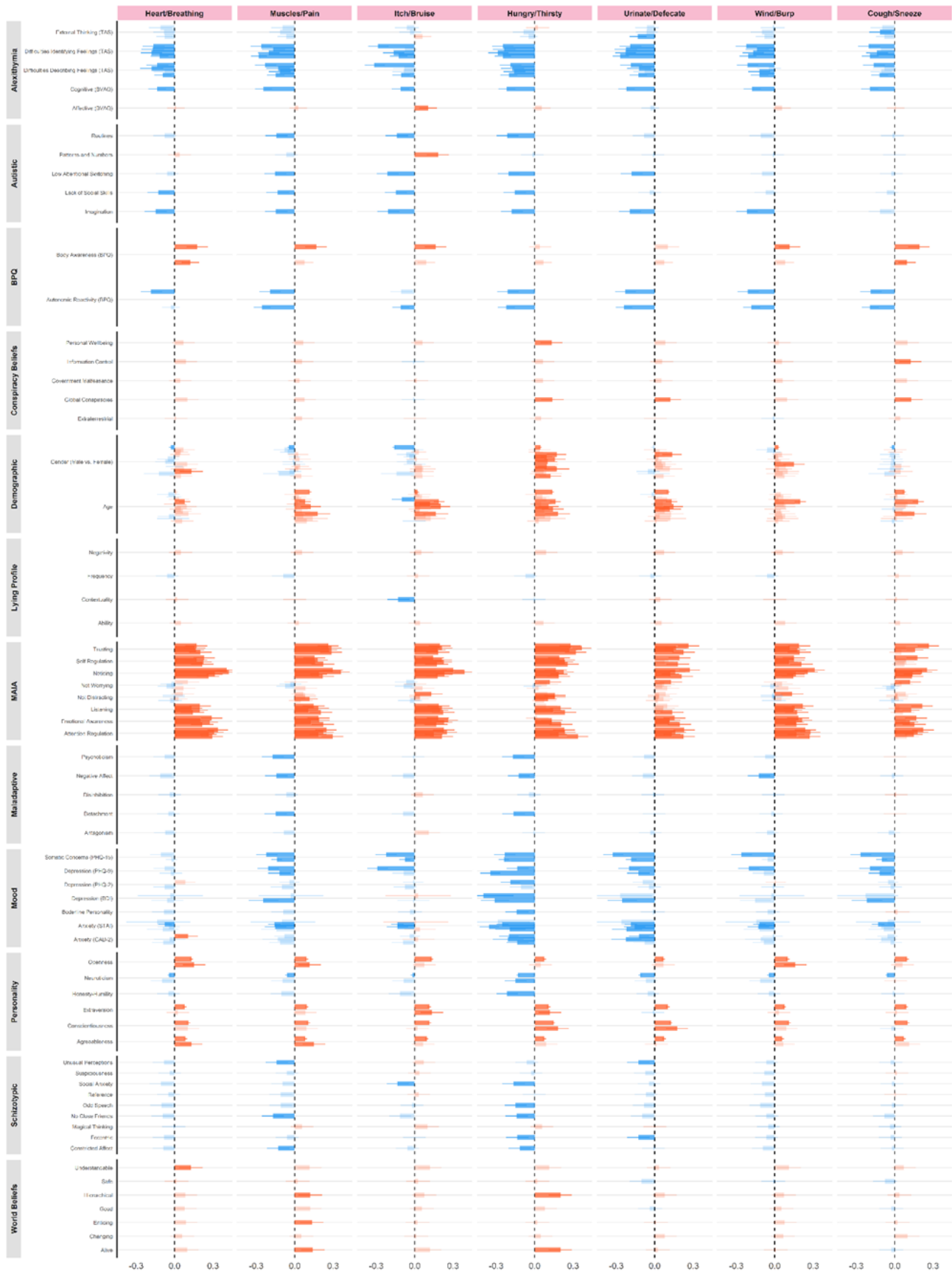
### *Discussion*

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 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 (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.

324   Furthermore, this study recommends using analog scales instead of 5-point scales. The

325   limited variability of the 5-point scale often results in most responses clustering around 3 or 4. As

326   shown in Figure 1, adopting an analog scale significantly increases variability. However, even

327   with an analog scale, IAS variability remains constrained. Greater variability allows for better

328   differentiation among participants, making dispersion an essential factor for obtaining meaningful

329   results. Enhancing variability would therefore be beneficial for the IAS.

330   Despite these improvements, certain limitations persist in the IAS that affect its accuracy.

331   Notably, some modalities are underrepresented—for instance, heart perception is measured by

332   only one item. Expanding modality coverage would enhance variability within each category,

333   leading to more nuanced results. Moreover, the IAS lacks a clear theoretical or empirical

334   structure, with only small item groupings. Ideally, a scale should allow for clear groupings that

335   support meaningful data analysis. In this study, each group contained only two items, resulting in

336   low scores and limited variability. Additionally, some IAS items are ambiguous, with their

337   interpretation depending on context. For example, an item about perceiving heartbeats and

338   another about vomiting could both relate to anxiety, leading to results that may differ from initial

339   expectations. Thus, the grouping and structure of the IAS require refinement.

340   Another concern is that all IAS items are phrased positively, which may influence

341   participant responses. While positive phrasing has advantages, it can also introduce response bias,

342   leading to unidimensional results. A more balanced phrasing approach, incorporating both

343   positively and negatively framed items, could yield more accurate responses.

344   Given these considerations, it is clear that context-specific, cross-modal items—such as

345   integrating cardioception and respiroception—are needed. Recognizing the necessity for a refined

346   interoception scale, this study proposes the development of the Multidimensional Interoceptive

347   Inventory (MInt). This new scale will be designed to align with recent findings on the IAS and

348   interoception research while allowing for direct comparison with IAS correlates.

349   [**TO DO**: add - previous work suggests the importance of physiological contexts

350   (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.

## References

Arslanova, I., Galvez-Pol, A., Kilner, J., Finotti, G., & Tsakiris, M. (2022). Seeing through each other's hearts: Inferring others' heart rate as a function of own heart rate perception and perceived social intelligence. *Affective Science*, *3*(4), 862–877.

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment*, *13*(1), 27–45.

Ben-Shachar, M. S., Lüdecke, D., & Makowski, D. (2020). Effectsize: Estimation of effect size indices and standardized parameters. *Journal of Open Source Software*, *5*(56), 2815.

Brand, S., Meis, A. C., Tünte, M. R., Murphy, J., Woller, J. P., Jungmann, S. M., Witthöft, M., Hoehl, S., Weymar, M., Hermann, C., & Ventura-Bort, C. (2023). A multi-site German validation of the Interoceptive Accuracy Scale and its relation to psychopathological symptom burden. *Communications Psychology*, *1*(1). https://doi.org/10.1038/s44271-023-00016-x

Brand, S., Petzke, T. M., & Witthöft, M. (2022). The differential relationship between self-reported interoceptive accuracy and attention with psychopathology. *Zeitschrift für Klinische Psychologie Und Psychotherapie*.

Brewer, R., Cook, R., & Bird, G. (2016). Alexithymia: A general deficit of interoception. *Royal Society Open Science*, *3*(10), 150664.

Campos, C., Rocha, N. B., & Barbosa, F. (2021). *Untangling self-reported interoceptive attention and accuracy: Evidence from the european portuguese validation of the body perception*

*questionnaire and the interoceptive accuracy scale*. http://dx.doi.org/10.31234/osf.io/a7wdj

Christensen, A. P., Garrido, L. E., & Golino, H. (2023). Unique variable analysis: A network

    psychometrics method to detect local dependence. *Multivariate Behavioral Research*, *58*(6),

    1165–1182.

Christensen, A. P., & Golino, H. (2021). Estimating the Stability of Psychological Dimensions via

    Bootstrap Exploratory Graph Analysis: A Monte Carlo Simulation and Tutorial. *Psych*, *3*(3),

    479–500. https://doi.org/10.3390/psych3030032

Clifton, J. D. W. (2020). Testing if primal world beliefs reflect experiences—or at least some

    experiences identified ad hoc. *Frontiers in Psychology*, *11*.

    https://doi.org/10.3389/fpsyg.2020.01145

Desmedt, O., Heeren, A., Corneille, O., & Luminet, O. (2022). What do measures of self-report

    interoception measure? Insights from a systematic review, latent factor analysis, and network

    approach. *Biological Psychology*, *169*, 108289.

DuBois, D., Ameis, S. H., Lai, M.-C., Casanova, M. F., & Desarkar, P. (2016). Interoception in

    Autism Spectrum Disorder: A review. *International Journal of Developmental Neuroscience*,

    *52*(1), 104–111. https://doi.org/10.1016/j.ijdevneu.2016.05.001

Erle, T. M., Mitschke, V., & Schultchen, D. (2021). Did my heart just leap or sink? The role of

    personality for the relation between cardiac interoception and well-being. *Personality and

    Individual Differences*, *170*, 110493. https://doi.org/10.1016/j.paid.2020.110493

Gabriele, E., Spooner, R., Brewer, R., & Murphy, J. (2022). Dissociations between self-reported

    interoceptive accuracy and attention: Evidence from the interoceptive attention scale.

    *Biological Psychology*, *168*, 108243.

Gaggero, G., Bizzego, A., Dellantonio, S., Pastore, L., Lim, M., & Esposito, G. (2021).

    Clarifying the relationship between alexithymia and subjective interoception. *PLoS One*,

    *16*(12), e0261126.

Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (2015). Knowing your

    own heart: Distinguishing interoceptive accuracy from interoceptive awareness. *Biological*

*Psychology*, *104*, 65–74.

Golino, H. F., & Epskamp, S. (2017). Exploratory graph analysis: A new approach for estimating the number of dimensions in psychological research. *PloS One*, *12*(6), e0174035.

Herbert, B. M., Herbert, C., & Pollatos, O. (2011). On the Relationship Between Interoceptive Awareness and Alexithymia: Is Interoceptive Awareness Related to Emotional Awareness? *Journal of Personality*, *79*(5), 1149–1175. https://doi.org/10.1111/j.1467-6494.2011.00717.x

Jahedi, S., & Méndez, F. (2014). On the advantages and disadvantages of subjective measures. *Journal of Economic Behavior & Organization*, *98*, 97–114. https://doi.org/10.1016/j.jebo.2013.12.016

Khalsa, S. S., Adolphs, R., Cameron, O. G., Critchley, H. D., Davenport, P. W., Feinstein, J. S., Feusner, J. D., Garfinkel, S. N., Lane, R. D., Mehling, W. E., et al. (2018). Interoception and mental health: A roadmap. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *3*(6), 501–513.

Khalsa, S. S., Adolphs, R., Cameron, O. G., Critchley, H. D., Davenport, P. W., Feinstein, J. S., Feusner, J. D., Garfinkel, S. N., Lane, R. D., Mehling, W. E., Meuret, A. E., Nemeroff, C. B., Oppenheimer, S., Petzschner, F. H., Pollatos, O., Rhudy, J. L., Schramm, L. P., Simmons, W. K., Stein, M. B., … Zucker, N. (2018). Interoception and Mental Health: A Roadmap. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *3*(6), 501–513. https://doi.org/10.1016/j.bpsc.2017.12.004

Kleckner, I. R., Wormwood, J. B., Simmons, W. K., Barrett, L. F., & Quigley, K. S. (2015). Methodological recommendations for a heartbeat detection-based measure of interoceptive sensitivity. *Psychophysiology*, *52*(11), 1432–1440.

Koike, H., & Nomura, M. (2023). Development and validation of japanese versions of the interoceptive accuracy scale and interoceptive attention scale. *SAGE Open*, *13*(4), 21582440231214639.

Lin, X.-X., Shen, H.-R., Lin, J.-X., Zhang, Y.-H., Murphy, J., Wang, Y.-Z., Sun, Y.-B., Wang, N., Wang, J.-Y., Wei, G.-X., & Luo, F. (2023). Psychometric validation and refinement of the

Chinese Interoceptive Accuracy Scale (IAS) in general population and patients with chronic

pain. *Journal of Psychosomatic Research*, *175*, 111541.

https://doi.org/10.1016/j.jpsychores.2023.111541

Makowski, D., Lau, Z. J., Pham, T., Te, A., Kirk, S., & Liauw Yong Tong, C. (2023). *The heart

can lie: The role of interoception and theory of mind in deception.*

http://dx.doi.org/10.31234/osf.io/p342w

Mehling, W. E., Acree, M., Stewart, A., Silas, J., & Jones, A. (2018). The multidimensional

assessment of interoceptive awareness, version 2 (MAIA-2). *PloS One*, *13*(12), e0208034.

Mehling, W. E., Price, C., Daubenmier, J. J., Acree, M., Bartmess, E., & Stewart, A. (2012). The

Multidimensional Assessment of Interoceptive Awareness (MAIA). *PLoS ONE*, *7*(11),

e48230. https://doi.org/10.1371/journal.pone.0048230

Morin, A. J. S., Arens, A. K., & Marsh, H. W. (2015). A bifactor exploratory structural equation

modeling framework for the identification of distinct sources of construct-relevant

psychometric multidimensionality. *Structural Equation Modeling: A Multidisciplinary

Journal*, *23*(1), 116–139. https://doi.org/10.1080/10705511.2014.961800

Murphy, J., Brewer, R., Plans, D., Khalsa, S. S., Catmur, C., & Bird, G. (2019). Testing the

independence of self-reported interoceptive accuracy and attention. *Quarterly Journal of

Experimental Psychology*, *73*(1), 115–133. https://doi.org/10.1177/1747021819879826

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

University of Maryland*, *10*, s15327752jpa5304_1.

Rodriguez, A., Reise, S. P., & Haviland, M. G. (2016). Evaluating bifactor models: Calculating

and interpreting statistical indices. *Psychological Methods*, *21*(2), 137.

Ruisch, B. C., Von Mohr, M., Naber, M., Tsakiris, M., Fazio, R. H., & Scheepers, D. T. (2022a).

Sensitive liberals and unfeeling conservatives? *Interoceptive sensitivity predicts political

liberalism. Politics and the Life Sciences*, *41*(2), 256–275. https://doi.org/10.1017/pls.2022.18

Ruisch, B. C., Von Mohr, M., Naber, M., Tsakiris, M., Fazio, R. H., & Scheepers, D. T. (2022b).

Sensitive liberals and unfeeling conservatives? *Interoceptive sensitivity predicts political

*liberalism*. *Politics and the Life Sciences*, *41*(2), 256–275. https://doi.org/10.1017/pls.2022.18

Schandry, R. (1981). Heart beat perception and emotional experience. *Psychophysiology*, *18*(4), 483–488.

Solano López, A. L., & Moore, S. (2018). Dimensions of Body-Awareness and Depressed Mood and Anxiety. *Western Journal of Nursing Research*, *41*(6), 834–853. https://doi.org/10.1177/0193945918798374

Suksasilp, C., & Garfinkel, S. N. (2022). Towards a comprehensive assessment of interoception in a multi-dimensional framework. *Biological Psychology*, *168*, 108262.

Todd, J., Swami, V., Aspell, J. E., Furnham, A., Horne, G., & Stieger, S. (2022). Are some interoceptive sensibility components more central than others? Using item pool visualisation to understand the psychometric representation of interoception. *Plos One*, *17*(12), e0277894.

Torregrossa, L. J., Amedy, A., Roig, J., Prada, A., & Park, S. (2022). Interoceptive functioning in schizophrenia and schizotypy. *Schizophrenia Research*, *239*, 151–159. https://doi.org/10.1016/j.schres.2021.11.046

Von Mohr, M., Silva, P. C., Vagnoni, E., Bracher, A., Bertoni, T., Serino, A., Banissy, M. J., Jenkinson, P. M., & Fotopoulou, A. (2023). My social comfort zone: Attachment anxiety shapes peripersonal and interpersonal space. *Iscience*, *26*(2).

**Figure 3**

*Different ways in which interoception can be measured.*