

## INVITED REVIEW

# The role of interoception in the overlap between eating disorders and autism: Methodological considerations

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## Abstract

Significant comorbidity has been demonstrated between feeding and eating disorders and autism. Atypical interoception (perception of bodily signals) may, at least in part, be responsible for this association, as it has been implicated in the aetiology of both conditions. However, significant methodological limitations are impeding progress in this area. This paper provides a brief overview of how interoception has been linked to autism and feeding and eating disorders in both adolescent and adult populations before identifying several issues with current measures of interoception. We suggest that methodological issues may be contributing to the inconsistency in the empirical literature, and provide suggestions for future research.

## KEYWORDS

anorexia, autism, bulimia, feeding and eating disorders, interoception

## Highlights

- Atypical interoception is linked to both feeding and eating disorders, and autism and may contribute to the comorbidity between the two.
- Existing measures of interoception across cardiac, gastric and respiratory domains are severely limited.
- Novel and better-validated measures of interoception will allow us to better understand the clinical potential of interoceptive training.

## 1 | INTRODUCTION

Feeding and eating disorders (henceforth EDs) are characterised by disturbed eating and eating-related behaviours that significantly impair one's physical and mental health (American Psychiatric Association, 2013). EDs have the highest mortality rates of all mental health

disorders and exhibit a concerning resistance to treatment (Treasure, 2019; van Eeden et al., 2021), highlighting a pressing need for a greater understanding of their aetiological mechanisms.

Autism spectrum disorder (henceforth 'autism') is defined by social difficulties and restricted and repetitive interests and behaviours (American Psychiatric

**Abbreviations:** 6AFC, six-alternative forced-choice; AN, anorexia nervosa; BN, bulimia nervosa; ED, eating disorder; HCT, heartbeat counting task; HDT, heartbeat discrimination task; IAS, Interoceptive Accuracy Scale; IATS, Interoceptive Attention Scale; MCS, method of constant stimulation; OSFED, other specified feeding and eating disorders; PAT, phase adjustment task.

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Association, 2013). We shall refer to those with autism as 'autistic', as preferred by the autistic community (Kenny et al., 2016). There is a considerable degree of co-occurrence between autism and EDs—a higher proportion of both adult and adolescent ED patients score above clinically significant thresholds on autism measures (Carpita et al., 2020; Huke et al., 2013), and adults and adolescents with EDs score higher on continuous measures of autistic traits when compared to the non-ED population (Baron-Cohen et al., 2013; Dell'Osso et al., 2018; Karjalainen et al., 2019; Westwood et al., 2016). Conversely, autistic adults have higher rates of EDs than non-autistic adults (Karjalainen et al., 2016). Furthermore, in adults, autistic traits correlate with ED symptoms in both ED patients and the general population (Dell'Osso et al., 2018). Elevated autistic traits have been observed in recovered adults and adolescents with EDs (Bentz et al., 2017; Karjalainen et al., 2019; Nazar et al., 2018), and ED patients report noticing autistic traits before the emergence of their ED (Mandy & Tchanturia, 2015; Westwood et al., 2018), suggesting that the association between EDs, especially anorexia nervosa (AN), and autistic traits is not solely due to starvation (Hiller & Pelli-cano, 2013). Potential reasons for the co-occurrence of ED and autism have been discussed previously (Brede et al., 2020; Carpita et al., 2020), but here we focus on the hypothesised role of interoception in the aetiology of both conditions and their overlap, and outline methodological issues to be addressed when investigating this—particularly the measurement of interoception. Given the hypothesised clinical potential for interoceptive training, assessing the evidential basis of interoception's role in autism and ED is crucial. The majority of research on interoception and autism in EDs concerns AN, bulimia nervosa (BN) and other specified feeding and eating disorders (OSFED), and thus we focus mainly on these conditions.

## 2 | INTEROCEPTION

Interoception is broadly considered to be a multidimensional construct encompassing the perception of the body's internal state (e.g., perceiving how fast one's heart is beating, or one's level of satiety; Craig, 2002; Ceunen et al., 2016; Murphy et al., 2017; Brewer et al., 2021). Interoception can be conceptualised within the model suggested by Murphy et al. (2019).

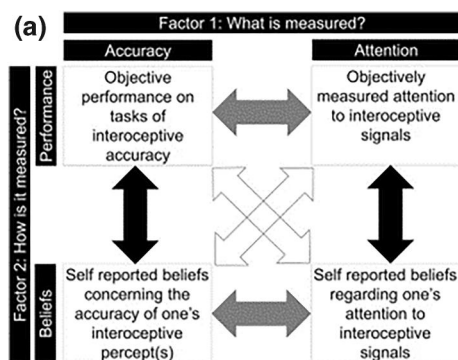
This model dissociates between the *accuracy* of an individual's perception of their internal states, and how much *attention* they pay to internal signals, both of which may be clinically relevant (Murphy et al., 2019).

Furthermore, one can distinguish between an individual's *objective* degree of accuracy when perceiving, or their *objective* degree of attention to, internal signals, and their *subjective* estimates of, or beliefs about, these values (see Figure 1). Whether subjective beliefs relating to interoception are consistent with objective measures (e.g., if an individual believes they have accurate interoceptive perception when they do not, sometimes referred to as *meta-cognition*) is thought to be of clinical relevance, specifically within the context of anxiety (Garfinkel et al., 2015), although this may apply to psychiatric conditions more broadly. The potential relevance to EDs can be illustrated with the example of intuitive eating. If an individual correctly believes they can accurately perceive signals of hunger and satiety, eating intuitively will allow them to meet their calorific needs. However, if an individual believes their perception is accurate when it is not, they may choose to eat intuitively rather than to rely on established meal times or calorific targets, which could result in them over or under-eating. In addition to the above, one's *evaluations* of particular interoceptive signals may also be of clinical relevance (Herbert et al., 2020; Murphy et al., 2020; Suksasilp & Garfinkel, 2022). For example, one may interpret satiety signals as aversive, which may result in avoidance of food.

Interoception may vary across domains (where 'domain' refers to a specific interoceptive signal or group of signals; Murphy et al., 2017). Although some evidence suggests that there is a degree of coherence in accuracy of perception across domains (e.g., between cardiac and gastric interoception; Herbert et al., 2012; Whitehead & Drescher, 1980), other evidence suggests a lack of coherence (Ferentzi et al., 2018; Garfinkel et al., 2016; Pollatos et al., 2016). With respect to attention, the degree of coherence across domains is currently unclear.

## 3 | HYPOTHESISED ROLE OF INTEROCEPTION IN AUTISM, EDS AND THEIR OVERLAP

Several theories suggest that atypical interoception has a causal role in the aetiology of autism (DuBois et al., 2016; Garfinkel et al., 2016; Quattrocki & Friston, 2014; but see Brewer et al., 2015), and EDs (Fassino et al., 2004; Herbert et al., 2020). However, these theories vary substantially in terms of the specific dimensions of interoception implicated, and the causal mechanisms believed to underlie the association between symptoms and atypical interoception. With respect to the role interoception may play in the overlap between EDs and autism, it may be that atypical interoception is associated with autistic symptoms or traits, which in turn predispose an



**FIGURE 1** The dimensions upon which individual differences in interoception can be observed (from Murphy et al., 2019)

individual to EDs. For example, autistic individuals may have high levels of interoceptive attention due to sensory sensitivity, to a degree which is unpleasant and overwhelming. This may result in them either avoiding situations like eating, where internal sensations such as satiety are heightened (Brede et al., 2020), or deliberately suppressing internal signals over time (Brewer et al., 2021), which may increase vulnerability to EDs. Alternatively, reduced objective interoceptive accuracy in autism could lead to difficulties in regulating food intake, or difficulties with emotion regulation, which could result in the use of abnormal eating behaviour as a coping strategy (Brede et al., 2020; Herbert et al., 2020). Further work is required to establish a more formal theory of the role of interoception in the overlap between EDs and autism. If it is the case that atypical interoception is responsible for the symptoms of either condition, or the association between them, then given that initial evidence suggests interoception may be improved with intervention (Quadt et al., 2021), interoception may represent a promising clinical target (see Carrard et al., 2011; Khoury et al., 2018). This may be especially relevant to individuals with both autism and EDs, who often report that existing models of ED therapy do not work for them, and demonstrate worse outcomes after intervention than non-autistic patients (Brede et al., 2020; Kinnaird et al., 2019; Tchanturia, 2021).

### 3.1 | Empirical research: Interoception in autism

Empirical research exploring interoception in autism has produced conflicting results. Three papers have reported higher self-reported attention to interoceptive signals in autistic adults (Fiene & Brownlow, 2015; Garfinkel et al., 2016; Zdankiewicz-Ścigała et al., 2021), but not

children (Palser et al., 2018). Less accurate perception of cardiac signals in autistic adults (Garfinkel et al., 2016) and children (Nicholson et al., 2019; Palser et al., 2018) has also been reported, but other studies have found typical perception in autistic adults (Nicholson et al., 2018; Schauder et al., 2015). In terms of objective respiratory accuracy, one study found typical performance in autistic adults, although the findings are of questionable validity due to the lack of a control task (Nicholson et al., 2019).

### 3.2 | Empirical research: Interoception in eating disorders

Results of studies of interoception in ED have been similarly mixed (Herbert, 2020; Jacquemot & Park, 2020; Klabunde et al., 2017; Martin et al., 2019). One meta-analysis demonstrated an effect whereby both adolescent and adult ED patients reported worse perception of gastric and hunger-related signals in everyday life, with a greater deficit in younger participants (Jenkinson et al., 2018). Similar results have been observed when considering self-reported attention across interoceptive domains in both adolescents and adults (Brown et al., 2017). Pollatos et al. (2008) reported impaired perception of cardiac signals in AN patients; however, several studies have failed to replicate this result (Eshkevari et al., 2014; Kinnaird et al., 2020; Lutz et al., 2019). Kinnaird et al. (2020) reported that AN patients believed their accuracy of perception to be impaired, and these beliefs correlated with illness severity. In contrast to a control group, beliefs were not correlated with accuracy of perception in the AN group. Other studies have failed to find a reduction in perceived accuracy in AN patients (Lutz et al., 2019). There is some evidence, however, that adults with EDs may evaluate interoceptive signals more negatively, as during breath-holding exercises participants with ED reported more stress and suffocation fear than healthy controls (Lapidus et al., 2020).

One limitation of the majority of work on interoception in ED is that interoception is only measured at one time point, despite evidence of state like variations in interoception in the general population (Wittkamp et al., 2018), as well as evidence that within ED patients specifically, the correspondence between perceived cardiac and respiratory intensity and heart rate fluctuates according to factors such as proximity to meal times (Khalsa et al., 2015). This also limits conclusions that can be drawn about the direction of influence, although preliminary longitudinal work has found self-reported interoceptive attention to predict later ED (Bizeul et al., 2001; Clausen et al., 2011). Even disregarding this

limitation, it is clear that research exploring the role of interoception in both autism and ED has produced extremely heterogeneous findings. We hypothesise that this heterogeneity is a result of the use of unreliable tests with limited validity. We suggest that before we can begin to look to develop interoceptive interventions, research testing the role of interoception in autism, EDs, and their association must overcome several methodological issues.

## 4 | METHODOLOGICAL ISSUES

### 4.1 | Measurement of interoception

#### 4.1.1 | Self-report measures

Low agreement between self-report measures make their interpretation difficult (Desmedt et al., 2021). Within ED research a substantial number of studies have assessed interoception using the Interoceptive Accuracy Subscale of the Eating Disorder Inventory (EDI, Garner et al., 1983), where respondents report their ratings of confidence in identifying emotions and sensations of hunger. It has been criticised as difficulties in determining one's emotional state pertain more to alexithymia (a sub-clinical condition characterised by difficulty identifying or describing one's own emotions; Nemiah et al., 1976) than interoception, and the sole focus on hunger perception prohibits a generalised measure of confidence in interoceptive perception (Kinnaird et al., 2020). Similarly, the Multidimensional Assessment of Interoceptive Awareness, which has been used to test interoceptive 'awareness' in both ED and autistic populations (Brown et al., 2017; Quadt et al., 2021), includes items that pertain to alexithymia and anxiety sensitivity rather than pure interoception (Mehling et al., 2012). A commonly used questionnaire in both ED and autism research is the Body Perception Questionnaire (Porges, 1993). This has been argued to conflate beliefs about interoceptive accuracy and attention (Murphy et al., 2019), with participants showing a large degree of heterogeneity in how they interpret the items (Gabriele et al., 2022). In response, the Interoceptive Accuracy Scale (IAS) and the Interoceptive Attention Scale (IATS) have since been developed as pure measures of beliefs about interoceptive accuracy and attention, respectively (Gabriele et al., 2022; Murphy et al., 2020). The IAS and IATS represent the most specific measures of beliefs about one's own interoceptive profile currently available. However, both measures are still undergoing refinement and as such have not yet been used or validated in either autistic or ED populations.

#### 4.1.2 | Objective measures

##### *Cardiac*

Problematically, the majority of experimental work on cardiac interoception in EDs and autism has used the heartbeat counting task (HCT, Schandry, 1981), or its variant the heartbeat tapping task (de Pascalis et al., 1984). Critiques of this approach have been well documented (Desmedt et al., 2018; Murphy et al., 2018; Windman et al., 1999), and as such a comprehensive evaluation is not necessary here. The most salient issue is that participants could achieve perfect performance on the task without being able to perceive their heartbeats at all if they have prior knowledge about what their heart rate should be (Ring & Brener, 1996; Ring et al., 2015).

An alternative to the HCT is the heartbeat discrimination task (HDT; Whitehead et al., 1977), in which participants judge which of two sets of auditory or visual tones is synchronous with their heartbeats. This method has been employed in both autistic and ED samples (Eshkevari et al., 2014; Nicholson et al., 2018). However, the test relies on the—false (Brener et al., 1993)—assumption that there are no individual differences in the delay following cardiac contraction with which individuals perceive their heartbeat. There are variations of the HDT that aim to address this issue by presenting tones at multiple different delays after cardiac contraction and assessing the consistency of synchronicity judgements (e.g. the six-alternative forced-choice [6AFC] and method of constant stimulation [MCS] methods; Brener et al., 1993; Clemens, 1984; Yates et al., 1985). These HDT variations—as long as they are coupled with appropriate control tasks assessing the participant's ability to judge the synchronicity of two stimuli (Knapp et al., 1997)—provide adequate tests of cardiac interoception but have not been used to test interoception in either ED or autism. This may be due to practical limitations: both measures are time-consuming, and performance is thus constrained by participants' ability to focus for an extended period, which may be impaired in EDs such as AN and BN (Bosanac et al., 2007).

The phase adjustment task (PAT; Plans et al., 2020) is a new test of cardiac interoception that both overcomes the use of pre-defined delays to test perception of heartbeats and is quicker than the 6AFC and MCS, therefore representing an advance on the HDT variants described above. The task presents participants with auditory tones that are at the same frequency as their heartbeats, but out of phase with those heartbeats. Participants use a dial to change the phase relationship between the tone and their heartbeat until they perceive them as synchronous. Interoceptive accuracy is determined by the consistency of their responses. The PAT is amenable for smartphone administration, increasing its acceptability for use in



clinical populations (especially those that may not wish to travel to novel laboratory environments). The design of the task also prohibits false positives (identifying participants as interoceptive who are not), and the use of a closely matched screening task prevents false negatives (identifying participants as not interoceptive when they in fact are). As of yet, the PAT not been used in either ED or autistic participants.

Finally, the heartrate discrimination task (Legrand et al., 2021) is a new measure in the cardiac domain that does not attempt to measure the accuracy of perception of cardiac signals, or the degree of attention paid to them. Instead, the task aims to measure the accuracy and precision of beliefs about heart rate. Whether individual differences in these parameters are of clinical relevance is yet to be established, but in its current instantiation, the heartrate discrimination task requires a well-matched control task to address questions relating to clinical relevance.

### *Respiratory*

Respiratory interoception has been measured by both detection and discrimination tasks (Harrison et al., 2021; Webster & Colrain, 2000; Zhao et al., 2002), in which participants are required to detect whether respiration is restricted using filters, or to judge which of two filters provides more respiratory resistance, respectively. In both of these tasks, findings may be confounded by the fact that longer respiratory restrictions have an intrinsic negative value. More recently, a task has been developed that overcomes this, by measuring individuals' ability to detect small differences in lengths of short respiratory occlusions (van den Houte et al., 2021), also reducing the time taken to run the experiment. This measure has not yet been used in autistic or ED populations. Pragmatically, administration of any respiratory interoception task requires the use of specialist equipment, such as clinical breathing filters, which makes it difficult to administer remotely or at scale.

### *Gastric*

Of high relevance to the field of EDs is the perception of gastric signals of satiety and fullness. Khalsa and colleagues provide a comprehensive overview of research of this nature in ED patients (Khalsa et al., 2022). Given the relevance of these signals, it is unfortunate that the most valid methods to assess their perception are invasive in nature, involving forced gastric distension, and are cumbersome and unpleasant to administer (Whitehead & Drescher, 1980). As an alternative, water-load tests are frequently performed in healthy populations (van Dyck et al., 2016), in which the amount of water required for participants to report satiety and a full stomach is measured. Water-load tests do not provide a measure of

the accuracy of perception of these signals, however, and may be considered a measure of beliefs about interoceptive signals and their relevance (in this case, the degree of water required to feel satiated), rather than the accuracy of interoceptive perception or the degree of attention paid to interoceptive signals. To our knowledge, none of these methods have been used in studies with autistic participants. With all of these methods, there are ethical issues associated with their use in both autistic participants and ED patients, where the induced feelings of fullness may be especially distressing.

## **4.2 | Interoceptive perception or the perception of internal states?**

For both tests of cardiac and respiratory accuracy, it is unknown whether participants' performances depend on the accurate detection of purely interoceptive signals, or other, non-interoceptive cues. Presumably, in respiratory tasks, participants detect a discrepancy between the expected and experienced degree of airflow for a given degree of respiratory (muscular) effort. The signal used to detect this discrepancy may result from any combination of stretch receptors in the skin of the mouth or chest, intra-oral or extra-oral pressure, changes in temperature of the airway, or numerous other signals. Similarly, cardiac perception tasks may rely on either interoceptive signals from baroreceptors, or non-interoceptive signals such as chest wall vibrations (Khalsa et al., 2009; Murphy et al., 2018). This is important if one considers that it is only perception of interoceptive signals that is of clinical relevance, but it is equally likely (Brewer et al., 2021; Ceunen et al., 2016) that what matters is perception of the signal itself, and not which receptors are involved. Addressing this question is a priority for future research, especially if the perception of interoceptive signals via exteroceptive means can ameliorate any symptoms associated with either autism or ED.

## **5 | CONCLUSION**

Given the reported associations between various EDs and autism, and the fact that interoception has been implicated in both conditions, it is feasible that interoception may contribute to the observed link between autism and EDs. However, current research does not provide compelling evidence for this, due to the limitations of the methodologies employed. The most pertinent issue is that current measures of interoception lack validity. Before research can be conducted into the potential for interoception based-interventions in autistic ED patients, more research

is required to test and develop promising novel measures of interoception across domains and dimensions.

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## CONFLICT OF INTEREST

There is no conflict of interest to declare.

## DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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## REFERENCES

- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). American Psychiatric Publishing.
- Baron-Cohen, S., Jaffa, T., Davies, S., Auyeung, B., Allison, C., & Wheelwright, S. (2013). Do girls with anorexia nervosa have elevated autistic traits? *Molecular Autism*, 4(1), 24. <https://doi.org/10.1186/2040-2392-4-24>
- Bentz, M., Jepsen, J. R. M., Pedersen, T., Bulik, C. M., Pederson, L., Pagsberg, A. K., & Plessen, K. J. (2017). Impairment of social function in young females with recent-onset anorexia nervosa and recovered individuals. *Journal of Adolescent Health*, 60(1), 23–32. <https://doi.org/10.1016/j.jadohealth.2016.08.011>
- Bizeul, C., Sadowsky, N., & Rigaud, D. (2001). The prognostic value of initial EDI scores in anorexia nervosa patients: A prospective follow-up study of 5–10 years. *Eating disorder inventory. European Psychiatry: The Journal of the Association of European Psychiatrists*, 16(4), 232–238. [https://doi.org/10.1016/s0924-9338\(01\)00570-3](https://doi.org/10.1016/s0924-9338(01)00570-3)
- Bosanac, P., Kurlender, S., Stojanovska, L., Hallam, K., Norman, T., McGrath, C., Burrows, G., Wesnes, K., Manktelow, T., & Olver, J. (2007). Neuropsychological study of underweight and “weight-recovered” anorexia nervosa compared with bulimia nervosa and normal controls. *International Journal of Eating Disorders*, 40(7), 613–621. <https://doi.org/10.1002/eat.20412>
- Brede, J., Babb, C., Jones, C., Elliott, M., Zanker, C., Tchanturia, K., Serpell, L., Fox, J., & Mandy, W. (2020). “For me, the anorexia is just a symptom, and the cause is the autism”: Investigating restrictive eating disorders in autistic women. *Journal of Autism and Developmental Disorders*, 50(12), 1–4296. <https://doi.org/10.1007/s10803-020-04479-3>
- Brener, J., Liu, X., & Ring, C. (1993). A method of constant stimuli for examining heartbeat detection: Comparison with the Brener-Kluytse and Whitehead methods. *Psychophysiology*, 30(6), 657–665. <https://doi.org/10.1111/j.1469-8986.1993.tb02091.x>
- Brewer, R., Happe, F., Cook, R., & Bird, G. (2015). Commentary on “Autism, oxytocin and interoception”: Alexithymia, not autism spectrum disorders, is the consequence of interoceptive failure. *Neuroscience and Biobehavioural Reviews*, 56, 348–353. <https://doi.org/10.1016/j.neubiorev.2015.07.006>
- Brewer, R., Murphy, J., & Bird, G. (2021). Atypical interoception as a common risk factor for psychopathology: A review. *Neuroscience & Biobehavioral Reviews*, 130(7), 470–508. <https://doi.org/10.1016/j.neubiorev.2021.07.036>
- Brown, T. A., Berner, L. A., Jones, M. D., Reilly, E. E., Cusack, A., Anderson, L. K., Kaye, W. H., & Wierenga, C. E. (2017). Psychometric evaluation and norms for the Multidimensional Assessment of Interoceptive Awareness (MAIA) in a clinical eating disorders sample. *European Eating Disorders Review*, 25(5), 411–416. <https://doi.org/10.1002/erv.2532>
- Carpita, B., Muti, D., Cremone, I. M., Fagioli, A., & Dell’Osso, L. (2020). Eating disorders and autism spectrum: Links and risks. *CNS Spectrums*, 1–9. Advance online publication. <https://doi.org/10.1017/S1092852920002011>
- Carrard, I., Crépin, C., Rouget, P., Lam, T., Golay, A., & Van der Linden, M. (2011). Randomised controlled trial of a guided self-help treatment on the Internet for binge eating disorder. *Behaviour Research and Therapy*, 49(8), 482–491. <https://doi.org/10.1016/j.brat.2011.05.004>
- Ceunen, E., Vlaeyen, J. W., & van Diest, I. (2016). On the origin of interoception. *Frontiers in Psychology*, 7, 743. <https://doi.org/10.3389/fpsyg.2016.00743>
- Clausen, L., Rosenvinge, J. H., Friborg, O., & Rokkedal, K. (2011). Validating the Eating Disorder Inventory-3 (EDI-3): A comparison between 561 female eating disorders patients and 878 females from the general population. *Journal of Psychopathology and Behavioral Assessment*, 33(1), 101–110. <https://doi.org/10.1007/s10862-010-9207-4>
- Clemens, W. J. (1984). Temporal arrangement of signals in heart-beat discrimination procedures. *Psychophysiology*, 21(2), 187–190. <https://doi.org/10.1111/j.1469-8986.1984.tb00202.x>
- Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature Reviews Neuroscience*, 3(8), 655–666. <https://doi.org/10.1038/nrn894>
- Dell’Osso, L., Carpita, B., Gesi, C., Cremone, I. M., Corsi, M., Massimetti, E., Muti, D., Calderani, E., Castellini, G., Luciano, M., Ricca, V., Carmassi, C., & Maj, M. (2018). Subthreshold autism spectrum disorder in patients with eating disorders. *Comprehensive Psychiatry*, 81, 66–72. <https://doi.org/10.1016/j.comppsy.2017.11.007>
- de Pascalis, V., Alberti, M. L., & Pandolfo, R. (1984). Anxiety, perception, and control of heart rate. *Perceptual & Motor Skills*, 59(1), 203–211. <https://doi.org/10.2466/pms.1984.59.1.203>
- Desmedt, O., Heeren, A., Corneille, O., & Luminet, O. (2021). What do measures of self-report interoception measure? Insights from a systematic review, latent factor analysis, and network approach. <https://doi.org/10.31234/osf.io/8mpz9>
- Desmedt, O., Luminet, O., & Corneille, O. (2018). The heartbeat counting task largely involves non-interoceptive processes: Evidence from both the original and an adapted counting task. *Biological Psychology*, 138, 185–188. <https://doi.org/10.1016/j.biopsycho.2018.09.004>

- 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>
- Eshkevri, E., Rieger, E., Musiat, P., & Treasure, J. (2014). An investigation of interoceptive sensitivity in eating disorders using a heartbeat detection task and a self-report measure. *European Eating Disorders Review: The Journal of the Eating Disorders Association*, 22(5), 383–388. <https://doi.org/10.1002/erv.2305>
- Fassino, S., Pierò, A., Gramaglia, C., & Abbate-Daga, G. (2004). Clinical, psychopathological and personality correlates of interoceptive awareness in anorexia nervosa, bulimia nervosa and obesity. *Psychopathology*, 37(4), 168–174. <https://doi.org/10.1159/000079420>
- Ferentzi, E., Bogdány, T., Szabolcs, Z., Csala, B., Horváth, Á., & Köteles, F. (2018). Multichannel investigation of interoception: Sensitivity is not a generalizable feature. *Frontiers in Human Neuroscience*, 12, 223. <https://doi.org/10.3389/fnhum.2018.00223>
- Fiene, L., & Brownlow, C. (2015). Investigating interoception and body awareness in adults with and without autism spectrum disorder. *Autism Research*, 8(6), 709–716. <https://doi.org/10.1002/aur.1486>
- 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. <https://doi.org/10.1016/j.biopsycho.2021.108243>
- Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (2015). Knowing your own heart: Distinguishing interoceptive accuracy from interoceptive awareness. *Biological Psychology*, 104, 65–74. <https://doi.org/10.1016/j.biopsycho.2014.11.004>
- Garfinkel, S. N., Tiley, C., O'Keeffe, S., Harrison, N. A., Seth, A. K., & Critchley, H. D. (2016). Discrepancies between dimensions of interoception in autism: Implications for emotion and anxiety. *Biological Psychology*, 114, 117–126. <https://doi.org/10.1016/j.biopsycho.2015.12.003>
- Garner, D. M., Olmstead, M. P., & Polivy, J. (1983). Development and validation of a multidimensional eating disorder inventory for anorexia nervosa and bulimia. *International Journal of Eating Disorders*, 2(2), 15–34. [https://doi.org/10.1002/1098-108X\(198321\)2:2<15::AID-EAT2260020203>3.0.CO;2-6](https://doi.org/10.1002/1098-108X(198321)2:2<15::AID-EAT2260020203>3.0.CO;2-6)
- Harrison, O. K., Garfinkel, S. N., Marlow, L., Finnegan, S. L., Marino, S., Köchli, L., Allen, M., Finnemann, J., Keur-Huizinga, L., Harrison, S. J., Stephan, K. E., Pattinson, K., & Fleming, S. M. (2021). The filter detection task for measurement of breathing-related interoception and metacognition. *Biological Psychology*, 165, 108185. <https://doi.org/10.1016/j.biopsycho.2021.108185>
- Herbert, B. M. (2020). Interoception and its role for eating, obesity, and eating disorders: Empirical findings and conceptual conclusions. *European Journal of Health Psychology*, 27(4), 188–205. <https://doi.org/10.1027/2512-8442/a000062>
- Herbert, B. M., Muth, E. R., Pollatos, O., & Herbert, C. (2012). Interoception across modalities: On the relationship between cardiac awareness and the sensitivity for gastric functions. *PLoS One*, 7(5), e36646. <https://doi.org/10.1371/journal.pone.0036646>
- Herbert, B. M., Pollatos, O., & Klusmann, V. (2020). Interoception and health: Psychological and physiological mechanisms. *European Journal of Health Psychology*, 27(4), 127–131. <https://doi.org/10.1027/2512-8442/a000064>
- Hiller, R., & Pellicano, L. (2013). Anorexia and autism: A cautionary note. *The Psychologist*, 26(11). <http://thepsychologist.bps.org.uk/volume-26/edition-11/letters>
- Huke, V., Turk, J., Saeidi, S., Kent, A., & Morgan, J. F. (2013). Autism spectrum disorders in eating disorder populations: A systematic review. *European Eating Disorders Review: The Journal of the Eating Disorders Association*, 21(5), 345–351. <https://doi.org/10.1002/erv.2244>
- Jacquemot, A., & Park, R. (2020). The role of interoception in the pathogenesis and treatment of anorexia nervosa: A narrative review. *Frontiers in Psychiatry*, 11, 281. <https://doi.org/10.3389/fpsyt.2020.00281>
- Jenkinson, P. M., Taylor, L., & Laws, K. R. (2018). Self-reported interoceptive deficits in eating disorders: A meta-analysis of studies using the Eating Disorder Inventory. *Journal of Psychosomatic Research*, 110, 38–45. <https://doi.org/10.1016/j.jpsychores.2018.04.005>
- Karjalainen, L., Gillberg, C., Råstam, M., & Wentz, E. (2016). Eating disorders and eating pathology in young adult and adult patients with ESSENCE. *Comprehensive Psychiatry*, 66(6), 79–86. <https://doi.org/10.1016/j.comppsy.2015.12.009>
- Karjalainen, L., Råstam, M., Paulson-Karlsson, G., & Wentz, E. (2019). Do autism spectrum disorder and anorexia nervosa have some eating disturbances in common? *European Child & Adolescent Psychiatry*, 28(1), 69–78. <https://doi.org/10.1007/s00787-018-1188-y>
- Kenny, L., Hattersley, C., Molins, B., Buckley, C., Povey, C., & Pellicano, E. (2016). Which terms should be used to describe autism? Perspectives from the UK autism community. *Autism: The International Journal of Research and Practice*, 20(4), 442–462. <https://doi.org/10.1177/1362361315588200>
- Khalsa, S. S., Berner, L. A., & Anderson, L. M. (2022). Gastrointestinal interoception in eating disorders: Charting a new path. *Current Psychiatry Reports*, 24, 47–60. Advance Online Publication. <https://doi.org/10.1007/s11920-022-01318-3>
- Khalsa, S. S., Craske, M. G., Li, W., Vangala, S., Strober, M., & Feusner, J. D. (2015). Altered interoceptive awareness in anorexia nervosa: Effects of meal anticipation, consumption and bodily arousal. *International Journal of Eating Disorders*, 48(7), 889–897. <https://doi.org/10.1002/eat.22387>
- Khalsa, S. S., Rudrauf, D., Feinstein, J. S., & Tranel, D. (2009). The pathways of interoceptive awareness. *Nature Neuroscience*, 12(12), 1494–1496. <https://doi.org/10.1038/nn.2411>
- Khoury, N. M., Lutz, J., & Schuman-Olivier, Z. (2018). Interoception in psychiatric disorders: A review of randomized, controlled trials with interoception-based interventions. *Harvard Review of Psychiatry*, 26(5), 250–263. <https://doi.org/10.1097/HRP.0000000000000170>
- Kinnaird, E., Norton, C., Stewart, C., & Tchanturia, K. (2019). Same behaviours, different reasons: What do patients with co-occurring anorexia and autism want from treatment? *International Review of Psychiatry (Abingdon, England)*, 31(4), 308–317. <https://doi.org/10.1080/09540261.2018.1531831>
- Kinnaird, E., Stewart, C., & Tchanturia, K. (2020). Interoception in anorexia nervosa: Exploring associations with alexithymia and

- autistic traits. *Frontiers in Psychiatry*, 11, 64. <https://doi.org/10.3389/fpsy.2020.00064>
- Klabunde, M., Collado, D., & Bohon, C. (2017). An interoceptive model of bulimia nervosa: A neurobiological review. *Journal of Psychiatric Research*, 94, 36–46. <https://doi.org/10.1016/j.jpsychires.2017.06.009>
- Knapp, K., Ring, C., & Brener, J. (1997). Sensitivity to mechanical stimuli and the role of general sensory and perceptual processes in heartbeat detection. *Psychophysiology*, 34(4), 467–473. <https://doi.org/10.1111/j.1469-8986.1997.tb02391.x>
- Lapidus, R. C., Puhl, M., Kuplicki, R., Stewart, J. L., Paulus, M. P., Rhudy, J. L., Feinstein, J. S., Khalsa, S. S., & Tulsa 1000 Investigators. (2020). Heightened affective response to perturbation of respiratory but not pain signals in eating, mood, and anxiety disorders. *PLoS One*, 15(7), e0235346. <https://doi.org/10.1371/journal.pone.0235346>
- Legrand, N., Nikolova, N., Correa, C., Brændholt, M., Stuckert, A., Kildahl, N., Vejlo, M., Fardo, F., & Allen, M. (2021). The heart rate discrimination task: A psychophysical method to estimate the accuracy and precision of interoceptive beliefs. *Biological Psychology*, 168(1708), 108239. <https://doi.org/10.1016/j.biopsycho.2021.108239>
- Lutz, A., Schulz, A., Voderholzer, U., Koch, S., vanDyck, Z., & Vögele, C. (2019). Enhanced cortical processing of cardio-afferent signals in anorexia nervosa. *Clinical Neurophysiology*, 130(9), 1620–1627. <https://doi.org/10.1016/j.clinph.2019.06.009>
- Mandy, W., & Tchanturia, K. (2015). Do women with eating disorders who have social and flexibility difficulties really have autism? A case series. *Molecular Autism*, 6(1), 6. <https://doi.org/10.1186/2040-2392-6-6>
- Martin, E., Dourish, C. T., Rotshtein, P., Spetter, M. S., & Higgs, S. (2019). Interoception and disordered eating: A systematic review. *Neuroscience & Biobehavioral Reviews*, 107(3), 166–191. <https://doi.org/10.1016/j.neubiorev.2019.08.020>
- 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>
- Murphy, J., Brewer, R., Catmur, C., & Bird, G. (2017). Interoception and psychopathology: A developmental neuroscience perspective. *Developmental Cognitive Neuroscience*, 23, 45–56. <https://doi.org/10.1016/j.dcn.2016.12.006>
- Murphy, J., Brewer, R., Hobson, H., Catmur, C., & Bird, G. (2018). Is alexithymia characterised by impaired interoception? Further evidence, the importance of control variables, and the problems with the heartbeat counting task. *Biological Psychology*, 136, 189–197. <https://doi.org/10.1016/j.biopsycho.2018.05.010>
- Murphy, J., Brewer, R., Plans, D., Khalsa, S. S., Catmur, C., & Bird, G. (2020). Testing the independence of self-reported interoceptive accuracy and attention. *Quarterly Journal of Experimental Psychology*, 73(1), 115–133. <https://doi.org/10.1177/1747021819879826>
- Murphy, J., Catmur, C., & Bird, G. (2019). Classifying individual differences in interoception: Implications for the measurement of interoceptive awareness. *Psychonomic Bulletin & Review*, 26(5), 1467–1471. <https://doi.org/10.3758/s13423-019-01632-7>
- Nazar, B. P., Peynenburg, V., Rhind, C., Hibbs, R., Schmidt, U., Gowers, S., Macdonald, P., Goddard, E., Todd, G., Micali, N., & Treasure, J. (2018). An examination of the clinical outcomes of adolescents and young adults with broad autism spectrum traits and autism spectrum disorder and anorexia nervosa: A multi centre study. *International Journal of Eating Disorders*, 51(2), 174–179. <https://doi.org/10.1002/eat.22823>
- Nemiah, J. C., Freyberger, H., & Sifneos, P. E. (1976). Alexithymia: A view of the psychosomatic process. In O. W. Hill (Ed.), *Modern trends in psychosomatic research* (Vol. 3, pp. 430–439). Butterworth.
- Nicholson, T., Williams, D., Carpenter, K., & Kallitsounaki, A. (2019). Interoception is impaired in children, but not adults, with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 49(9), 3625–3637. <https://doi.org/10.1007/s10803-019-04079-w>
- Nicholson, T. M., Williams, D. M., Grainger, C., Christensen, J. F., Calvo-Merino, B., & Gaigg, S. B. (2018). Interoceptive impairments do not lie at the heart of autism or alexithymia. *Journal of Abnormal Psychology*, 127(6), 612–622. <https://doi.org/10.1037/abn0000370>
- Palser, E. R., Fotopoulou, A., Pellicano, E., & Kilner, J. M. (2018). The link between interoceptive processing and anxiety in children diagnosed with autism spectrum disorder: Extending adult findings into a developmental sample. *Biological Psychology*, 136, 13–21. <https://doi.org/10.1016/j.biopsycho.2018.05.003>
- Plans, D., Ponzo, S., Morelli, D., Cairo, M., Ring, C., Keating, C. T., Cunningham, A. C., Catmur, C., Murphy, J., & Bird, G. (2020). Measuring interoception: The phase adjustment task. *Biological Psychology*, 165(2). <https://doi.org/10.1016/j.biopsycho.2021.108171>
- Pollatos, O., Herbert, B. M., Mai, S., & Kammer, T. (2016). Changes in interoceptive processes following brain stimulation. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 371(1708), 20160016. <https://doi.org/10.1098/rstb.2016.0016>
- Pollatos, O., Kurz, A. L., Albrecht, J., Schreder, T., Kleemann, A. M., Schöpf, V., Kopietz, R., Wiesmann, M., & Schandry, R. (2008). Reduced perception of bodily signals in anorexia nervosa. *Eating Behaviors*, 9(4), 381–388. <https://doi.org/10.1016/j.eatbeh.2008.02.001>
- Porges, S. W. (1993). *Body perception questionnaire*. Laboratory of Developmental Assessment: University of Maryland.
- Quadt, L., Garfinkel, S. N., Mulcahy, J. S., Larsson, D. E., Silva, M., Jones, A. M., Strauss, C., & Critchley, H. D. (2021). Interoceptive training to target anxiety in autistic adults (ADIE): A single-center, superiority randomized controlled trial. *EClinicalMedicine*, 39, 101042. <https://doi.org/10.1016/j.eclinm.2021.101042>
- Quattrocki, E., & Friston, K. (2014). Autism, oxytocin and interoception. *Neuroscience & Biobehavioral Reviews*, 47, 410–430. <https://doi.org/10.1016/j.neubiorev.2014.09.012>
- Ring, C., & Brener, J. (1996). Influence of beliefs about heart rate and actual heart rate on heartbeat counting. *Psychophysiology*, 33(5), 541–546. <https://doi.org/10.1111/j.1469-8986.1996.tb02430.x>
- Ring, C., Brener, J., Knapp, K., & Mailloux, J. (2015). Effects of heartbeat feedback on beliefs about heart rate and heartbeat counting: A cautionary tale about interoceptive awareness. *Biological Psychology*, 104, 193–198. <https://doi.org/10.1016/j.biopsycho.2014.12.010>
- Schandry, R. (1981). Heart beat perception and emotional experience. *Psychophysiology*, 18(4), 483–488. <https://doi.org/10.1111/j.1469-8986.1981.tb02486.x>



- Schauder, K. B., Mash, L. E., Bryant, L. K., & Cascio, C. J. (2015). Interoceptive ability and body awareness in autism spectrum disorder. *Journal of Experimental Child Psychology*, 131, 193–200. <https://doi.org/10.1016/j.jecp.2014.11.002>
- Suksasilp, C., & Garfinkel, S. N. (2022). Towards a comprehensive assessment of interoception in a multi-dimensional framework. *Biological Psychology*, 168, 108262. <https://doi.org/10.1016/j.biopsycho.2022.108262>
- Tchanturia, K. (2021). *Supporting autistic people with eating disorders: A guide to adapting treatment and supporting recovery*. Jessica Kingsley Publishers.
- Treasure, J. (2019). Treatment resistance in eating disorders: A question of uncertain targets or insufficient personalization? *International Review of Psychiatry*, 31(4), 305–307. <https://doi.org/10.1080/09540261.2019.1626142>
- van den Houte, M., Vlemincx, E., Franssen, M., van Diest, I., van Oudenhove, L., & Luminet, O. (2021). The respiratory occlusion discrimination task: A new paradigm to measure respiratory interoceptive accuracy. *Psychophysiology*, 58(4), e13760. <https://doi.org/10.1111/psyp.13760>
- VanDyck, Z., Vögele, C., Blechert, J., Lutz, A. P., Schulz, A., & Herbert, B. M. (2016). The water load test as a measure of gastric interoception: Development of a two-stage protocol and application to a healthy female population. *PLoS One*, 11(9), e0163574. <https://doi.org/10.1371/journal.pone.0163574>
- vanEeden, A. E., vanHoeken, D., & Hoek, H. W. (2021). Incidence, prevalence and mortality of anorexia nervosa and bulimia nervosa. *Current Opinion in Psychiatry*, 34(6), 515–524. <https://doi.org/10.1097/YCO.0000000000000739>
- Webster, K. E., & Colrain, I. M. (2000). The relationship between respiratory-related evoked potentials and the perception of inspiratory resistive loads. *Psychophysiology*, 37(6), 831–841. <https://doi.org/10.1111/1469-8986.3760831>
- Westwood, H., Eisler, I., Mandy, W., Leppanen, J., Treasure, J., & Tchanturia, K. (2016). Using the autism-spectrum quotient to measure autistic traits in anorexia nervosa: A systematic review and meta-analysis. *Journal of Autism and Developmental Disorders*, 46(3), 964–977. <https://doi.org/10.1007/s10803-015-2641-0>
- Westwood, H., Mandy, W., Simic, M., & Tchanturia, K. (2018). Assessing ASD in adolescent females with anorexia nervosa using clinical and developmental measures: A preliminary investigation. *Journal of Abnormal Child Psychology*, 46(1), 183–192. <https://doi.org/10.1007/s10802-017-0301-x>
- Whitehead, W. E., & Drescher, V. M. (1980). Perception of gastric contractions and self-control of gastric motility. *Psychophysiology*, 17(6), 552–558. <https://doi.org/10.1111/j.1469-8986.1980.tb02296.x>
- Whitehead, W. E., Drescher, V. M., Heiman, P., & Blackwell, B. (1977). Relation of heart rate control to heartbeat perception. *Biofeedback and Self-Regulation*, 2(4), 371–392. <https://doi.org/10.1007/BF00998623>
- Windmann, S., Schonecke, O. W., Fröhlig, G., & Maldener, G. (1999). Dissociating beliefs about heart rates and actual heart rates in patients with cardiac pacemakers. *Psychophysiology*, 36(3), 339–342. <https://doi.org/10.1017/S0048577299980381>
- Wittkamp, M. F., Bertsch, K., Vögele, C., & Schulz, A. (2018). A latent state-trait analysis of interoceptive accuracy. *Psychophysiology*, 55(6), e13055. <https://doi.org/10.1111/psyp.13055>
- Yates, A. J., Jones, K. E., Marie, G. V., & Hogben, J. H. (1985). Detection of the heartbeat and events in the cardiac cycle. *Psychophysiology*, 22(5), 561–567. <https://doi.org/10.1111/j.1469-8986.1985.tb01651.x>
- Zdankiewicz-Ścigała, E., Ścigała, D., Sikora, J., Kwaterniak, W., & Longobardi, C. (2021). Relationship between interoceptive sensibility and somatoform disorders in adults with autism spectrum traits. The mediating role of alexithymia and emotional dysregulation. *PLoS One*, 16(8), e0255460. <https://doi.org/10.1371/journal.pone.0255460>
- Zhao, W., Martin, A. D., & Davenport, P. W. (2002). Detection of inspiratory resistive loads in double-lung transplant recipients. *Journal of Applied Physiology*, 93(5), 1779–1785. <https://doi.org/10.1152/japplphysiol.00210.2002>

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