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Somatic symptom distress is not related to cardioceptive accuracy

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ABSTRACT

Objective: (Cardiac) interoception was long considered a key mechanism behind symptom perception in persistent somatic symptoms (PSS). In this study, we aimed to extend earlier findings to clarify this potential interoceptive mechanisms of PSS.
Methods: A cross-sectional sample of 251 participants (23.1% with self-reported functional somatic syndrome) completed a laboratory study with two cardioceptive accuracy tasks (Schandry task and a new cardiac signal detection task) and multiple questionnaires. Somatic symptom distress and associated constructs were assessed with the PHQ-15, as well as with a novel multidimensional questionnaire measure (HiTOP-SF1) derived from the somatoform spectrum of the Hierarchical Taxonomy of Psychopathology (HiTOP). Correlations (frequentist and Bayesian) and structural equation modelling (SEM) helped further investigate the interplay between these variables.
Results: There were no significant correlations between measures of interoception and somatic symptom distress. Self-report and behavioral cardioceptive accuracy measures did not correlate significantly. No significant covariances emerged between diagnostic tools and cardioceptive accuracy; Bayesian analyses supported the lack of association between interoception and symptom perception.
Conclusions: Cardiac interoception (specifically cardioceptive accuracy) unlikely represents a key mechanism in PSS etiology. We recommend investigating other factors in PSS.

1. Introduction

Somatic symptoms are experienced by the vast majority of the population on a daily basis [1]. The perception of bodily symptoms is only loosely related to the organic status (e.g., [2]). Even if there is a pathophysiological background, severity of symptoms is often disproportional to the condition in question [3–5]. Nearly two thirds of all symptoms reported in primary care settings are persistent somatic symptoms [6], and the prevalence of somatoform disorders is around 4.9% [7]. Thus, understanding the background of somatic symptoms is of importance from both theoretical and practical point of view.

The current state-of-the-art explanatory model is the predictive processing framework, postulating that symptom perception is an active constructional process [8,9]. In principle, human brains non-consciously develop hypotheses (priors) about bodily states and these computational hypotheses actively shape the conscious representation of symptoms. For healthy individuals, priors and input from the body are processed in a balanced/adaptive way (cf. Fig. 2a, [9]). However, in people with persistent somatic symptoms, the priors dominate the integration process, which can even lead to the perception of symptoms in the complete absence of peripheral input [10]. However, whether the perception of sensory input (i.e., interoceptive information) plays a role in symptom reporting remains an open question.

Empirical evidence consistently shows that the accuracy of perception of interoceptive information (interoceptive accuracy: IAc) shows substantial individual differences and is modality-specific; for example, the acuity of perception of gastric changes is not strongly associated with the accuracy of perception of cardiac activity [11–13]. The most frequently assessed interoceptive modality is the cardiac modality (cardioceptive accuracy, CAc). In typical tasks assessing CAc, participants are asked to focus on their heartbeats, and track them (via mental counting or button presses) or compare them to rhythmic external stimuli; in principle, perceived heartbeats are compared to actual heartbeats, typically assessed via electrocardiography (ECG).

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Interoceptive accuracy is not the only relevant aspect of interoception and different taxonomies exist (e.g., [14–17]). For example, self-reported, subjective attention towards and *perceived* accuracy of the detection of bodily signals (also called interoceptive sensibility) are supposed relevant subfacets of interoception [16]. In self-reports, interoceptive accuracy and attention are usually not related to each other [18,19]. Self-report measures of IAc usually negatively relate to PSS and psychopathology [20,21], while self-reported interoceptive attention is mostly positively related [20,22,23]. However, CAc is mostly independent from self-reported interoception [15,24–26].

Meta-analytic evidence showed reduced IAc in functional, but not somatic symptom and illness anxiety disorders, with CAc tasks not often presented in functional disorders [27]. Concerning CAc, the vast majority of empirical studies did not find a significant association with mental health outcomes [28,29]. Additionally, a liberal response tendency towards somatosensory information in the sense of reporting sensations, when they are not present was found in the meta-analyses. Unfortunately, cardioceptive accuracy and response tendency are conflated in the most commonly used CAc task, the Schandry task [30]. Thus, using a CAc task in which sensitivity and response bias are separated could lead to new insights.

The main goal of the current study was to shed more light on the association between (cardiac) interoception and PSS in a methodologically sound way. To this end, we used different paradigms assessing CAc, such as the traditional Schandry task as well as a new task enabling us to distinguish sensitivity and bias to cardiac signals [30] and wanted to compare performance parameters and validity. Furthermore, somatic symptom distress was assessed with two instruments: the more established Patient Health Questionnaire and, in contrast, the HiTOP somatoform spectrum questionnaire (HiTOP-SF1), a novel multidimensional nosological system [31–33]. This allowed us to explore somatic symptom distress from both a traditional clinical perspective as well as a more transdiagnostic, comprehensive, and multidimensional perspective (using the HiTOP-SF1). Finally, we employed both frequentist and Bayesian statistics, a latent variable approach, and a comparatively large, heterogeneous sample. Based on the predictive processing framework, we hypothesized a significant relationship between less accurate, less sensitive and more liberally biased cardioception and higher symptom reporting. We also explored whether self-reported interoception was associated with higher symptom reporting.

2. Methods

2.1. Transparency and openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow JARS [34]. This study's design and analysis plan are preregistered at osf.io [35]. Data and code are available at https://doi.org/10.17605/OSF.IO/NTPU4. All non-physical materials are publicly available (questionnaires, scripts for ECG tasks). Data were analyzed using only the tools and programs listed below.

We obtained ethical approval in accordance with the 7th revision of the Helsinki Declaration from the local ethics commission.

2.2. Participants

To have enough statistical power and stable estimate of correlations, we determined $N = 250$ persons as an ideal sample size, with some overrecruitment, as this is the recommended sample size for SEM analyses [36]. We recruited 265 participants via student mailing lists, posters in the city center, newspaper articles/press statements, and social media. Participants were eligible if they were between 18 and 65 years old, did not have epilepsy or Parkinson's disease, and had sufficient proof of COVID vaccination or recovery status (only for the time period February to May 2022, according to state and university regulations in Rhineland-Palatinate), and gave informed consent in writing. Eleven participants had incomplete data sets and were therefore excluded, and $n = 3$ were excluded because of technical difficulties with the ECG, so the final sample size was $N = 251$ (approx. 69% women, 31% men, <1% non-binary; $M_{age} = 28.4$, $SD_{age} = 10.7$, range: 18–65 years). All demographic details can be seen in Table 1. Participants were compensated with 30€ or 2 to 2.5 h participation credits.

The recruitment and data collection period spanned from 02/2022 to 08/2022.

2.3. Materials

2.3.1. Questionnaire measures

We used two types of questionnaires: somatic symptom-related questionnaires (PHQ-15, and HiTOP-SF1), and interoceptive attention and accuracy related questionnaires (IATS, IAS, and ISAQ). Other questionnaires were administered but are not reported here as they are not relevant to the particular study questions. See Supplement 1 for a full description.

2.3.2. Schandry task

This heartbeat perception task was originally developed by Schandry [37]. It consists of 3 trials in which participants are asked to count all heartbeats they perceive (without touching their pulse or using a smartwatch) in a 25, 35, or 45 s timeframe. We instructed participants not to guess their heartbeats but encouraged them to count weak or uncertain signals. The beginning and the end of this timeframe was marked by a sound, and participants indicated their response by typing it into a field. In addition, we decided to add a confidence rating on a scale from 1 to 9 to investigate how sure participants were that their number corresponded to the real number of heartbeats. Here, the internal consistency was $\alpha = .821$.

2.3.3. Cardiovascular Signal Detection Task (cvSDT)

This task [30] is similar to the Schandry task in that participants are instructed to count their heartbeats between two beeps. However, the response format is forced single choice; participants have to decide whether they counted a certain interval (e.g., "8–10 beats", option 1) or more/less (option 2). The trial length is synchronized to the R-waves in the ECG. After 4 practice trials, there were 50 trials. In 40, option 2 was "less", and in 10, option 2 is "more". These 10 "more" trials count as distractor trials. In half of all trials, the presented interval is correct. This procedure allows the calculation of hits, false alarms, sensitivity, and

Table 1
Demographic information.

	M or *n* (%) (Total Sample: 251)
Occupation	
Students	188 (74.9%)
Employees	35 (13.9%)
Job-seeking or homemaker	9 (3.6%)
Self-Employed	6 (2.4%)
Retired	6 (2.4%)
Civil servants	4 (1.6%)
Other	3 (1.2%)
Education	
Tertiary Entrance Diploma	137 (54.6%)
University Degree	98 (39.0%)
Middle-level High School Diploma	8 (3.2%)
Low-level High School Diploma	7 (2.8%)
No finished education	1 (0.4%)
Body Mass Index[1] (range: 15.52–52.06)	23.43 ($SD = 4.82$)
Self-reported psychopathological condition	58 (23.1%)
Self-reported somatic condition	52 (20.7%)
Self-reported functional disorder	58 (23.1%)
On medication	86 (34.3%)

Note. 1 Five people declined to state their body weight.

response bias (see below).

2.4. Design and procedure

This study used a cross-sectional design. Interested participants were asked to provide their phone numbers so that we could call them for a screening. This screening consisted of three questions to check eligibility (age, epilepsy status, Parkinson's status), and more details about the tasks participants would solve. Participants were told that they would be participating in a study about how psychological processes influence symptom- and body perception. At the end of the conversation, an appointment was scheduled. Two days before the session, participants received an email reminding them of their participation. They were asked not to take recreational drugs or alcohol 24 h prior to the experiment. Furthermore, they were asked to fill in the battery of questionnaires via the online platform SoSci Survey [38].

On the day of the experiment, participants gave informed consent. The participants completed, in this order, the Schandry task, cvSDT, as well as two other tasks pertaining to affective picture perception (which are described in [35] but not here as they are independent of the cardioception tasks). For technical details on the apparatus, see Supplement 2. At the end of the session, participants were able to ask more questions and give feedback. Participants were then compensated with 30€ or 2–2.5 h participation credits for psychology students.

2.5. Statistical analysis

Data were analyzed using SPSS Version 27 [39], R version 4.1.2 [40] and JASP 0.16.2 [41]. In R, we used the packages *lavaan*, *psych*, and *foreign* [42–44]. For data cleaning, we first removed all duplicates (i.e., people who accidentally filled in the questionnaire twice – only the first attempt was used).

After data cleanup, we first calculated demographic statistics, descriptives, sum scores, frequencies, and internal consistencies. Then, we calculated typical cardioception parameters for each task. In the Schandry task, the typical parameter is a measure of cardioceptive accuracy of heartbeat perception, using the formula $HBP = \frac{1}{n}\sum_{k=1}^{n} 1 - |\frac{recorded - perceived}{recorded}|$ [37]. A HBP score close to 1 indicates high cardioceptive accuracy, while one close to 0 means poor cardioceptive accuracy.

In the cvSDT task, we were interested in hits and false alarms in the "less" trials. In the "more" trials, the more response option was chosen so rarely that we decided to shorten the original protocol and include 10 "more" trials as distractors, only. Hit- and false alarm rates were Snodgrass-corrected [45]. We calculated sensitivity $d' = z(\text{Hits}) - z(\text{False Alarms})$ and response bias $c = -[z(\text{Hits}) + z(\text{False Alarms})]/2$ by first loglinearly transforming corrected hit and false alarm rates into z-scores (appendix 6 of [46]). High sensitivity is an indicator of higher cardioceptive accuracy.

As a next step, we computed Pearson correlations between the different constructs, with a specific focus on somatic symptom measures (PHQ-15 and HiTOP-SF) and cardioception tasks. Beyond the frequentist approach, we also used Bayesian statistics to avoid issues with multiple testing and frequentist approaches to be able to support the null hypothesis. A Bayes Factor (BF_{10}) > 3 was regarded as support of the alternative hypothesis, whereas BF10 < 0.33 as indicating the superiority of the null hypothesis [47].

Next, we conducted Structural Equation Models (SEM) to investigate the relationships between symptom reports (PHQ-15 and HiTOP) and cardioception tasks. This resulted in 6 models: (PHQ-15; HiTOP) * (base model; Schandry; cvSDT). For the PHQ-15-based models, we used a WLSMV estimator with theta parametrization, as these models use categorical (=ordinal) data to calculate latent variables. Our PHQ-15 SEM models were built according to the bifactor models put forward by Witthöft and colleagues [10,48,49]. As is the rule for bifactor models, the g-factor was not allowed to correlate with the sensory components, because these two factors must be orthogonal [50]. Lastly, the error variances of the latent variables were set to 1. In the cvSDT model we decided to only estimate the covariance between the fatigue and the cardio components with c, d', and c*d' to not overfit the model and because we did not see any theoretical reasons why a heartbeat task should relate to pain or gastrointestinal symptoms (e.g., [12]).

For the HiTOP measurement model, we used the five subscales to build a general factor model of somatoform symptom distress. We added a correlation between health anxiety and disease conviction as these are highly related and central components of hypochondriasis. Conversion symptoms were included in the latent variable construction but not correlated to the other outcome measures, as already the original HiTOP-SF authors reported difficulties with this scale [32]. For this model, we used a maximum likelihood mean- and variance-adjusted estimator (MLMV). We used common model fit parameters such as χ^2, Root Mean Square Error of Approximation (RMSEA), Root Mean Square Residual (SRMR), and the Comparative Fit Index (CFI).

3. Results

3.1. Cardioceptive accuracy analyses

The average performance on the Schandry Task was $M_{HBP} = .52$ $(SD = .27)$. In the cvSDT task, average sensitivity was $d' = 0.70$ $(SD = 0.526)$, while average bias was $c = .23$ $(SD = 0.467)$. In the 'more' conditions, the hit rate was very high at $M = 97.6\% (SD = 8.4\%)$ of cases. The percentage of false alarms was also very low at $M = 2.4\% (SD = 8.4\%)$. On the other hand, the hit rate for the 'less' condition was much lower ($M = 29.0\%, SD = 24.9\%$) and the false-alarm rate was higher at $M = 5.4\% (SD = 9.4\%)$ on average.

3.2. Correlational analyses and task comparison

See Table 2 for correlations between the assessed variables. Note that convergent correlations were mostly high and as expected between questionnaires, such as measures of somatic symptom distress ($r = 0.621, p < .001$ between HiTOP-SF1 and PHQ-15) or interoception (e.g., medium sized correlations between ISAQ, IAS, and IATS). In contrast, behavioral measures of interoception (d', c, HBP) did not correlate significantly with interoception questionnaires, except for a weak correlation between IAS and c ($r = .152, p = .016$). The behavioral measures of cardioceptive accuracy also did not significantly correlate with symptom reporting (all correlations between $r = [-0.08; 0.03]$). Exploring the associations between self-reported interoception and symptom reporting, we found that there were no significant correlations between the three interoception questionnaires and the two measures of somatic symptom distress.

Regarding performance on the two cardioception tasks, there was a high negative correlation between d' and c ($r = -.621, p < .001$, suggesting that higher sensitivity was associated with a more liberal response behaviour, as well as a small negative correlation between c and HBP ($r = -.207, p < .001$), implying that a better performance in the Schandry task was associated with a more liberal response style in the cvSDT task. HBP and d' were correlated moderately ($r = .358$, $p < .001$) and people who rated their confidence higher after in the Schandry task had higher HBP scores ($r = .599, p < .001$).

See Supplement 3 for all Bayesian correlations. Note that the basically same patterns emerged as mentioned above in the section on Pearson's correlations.

3.3. Structural equation modelling

3.3.1. PHQ-15

The baseline PHQ-15 model can be seen in Supplement 4. The PHQ-

Table 2
Pearson's correlations of all measures.

	M	*SD*	1.	2.	3.	4.	5.	6.	7.	8.
1. d'	.70	.526	–							
2. c	.23	.467	-.621*** [-.69, -.54]	–						
3. HBP	.52	.270	.358*** [.25, .46]	-.207*** [-.32, -.09]	–					
4. Mean conf	4.47	2.026	.123 [-.00, .24]	.004 [-.12, 13]	.599*** [.51, .67]	–				
5. HiTOP-SF	74.76	15.724	-.084 [-.21, .04]	.031 [-.09, .15]	-.011 [-.13, .11]	-.002 [-.13, .12]	–			
6. PHQ-15	6.73	4.541	-.029 [-.15, .95]	-.014 [-.14, .11]	-.032 [-.16, .09]	-.099 [-.22, .03]	.621*** [.54, .69]	–		
7. IAS	84.16	9.618	-.076 [-.20, .05]	.152* [.03, .27]	.058 [-.07, .18]	.145* [.02, .26]	-.051 [-.17, .07]	-.013 [-.14, .11]	–	
8. IATS	46.47	14.122	.050 [-.07, .17]	.001 [-.12, .13]	-.028 [-.15, .10]	.018 [-.11, .14]	.123 [.00, .24]	.207*** [.09, .32]	.008 [-.12, .13]	–
9. ISAQ	55.32	7.915	.090 [-.03, .21]	-.015 [-.14, .11]	.071 [-.05, .19]	.096 [-.03, .22]	.184** [.06, .30]	.094 [-.03, .21]	.465*** [.36, .55]	.345*** [.23, .45]

Notes. c = Bias in cvSDT, d' = sensitivity in cvSDT, HBP = Heartbeat perception score in Schandry task, mean conf = mean confidence after Schandry trials, HiTOP-SF = HiTOP somatoform phase 1 items, PHQ-15 = Patient Health Questionnaire 15, IAS = Interoceptive Accuracy Scale, IATS = Interoceptive Attention Scale, ISAQ = Interoceptive Sensitivity and Attention Questionnaire,
*$p < .05$. **$p < .01$. ***$p < .001$.

15 model with Schandry performance (Fig. 1) had a good model fit. However, note that none of the correlations with the Schandry parameter were significant, nor greater than |0.11|.

Finally, the model with PHQ-15 (Fig. 2) and cvSDT parameters also had a good fit. The fatigue latent variable shows significant positive correlations with the cvSDT response bias variable as well as the interaction term between response bias and d': $r_{fatigue\sim c} = .189, p = .045$; $r_{fatigue\sim c*d} = .263, p < .001$ (but also: $r_{fatigue\sim d} = .019, p = .869$). In other words, high fatigue is related either to a comparatively more liberal response bias in case of rather low sensitivity (d'), or to a relatively more conservative response bias in case of higher sensitivity (d'). The g-factor did not show any significant correlations with the cvSDT ($r_{gfactor\sim c} = -.053, r_{gfactor\sim d} = -.017, r_{gfactor\sim c*d} = -.006$, all $p > .50$). Neither did the cardiorespiratory variable ($r_{cardiac\sim c} = .034$, $r_{cardiac\sim d} = -.097$,

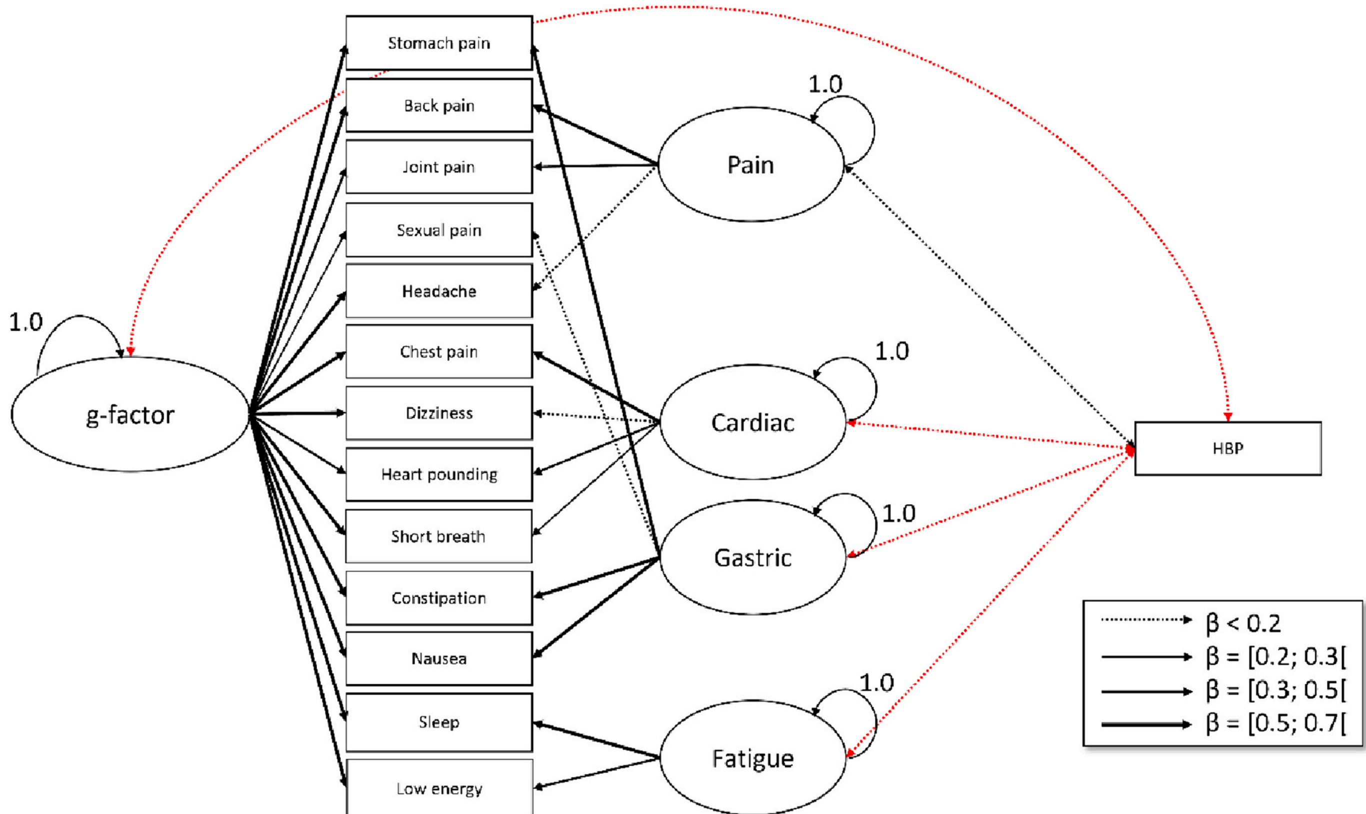

Fig. 1. Structural Equation Model of PHQ with Schandry Performance.
Note. G-factor = general somatic factor; HBP = Heartbeat perception (as measured by Schandry Task). Double-headed arrows depict correlations, while single-headed arrows depict latent variable construction. Red arrows indicate negative relationships. All paths with β > 0.3 were significant at p < .05. The loading of Sexual Pain (Item 5) on the g-factor was also significant (p = .011) despite the smaller loading. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. Structural Equation Model of PHQ with cvSDT Parameters.
Note. G-factor = general somatic factor; c = (cardioceptive) bias, d = (cardioceptive) sensitivity. Double-headed arrows depict correlations, while single-headed arrows depict latent variable construction. Red arrows indicate negative relationships. All paths with $\beta > 0.3$ were significant at $p < .05$. The loading of Sexual Pain (Item 5) on the g-factor was also significant ($p = .011$) despite the smaller loading. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

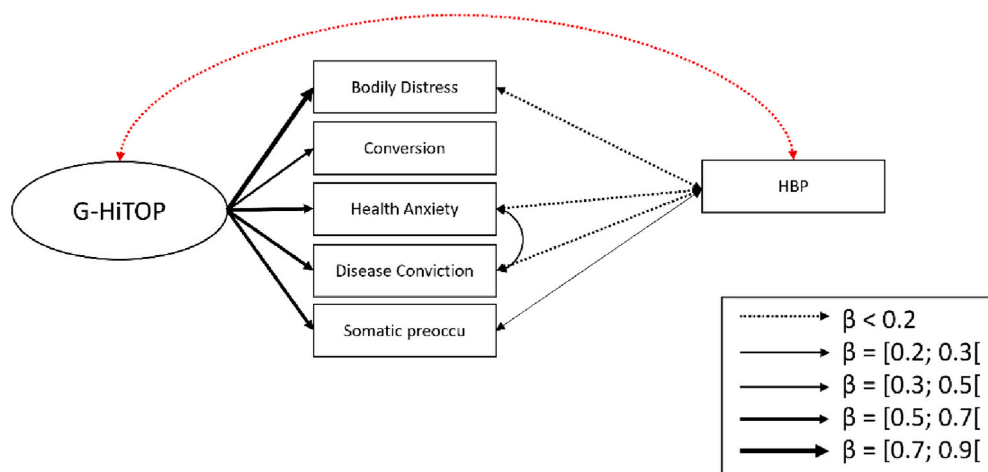

Fig. 3. Structural Equation Model of HiTOP with Schandry Performance.
Note. G-HiTOP = general factor of the HiTOP somatoform spectrum; HBP = Heartbeat perception (as measured by Schandry Task). Double-headed arrows depict correlations, while single-headed arrows depict latent variable construction. Red arrows indicate negative relationships. All paths with $\beta > 0.3$ were significant at $p < .001$. Despite its smaller correlation ($r = .267$), the correlation between Health Anxiety and Disease Conviction was also significant ($p = .011$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

$r_{cardiac\sim c^*d} = .050$, all $p > .29$).

3.3.2. HiTOP

For the baseline HiTOP (Supplement 6), bodily distress was most strongly associated with the g-SF-HiTOP factor. In the HiTOP-Schandry model (Fig. 3), the highest (but not significant) correlation was with the Somatic Preoccupation residual ($r = .226, p = .062$), while the g-SF-HiTOP had a negative (but not significant) correlation with the Schandry variable ($r = -.123, p = .463$).

Lastly, in the model with HiTOP and cvSDT parameters (Fig. 4), the subscale scores did not correlate significantly with the interaction term c*d' and the g-SF-HiTOP correlated insignificantly at $r_{g-SF-HiTOP} = -.570$ ($p = .105$). The residual of health anxiety was significantly negatively correlated to sensitivity ($r_{HA\sim d} = -.308, p = .021$), suggesting that health anxiety (without somatic symptom distress) is associated with lower cardioceptive sensitivity. The latent g-SF-HiTOP had a (non-significant) positive correlation with d' ($r_{g-SF-HiTOP\sim d} = .168, p = .379$). Health anxiety and somatic preoccupation were also both positive correlates of bias ($r_{HA\sim c} = .316, p = .017; r_{som.preocc.\sim c} = .325, p = .023$). G-SF-HiTOP however was correlated non-significantly and negatively ($r_{g-SF-HiTOP\sim c} = -.369, p = .197$).

The exact parameters can be seen in Supplements 4 to 9.

4. Discussion

The aim of this study was to broadly test possible associations between cardioception and somatic symptom perception using a multi-method approach and employing two different cardioception tasks. Across all these approaches and against our expectations, we found few to no significant associations between various measures of cardioception and symptom perception, and this was further supported by Bayes-Factors in favor of the null-hypothesis.

In this study, we also aimed to replicate and extend earlier findings on the cardiovascular Signal Detection Task [30]. Like in Pohl and colleagues' study, we found a significant positive correlation between d' and Schandry performance, as well as negative correlations between c and Schandry performance. This nicely demonstrates that performance in the Schandry task actually represents a combination of cardiac sensitivity and response bias and further validates the use of the cvSDT task. However, we were not able to replicate the finding of a significant association between d' and PHQ-15.

Regarding interoception measures, self-reported interoceptive accuracy and interoceptive attention questionnaire scores did not correlate. However, there was no evidence for significant correlations between interoception questionnaires and cardioceptive measures, neither from a frequentist nor a Bayesian point of view. This is in line with the literature [15,24,25,51]. Lastly, the correlation between confidence on the Schandry task and Schandry task performance was unusually high, underlining again that "good" heartbeat perception has a strong self-assessment component [15,52].

To test our hypothesis that symptom reporting is associated with less accurate (lower *d'*, lower HBP) and more liberally biased (higher *c*) cardioception, we first inspected the respective correlations. These were all very small and non-significant. In the structural equation models, we were able to go a step further and investigate which facets of PSS were most related to cardioception components. Based on theoretical reasons, we only tested relationships between g-factor, fatigue, and cardiac symptom groups with cvSDT components. Interestingly, we found higher and more stable relationships between cvSDT parameters and fatigue than with cardiac symptoms, especially when looking at the c*d' interaction. This suggests that people who score high on fatigue symptom questions – adjusted for motivational components – in the PHQ-15 are most likely to detect cardiac signals, but with a conservative bias. One potential explanation is that fatigue might not be an actual sensory process but more a reflection of lower attentional capacity. This could mean that the conservative bias is a result of depleted resources. Together with an average d', this would lead to a higher value for the interaction term.

The latent variable of the HiTOP-SF did not correlate with c, d', or c*d', we found in a structural equation model. However, health anxiety (as a residual independent of g-SF-HiTOP) was a significant correlate of both c and d', indicating that being more worried about one's health coincides with poorer heartbeat detection ability and a more conversative response bias. This is partly in line with previous findings of

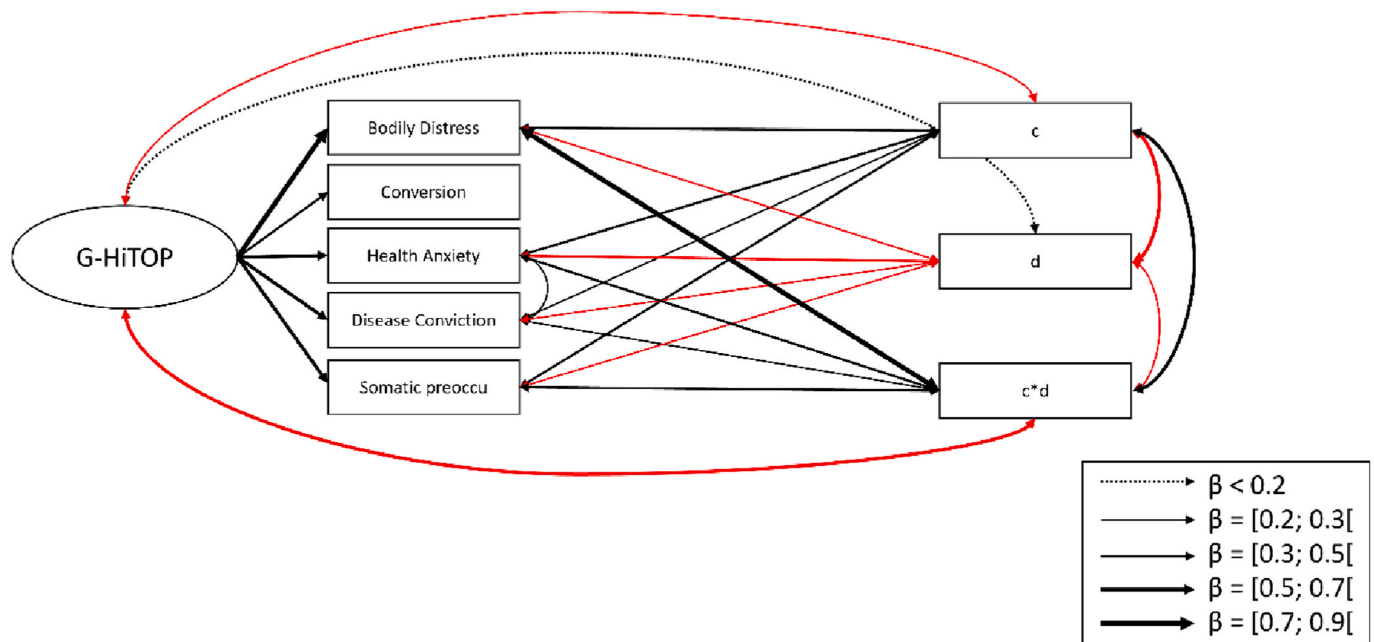

Fig. 4. Structural Equation Model of HiTOP with cvSDT Performance Parameters.
Note. G-HiTOP = general factor of the HiTOP somatoform spectrum; c = (cardioceptive) bias, d = (cardioceptive) sensitivity. Double-headed arrows depict correlations, while single-headed arrows depict latent variable construction. Red arrows indicate negative relationships. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

negative associations between health anxiety and cardioception in the Schandry Paradigm [53]. Due to conceptual reasons, we included a correlated error term between health anxiety and disease conviction, as they represent core tenets of hypochondriasis [54,55].

As a last note on the SEMs: Neither the HiTOP nor the PHQ-15 showed any significant correlations with the Schandry scores, which fits with the finding that there were no significant associations between Schandry score and any symptom reporting measure. This also demonstrates that the cvSDT task might be a more informative measure for future research.

This leads us to question the construct and convergent validity of cardioceptive accuracy tasks, as well as wondering whether measurement issues might be covering the real relationship between interoception measures and symptom reports.

It seems that cardiac interoceptive abilities – or specifically, cardioceptive accuracy – do not significantly covary with or cause PSS. One potential reason is that probing interoception in 'neutral' lab conditions is not comparable to interoception in daily life, where bodily signals may be experienced as threatening. In terms of Van den Bergh's Better Safe than Sorry model [56], physiological signals in these neutral conditions may not be classified as threatening and therefore not set off the vicious cycle of somatic symptom distress. Future research should assess the perception of arousal changes, as well as variations in interoception in threatening contexts.

Another reason for this is the lack of construct validity. While interoception researchers can agree on a common definition of interoceptive accuracy, there does not seem to be one latent variable underlying all the different measures. For example, one often-cited confounding variable in heartbeat paradigms is expectation [52]. As mentioned above, questionnaires of interoception have been found to measure different underlying concepts and reflect individuals' generalization across time and modalities [57,58]. Also, different domains of behavioral interoceptive accuracy do not correlate either, suggesting that there might not be a single underlying accuracy ability [13,26,59,60]. An elaborate study by Ferentzi, Bogdány, et al. [12] compared interoceptive accuracy across various domains (pain, gastric, heartbeat, proprioception, balancing ability, and bitter taste perception) and found that only tasks from the same sensory modality correlated with each other. This is also underlined by findings from structural equation modelling and factor analyses that suggest multiple underlying, discrete symptom groups (e.g., [22,49]). Since no association was found between cardioceptive accuracy and the sensory part of cardiorespiratory symptoms, it is possible that any priors simply overwrite the very weak interoceptive input (as the motivational g-factor is more involved in heartbeat perception). In other words, cardioception and the "unbiased" part of cardiac symptoms is independent in normally functioning individuals.

Either the lack of associations between behavioral interoceptive accuracy and somatic symptom burden are due to the challenge of current operationalization forms or potentially, the interoception dimension that is more involved in symptom perception is interoceptive attention. Even having symptoms – noticing that they are there – can be seen as a form of interoceptive attention [56,61]. Following Murphy and colleagues' [16] argument and standard practices for validating measures, the best way to assess the contribution of interoceptive attention to symptom perception would be to compare correlations of both self-report and behavioral measures of interoceptive attention to symptom perception. While for subjective measures (i.e., questionnaires such as the IATS) this is easy, there are still very few performance measures of interoceptive attention. One large problem is demand characteristics: would people notice the same symptoms if they had not been asked to pay attention to their bodies? As a result, the only interoceptive attention task beknown to the authors is experience sampling or ecological momentary assessment [16,62]. However, this is a quite nonspecific, arguably not very objective, as well as time- and resource-intensive method. A more objective, behavioral task was put forward by Pennebaker and Brittingham [63], where participants' attention was distracted from their body with an arithmetic task and body focus was assessed as their performance in recalling six subtle bursts of air delivered to their forearm during the task. More powerful distraction led to worse detection performance.

One limitation of our study is that the order of tasks was fixed and therefore carry-over effects may have influenced the cvSDT task. However, the sequence of task presentation did not affect Schandry scores in the first implementation of the cvSDT [30]. Also, our study consisted of a general, heterogeneous sample of people with moderate symptom distress, not a clinical sample. While some may consider this a limitation, we argue that this is a strength in disguise, as we were interested in the distribution of relevant traits across the population, so that we could reach more generalizable conclusions. Of course, a sample with higher symptom load (e.g., a clinical sample of patients with the diagnosis of a somatic symptom disorder or a particular functional somatic syndrome) may have produced different results, but then we would not be able to draw conclusions about healthy individuals.

In conclusion, there is no link between cardioceptive accuracy and symptom reporting, or between cardioceptive tasks and self-reported interoceptive accuracy. If interoceptive accuracy exists, it is a highly specific ability and researchers should keep this granularity in mind when assessing it, at best using multiple measures from different sensory domains. However, we argue that it is more feasible to explore different routes to symptom perception. For future research with cardioception tasks, we recommend the cvSDT task, as it is a feasible, valid measure and provides more insight into the processing cardioceptive signals than the Schandry task. Most importantly, the cvSDT allows for a separation of the cardiac detection ability (in terms of sensitivity) and the response bias, whereas accuracy scores in the HBP remain ambiguous in this respect (i.e., they reflect a mixture of the ability to truly detect heartbeats and choosing a more liberal response strategy).

Author contributions

Conceptualization: all authors; Methodology: M. Witthöft, A. Pohl, F. Köteles; Software: A. Pohl; Formal Analysis: T. Petzke, M. Witthöft; Investigation: T. Petzke; Resources: A. Pohl, M. Witthöft; Data Curation: T. Petzke; Writing – Original Draft: T. Petzke; Writing – Review & Editing: M. Witthöft, A. Pohl, F. Köteles; Visualization: T. Petzke, M. Witthöft; Supervision: M. Witthöft, A. Pohl; Project Administration: T. Petzke, A. Pohl; Funding Acquisition: M. Witthöft.

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We have no known conflict of interest to disclose. The preregistration, data, and code are available at https://doi.org/10.17605/OSF.IO/NTPU4.

CRediT authorship contribution statement

Tara M. Petzke: Writing – original draft, Visualization, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Ferenc Köteles:** Writing – review & editing, Methodology, Conceptualization. **Anna Pohl:** Writing – review & editing, Supervision, Software, Resources, Project administration, Methodology, Conceptualization. **Michael Witthöft:** Writing – review & editing, Visualization,

Supervision, Software, Resources, Methodology, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that there were no conflicts of interest with respect to the authorship or the publication of this article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpsychores.2024.111655.

References

[1] J.W. Pennebaker, The Psychology of Physical Symptoms, Springer, New York, New York, NY, 1982.
[2] P. Fink, A. Schröder, One single diagnosis, bodily distress syndrome, succeeded to capture 10 diagnostic categories of functional somatic syndromes and somatoform disorders, J. Psychosom. Res. 68 (2010) 415–426, https://doi.org/10.1016/j.jpsychores.2010.02.004.
[3] A.J. Barsky, Patients who amplify bodily sensations, Ann. Intern. Med. 91 (1979) 63–70, https://doi.org/10.7326/0003-4819-91-1-63.
[4] A.J. Barsky, J.D. Goodson, R.S. Lane, P.D. Cleary, The amplification of somatic symptoms, Psychosom. Med. 50 (1988) 510–519, https://doi.org/10.1097/00006842-198809000-00007.
[5] A.J. Barsky, D.A. Silbersweig, The amplification of symptoms in the medically ill, J. Gen. Intern. Med. 38 (2023) 195–202, https://doi.org/10.1007/s11606-022-07699-8.
[6] N. Steinbrecher, S. Koerber, D. Frieser, W. Hiller, The prevalence of medically unexplained symptoms in primary care, Psychosomatics 52 (2011) 263–271, https://doi.org/10.1016/j.psym.2011.01.007.
[7] H.U. Wittchen, F. Jacobi, J. Rehm, A. Gustavsson, M. Svensson, B. Jönsson, J. Olesen, C. Allgulander, J. Alonso, C. Faravelli, L. Fratiglioni, P. Jennum, R. Lieb, A. Maercker, J. van Os, M. Preisig, L. Salvador-Carulla, R. Simon, H.-C. Steinhausen, The size and burden of mental disorders and other disorders of the brain in Europe 2010, European neuropsychopharmacology the journal of the European college of, Neuropsychopharmacology 21 (2011) 655–679, https://doi.org/10.1016/j.euroneuro.2011.07.018.
[8] K. Friston, The free-energy principle: a unified brain theory? Nat. Rev. Neurosci. 11 (2010) 127–138, https://doi.org/10.1038/nrn2787.
[9] O. Van den Bergh, M. Witthöft, S. Petersen, R.J. Brown, Symptoms and the body: taking the inferential leap, Neurosci. Biobehav. Rev. 74 (2017) 185–203, https://doi.org/10.1016/j.neubiorev.2017.01.015.
[10] M. Witthöft, A.-K. Bräscher, S.M. Jungmann, F. Köteles, Somatic symptom perception and Interoception, Z. Psychol. 228 (2020) 100–109, https://doi.org/10.1027/2151-2604/a000403.
[11] L. Crucianelli, A. Enmalm, H.H. Ehrsson, Interoception as independent cardiac, thermosensory, nociceptive, and affective touch perceptual submodalities, Biol. Psychol. 172 (2022) 108355, https://doi.org/10.1016/j.biopsycho.2022.108355.
[12] E. Ferentzi, T. Bogdány, Z. Szabolcs, B. Csala, Á. Horváth, F. Köteles, Multichannel investigation of Interoception: sensitivity is not a generalizable feature, Front. Hum. Neurosci. 12 (2018) 223, https://doi.org/10.3389/fnhum.2018.00223.
[13] S.N. Garfinkel, M.F. Manassei, M. Engels, C. Gould, H.D. Critchley, An investigation of interoceptive processes across the senses, Biol. Psychol. 129 (2017) 371–372, https://doi.org/10.1016/j.biopsycho.2017.08.010.
[14] O. Desmedt, O. Luminet, P. Maurage, O. Corneille, Discrepancies in the Definition and Measurement of Interoception: A Comprehensive Discussion and Suggested Ways Forward, 2022.
[15] S.N. Garfinkel, A.K. Seth, A.B. Barrett, K. Suzuki, H.D. Critchley, Knowing your own heart: distinguishing interoceptive accuracy from interoceptive awareness, Biol. Psychol. 104 (2015) 65–74, https://doi.org/10.1016/j.biopsycho.2014.11.004.
[16] J. Murphy, C. Catmur, G. Bird, Classifying individual differences in interoception: implications for the measurement of interoceptive awareness, Psychon. Bull. Rev. 26 (2019) 1467–1471, https://doi.org/10.3758/s13423-019-01632-7.
[17] C. Suksasilp, S.N. Garfinkel, Towards a comprehensive assessment of interoception in a multi-dimensional framework, Biol. Psychol. 168 (2022) 108262, https://doi.org/10.1016/j.biopsycho.2022.108262.
[18] M.R. Tünte, T.M. Petzke, S. Brand, J. Murphy, M. Witthöft, S. Hoehl, M. Weymar, C. Ventura-Bort, He who seeks finds (Bodily Signals): differential effects of self-reported interoceptive attention and accuracy on subclinical psychopathology in a german sample, in preparation (2022).
[19] S. Brand, T.M. Petzke, M. Witthöft, The differential relationship between self-reported interoceptive accuracy and attention with psychopathology, Z. Klin. Psychol. Psychother. 51 (2022) 165–175, https://doi.org/10.1026/1616-3443/a000678.
[20] S. Brand, A.C. Meis, M.R. Tünte, J. Murphy, J.P. Woller, S.M. Jungmann, M. Witthöft, S. Hoehl, M. Weymar, C. Hermann, C. Ventura-Bort, A multi-site German validation of the interoceptive accuracy scale and its relation to psychopathological symptom burden, Commun. Psychol. 1 (2023) 501, https://doi.org/10.1038/s44271-023-00016-x.
[21] J. Murphy, R. Brewer, D. Plans, S.S. Khalsa, C. Catmur, G. Bird, Testing the independence of self-reported interoceptive accuracy and attention, Q. J. Exp. Psychol. 73 (2020) 115–133, https://doi.org/10.1177/1747021819879826.
[22] E. Gabriele, R. Spooner, R. Brewer, J. Murphy, Dissociations between self-reported interoceptive accuracy and attention: evidence from the interoceptive attention scale, Biol. Psychol. 168 (2022) 108243, https://doi.org/10.1016/j.biopsycho.2021.108243.
[23] D.A. Trevisan, W.E. Mehling, J.C. McPartland, Adaptive and maladaptive bodily awareness: distinguishing interoceptive sensibility and interoceptive attention from anxiety-induced somatization in autism and alexithymia, Autism Res. Off. J. Int. Soc. Autism Res. 14 (2021) 240–247, https://doi.org/10.1002/aur.2458.
[24] L. Emanuelsen, R. Drew, F. Köteles, Interoceptive sensitivity, body image dissatisfaction, and body awareness in healthy individuals, Scand. J. Psychol. 56 (2015) 167–174, https://doi.org/10.1111/sjop.12183.
[25] V. Ainley, M. Tsakiris, Body conscious? Interoceptive awareness, measured by heartbeat perception, is negatively correlated with self-objectification, PLoS One 8 (2013) e55568, https://doi.org/10.1371/journal.pone.0055568.
[26] E. Ferentzi, F. Köteles, B. Csala, R. Drew, B.T. Tihanyi, G. Pulay-Kottlár, B. K. Doering, What makes sense in our body? Personality and sensory correlates of body awareness and somatosensory amplification, Personal. Individ. Differ. 104 (2017) 75–81, https://doi.org/10.1016/j.paid.2016.07.034.
[27] C. Wolters, A.L. Gerlach, A. Pohl, Interoceptive accuracy and bias in somatic symptom disorder, illness anxiety disorder, and functional syndromes: a systematic review and meta-analysis, PLoS One 17 (2022) e0271717, https://doi.org/10.1371/journal.pone.0271717.
[28] K.L. Adams, A. Edwards, C. Peart, L. Ellett, I. Mendes, G. Bird, J. Murphy, The association between anxiety and cardiac interoceptive accuracy: a systematic review and meta-analysis, Neurosci. Biobehav. Rev. 140 (2022) 104754, https://doi.org/10.1016/j.neubiorev.2022.104754.
[29] O. Desmedt, M. Van den Houte, M. Walentynowicz, S. Dekeyser, O. Luminet, O. Corneille, How Does Heartbeat Counting Task Performance Relate to Theoretically-Relevant Mental Health Outcomes? A Meta-Analysis vol. 8, Psychology, Collabra, 2022, https://doi.org/10.1525/collabra.33271.
[30] A. Pohl, A.-C. Hums, G. Kraft, F. Köteles, A.L. Gerlach, M. Witthöft, Cardiac interoception: a novel signal detection approach and relations to somatic symptom distress, Psychol. Assess. 33 (2021) 705–715, https://doi.org/10.1037/pas0001012.
[31] L.J. Simms, A.G.C. Wright, D. Cicero, R. Kotov, S.N. Mullins-Sweatt, M. Sellbom, D. Watson, T.A. Widiger, J. Zimmermann, Development of measures for the hierarchical taxonomy of psychopathology (HiTOP): a collaborative scale development project, Assessment 29 (2022) 3–16, https://doi.org/10.1177/10731911211015309.
[32] D. Watson, H.F. Levin-Aspenson, M.A. Waszczuk, C.C. Conway, T. Dalgeish, M. N. Dretsch, N.R. Eaton, M.K. Forbes, K.T. Forbush, K. Hobbs, G. Michelini, B. D. Nelson, M. Sellbom, T. Slade, S.C. South, M. Sunderland, I. Waldman, M. Witthöft, A. Wright, R. Kotov, R.F. Krueger, HiTOP Utility Workgroup, Validity and utility of Hierarchical Taxonomy of Psychopathology (HiTOP): III. Emotional dysfunction superspectrum, World Psychiatr. 21 (2022) 26–54.
[33] R. Kotov, R.F. Krueger, D. Watson, T.M. Achenbach, R.R. Althoff, R.M. Bagby, T. A. Brown, W.T. Carpenter, A. Caspi, L.A. Clark, N.R. Eaton, M.K. Forbes, K. T. Forbush, D. Goldberg, D. Hasin, S.E. Hyman, M.Y. Ivanova, D.R. Lynam, K. Markon, J.D. Miller, T.E. Moffitt, L.C. Morey, S.N. Mullins-Sweatt, J. Ormel, C. J. Patrick, D.A. Regier, L. Rescorla, C.J. Ruggero, D.B. Samuel, M. Sellbom, L. J. Simms, A.E. Skodol, T. Slade, S.C. South, J.L. Tackett, I.D. Waldman, M. A. Waszczuk, T.A. Widiger, A.G.C. Wright, M. Zimmerman, The hierarchical taxonomy of psychopathology (HiTOP): a dimensional alternative to traditional nosologies, J. Abnorm. Psychol. 126 (2017) 454–477, https://doi.org/10.1037/abn0000258.
[34] A.E. Kazak, Editorial: journal article reporting standards, Am. Psychol. 73 (2018) 1–2, https://doi.org/10.1037/amp0000263.
[35] ETUDE, ESR1 Study 1, Open Science Framework, 2022.
[36] F.D. Schönbrodt, M. Perugini, At what sample size do correlations stabilize? J. Res. Pers. 47 (2013) 609–612, https://doi.org/10.1016/j.jrp.2013.05.009.
[37] R. Schandry, Heart beat perception and emotional experience, Psychophysiology 18 (1981) 483–488, https://doi.org/10.1111/j.1469-8986.1981.tb02486.x.
[38] D.J. Leiner, SoSci Survey, 2019.
[39] I.B.M. Corp, IBM SPSS Statistics for Windows, IBM Corp, Armonk, NY, 2017.
[40] R Core Team, R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria, 2013.
[41] J.A.S.P. Team, JASP (Version 0.16.4)[Computer software], 2022. https://jasp-stats.org/.
[42] R Core Team, foreign: Read Data Stored by 'Minitab', 'S', 'SAS', 'SPSS', 'Stata', 'Systat', 'Weka', 'dBase', 2022. https://CRAN.R-project.org/package=foreign.
[43] Y. Rosseel, Lavaan an R package for structural equation modeling, J. Stat. Softw. 48 (2012), https://doi.org/10.18637/jss.v048.i02.
[44] W. Revelle, Psych: Procedures for Psychological, Psychometric, and Personality Research, Evanston, Illinois, 2022. https://CRAN.R-project.org/package=psych.
[45] J.G. Snodgrass, J. Corwin, Pragmatics of measuring recognition memory: applications to dementia and amnesia, J. Exp. Psychol. Gen. 117 (1988) 34–50, https://doi.org/10.1037/0096-3445.117.1.34.
[46] N.A. Macmillan, C.D. Creelman, Detection Theory: A user's Guide, 2nd ed, Lawrence Erlbaum Associates Publishers, Mahwah, NJ, US, 2005.
[47] A.F. Jarosz, J. Wiley, What are the odds? A practical guide to computing and reporting Bayes factors, J. Probl. Solving 7 (2014), https://doi.org/10.7771/1932-6246.1167.

[48] M. Witthöft, S. Fischer, F. Jasper, F. Rist, U.M. Nater, Clarifying the latent structure and correlates of somatic symptom distress: a bifactor model approach, Psychol. Assess. 28 (2016) 109–115, https://doi.org/10.1037/pas0000150.

[49] M. Witthöft, W. Hiller, N. Loch, F. Jasper, The latent structure of medically unexplained symptoms and its relation to functional somatic syndromes, Int. J. Behav. Med. 20 (2013) 172–183, https://doi.org/10.1007/s12529-012-9237-2.

[50] S.P. Reise, The rediscovery of Bifactor measurement models, Multivar. Behav. Res. 47 (2012) 667–696, https://doi.org/10.1080/00273171.2012.715555.

[51] E. Ferentzi, R. Drew, B.T. Tihanyi, F. Köteles, Interoceptive accuracy and body awareness - temporal and longitudinal associations in a non-clinical sample, Physiol. Behav. 184 (2018) 100–107, https://doi.org/10.1016/j.physbeh.2017.11.015.

[52] J. Körmendi, E. Ferentzi, F. Köteles, Expectation predicts performance in the mental heartbeat tracking task, Biol. Psychol. 164 (2021) 108170, https://doi.org/10.1016/j.biopsycho.2021.108170.

[53] S. Krautwurst, A.L. Gerlach, L. Gomille, W. Hiller, M. Witthöft, Health anxiety—an indicator of higher interoceptive sensitivity? J. Behav. Ther. Exp. Psychiatry 45 (2014) 303–309, https://doi.org/10.1016/j.jbtep.2014.02.001.

[54] S. Rachman, Health anxiety disorders: a cognitive construal, Behav. Res. Ther. 50 (2012) 502–512, https://doi.org/10.1016/j.brat.2012.05.001.

[55] American Psychiatric Association, Diagnostic and Statistical Manual of Mental Disorders, American Psychiatric Association, 2013.

[56] O. Van den Bergh, J. Brosschot, H. Critchley, J.F. Thayer, C. Ottaviani, Better safe than sorry: a common signature of general vulnerability for psychopathology, Perspect. Psychol. Sci. 16 (2021) 225–246, https://doi.org/10.1177/1745691620950690.

[57] O. Desmedt, A. Heeren, O. Corneille, O. Luminet, What do measures of self-report interoception measure? Insights from a systematic review, latent factor analysis, and network approach, Biol. Psychol. 169 (2022) 108289, https://doi.org/10.1016/j.biopsycho.2022.108289.

[58] L. Vig, F. Köteles, E. Ferentzi, Questionnaires of interoception do not assess the same construct, PLoS One 17 (2022) e0273299, https://doi.org/10.1371/journal.pone.0273299.

[59] S.N. Garfinkel, M.F. Manassei, G. Hamilton-Fletcher, Y. In den Bosch, H. D. Critchley, M. Engels, Interoceptive dimensions across cardiac and respiratory axes, Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci. 371 (2016), https://doi.org/10.1098/rstb.2016.0014.

[60] Z. van Dyck, C. Vögele, J. Blechert, A.P.C. Lutz, A. Schulz, B.M. Herbert, 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 (2016) e0163574, https://doi.org/10.1371/journal.pone.0163574.

[61] V. Pitron, J.V. Haanes, L. Hillert, F.G. Köteles, D. Léger, C. Lemogne, S. Nordin, R. Szemerszky, I. van Kamp, C. van Thriel, M. Witthöft, O. Van den Bergh, Electrohypersensitivity is always real, Environ. Res. 218 (2022) 114840, https://doi.org/10.1016/j.envres.2022.114840.

[62] M. Csikszentmihalyi, R. Larson, Validity and reliability of the experience-sampling method, in: M. Csikszentmihalyi (Ed.), Flow and the Foundations of Positive Psychology, Springer, Netherlands, Dordrecht, 2014, pp. 35–54.

[63] J.W. Pennebaker, G.L. Brittingham, Environmental and sensory cues affecting the perception of physical symptoms, Adv. Environ. Psychol. 4 (1982) 115–136.

[64] J.G.M. Rosmalen, C. Burton, A. Carson, F. Cosci, L. Frostholm, N. Lehnen, T.C. Olde Hartman, C.U. Rask, J. Rymaszewska, J. Stone, L.M. Tak, M. Witthöft, B. Löwe, The European training network ETUDE (encompassing training in fUnctional disorders across Europe): a new research and training program of the EURONET-SOMA network recruiting 15 early stage researchers, J. Psychosom. Res. 141 (2021) 110345, https://doi.org/10.1016/j.jpsychores.2020.110345.