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Did my heart just leap or sink? The role of personality for the relation between cardiac interoception and well-being

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ABSTRACT

Interoceptive accuracy (IAc), the ability to perceive signals from within the body, has been linked to many beneficial health outcomes but also to psychopathologies such as anxiety disorders. Therefore, its relation to a person's subjective well-being (SWB) is unclear. Here, we predicted that individuals who are prone to interpreting interoceptive signals positively benefit from IAc and exhibit higher SWB. In contrast, individuals with predispositions towards negative interpretations suffer from it, resulting in lower SWB. Participants completed a measure of cardiac IAc, measures of extraversion, neuroticism, optimism and pessimism as personality traits that have been related to positive and negative attributional styles, and various measures of well-being. Psychiatric and physical well-being were predicted by the interaction between optimism/pessimism and IAc. While for optimistic participants, IAc did not predict higher well-being, for pessimistic individuals, it predicted lower well-being. These findings shed light on the role of interoception for SWB and its adaptiveness for individuals with different personalities.

1. Introduction

Interoception refers to the process by which the nervous system senses, interprets, and integrates signals originating from within the body, such as the heartbeat, breathing, or gastrointestinal signals (Khalsa et al., 2018). Garfinkel et al. (2015) recently proposed that interoception consists of three dimensions: Interoceptive accuracy (IAc; objective ability to detect interoceptive signals such as the heartbeat), interoceptive sensitivity (IS; subjective beliefs about one's IAc; assessed by questionnaires or confidence ratings), and the correspondence of both, interoceptive awareness (IAw).

Ample research has investigated the importance of especially cardiac IAc for various beneficial functions such as emotion perception/-regulation, self-regulation, or empathy (e.g., Barrett et al., 2004; Dunn et al., 2010; Füstös et al., 2012; Grynberg & Pollatos, 2015; Herbert et al., 2007; Weiss et al., 2014). Other studies found lower cardiac IAc in many psychopathologies, including anorexia nervosa, somatization disorder, depression, or autism (e.g., Dunn et al., 2007; Fischer et al., 2016; Garfinkel et al., 2016; Pollatos et al., 2008). These findings suggest that cardiac IAc is positively related to various physical and mental health indicators and well-being and have been summarized as the "adaptive view on IAc" (Bakal et al., 2008; Mehling et al., 2009).

However, there is also a "maladaptive view" based on studies showing enhanced cardiac IAc in anxiety or panic disorders, which negatively affects a person's well-being (Domschke et al., 2010; Paulus & Stein, 2006; Pollatos et al., 2007). While there is a wealth of evidence for both views, what is less understood is when IAc and well-being are positively or negatively related.

In case of cardiac IAC, perceiving one's heartbeat is an ambiguous event. Thus, it is implausible to assume that there would be a direct positive or negative relation between cardiac IAc and well-being. While people with high cardiac IAc might feel their heartbeat more frequently than others, from this it does not follow that they will interpret it more positively or negatively. Indeed, Herbert and Pollatos (2012) argued that feeling one's heartbeat can both be read as feedback that the organism is functioning well but also indicate that something is wrong with the organism. This suggests that moderators affecting how interoceptive signals are interpreted could determine how cardiac IAc and a person's well-being are related.

So far, only one study has investigated the relation between IAc and subjective well-being (SWB; Ferentzi, Horváth, & Köteles, 2019), showing no zero-order correlation between them. The present study

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goes beyond this in two ways. First, in addition to a measure of SWB, we assessed physical and psychiatric well-being to provide a more fine-grained view on the relation between well-being and cardiac IAc. Second, instead of investigating a linear association between cardiac IAc and well-being, we predict that for individuals who tend to interpret their interoceptive perceptions negatively, high cardiac IAc correlates with lower SWB. In contrast, for individuals who tend to interpret these experiences more positively by default, high cardiac IAc correlates with enhanced SWB. Two plausible determinants of whether these signals are interpreted positively or negatively are the personality trait pairs of extraversion/neuroticism and optimism/pessimism.

Extraversion and neuroticism are two personality traits of the "Big-Five" and one of their main definitional features historically has been their relation to positive and negative affect, respectively (Costa & McCrae, 1980). These relations can be explained by differenent explanatory styles. For example, Uziel (2006) demonstrated that when individuals high on these dimensions evaluate events, extraverts focus on positive aspects, whereas neurotics focus on the negative. Given the domain generality of these explanatory styles, for the present research, we assumed that an extraverted person will likely interpret interoceptive signals as something positive, whereas a neurotic likely will create a more negative explanation.

Similarly, optimism and pessimism describe stable expectations about the outcomes of life events (Scheier & Carver, 1985). These personality traits are also associated with specific explanatory or attributional styles. As summarized by Gillham et al. (2001), optimists tend to attribute positive things as internally caused, stable, and global, whereas pessimists tend to use the same set of attributes for negative events. Thus, also this personality trait pair predisposes an individual towards explaining life events in positive or negative ways, and we argue that due to the domain generality of these traits, the same applies to interoceptive signals.

We therefore predict that a person who is predisposed to interpret events positively (i.e., optimistic or extraverted people) and who perceives interoceptive signals more frequently (high IAc), will more frequently experience positive affect from interoceptive signals, which contributes to higher SWB. A person who experiences these signals often (high IAc) but interprets them negatively (i.e., pessimistic or neurotic individuals), on the other hand, will experience frequent negative affect resulting in lower SWB. Thus, the main hypothesis of this study was that these two personality traits and cardiac IAc would interactively predict SWB.

2. Methods

2.1. Open practices and power analysis

All analyses were pre-registered. The full data-analysis plan, data, and materials can be found at https://osf.io/7eu5a/. For our power analysis, the minimal effect size of interest was set to $R^2 = .09$ (a medium-sized correlation of $r = .30$). To be sensitive for such effects with a power of $(1\text{-}\beta) = .80$, $N = 82$ participants were needed. Since more resources were available, $N = 101$ participants were tested.

2.2. Materials and procedure

Participants were tested individually in a 35-min study that was run first in a 90-min session together with unrelated experiments (Erle & Topolinski, 2018) for a compensation of 10 Euro. Upon arrival, participants gave informed consent and completed a simple reaction time task (Erle, 2019), followed by the measures of interoception, personality, and SWB in this order.

2.2.1. Interoception

To measure participants' cardiac IAc, they completed a heartbeat-counting-task (HCT; Schandry, 1981). They were instructed to sit comfortably with both feet on the floor and both hands in their lap (what Schulz and Vögele (2015) call the "standard instruction for the task"). After adopting this position, they had to silently count the number of heartbeats they perceived in between to sounds without any aids (e.g., checking their pulse). For each trial, participants also rated how confident they were about their count. They first completed a training trial of 10s to familiarize them with this procedure, followed by four test trials (25 s, 35 s, 45 s, and 60 s). Concurrently, participants' actual number of heartbeats was measured using electrocardiography, acquired with a 16-channel amplifier (V-Amp, Brain Products GmbH, Gilching, Germany) at a sampling rate of 1000 Hz.

2.2.2. Personality traits

Participants completed the NEO-FFI (German version: Borkenau & Ostendorf, 1993) as a measure of Extraversion (exemplary item: "I often feel as if I'm bursting with energy.") and Neuroticism (exemplary item: "I often feel tense and jittery."). Extraversion is related to exhileration and an optimistic outlook. Neuroticism describes a predisposition towards tenseness and uncertainty (Borkenau & Ostendorf, 1993, p. 7). The NEO-FFI assesses these two constructs on 12-item scales. For every item the participants indicate on a scale from 1 ("very inaccurate") to 5 ("very accurate") how well it describes them.

They also completed the Life-Orientation-Test (LOT-R; German version: Glaesmer et al., 2008) as a measure of Optimism (exemplary item: "In uncertain times, I usually expect the best.") and Pessimism (exemplary item: "I hardly ever expect things to go my way."). The LOT-R assesses these two constructs on 3-item scales. Participants respond to all items on a scale from 1 ("I disagree a lot") to 5 ("I agree a lot").

2.2.3. Well-being

Participants completed a German translation of the Oxford Happiness Questionnaire (OHQ; Hills & Argyle, 2002), which comprises 29 items (rated on six-point rating scales; exemplary item: "I feel that life is very rewarding"). The OHQ served as a measure of global SWB. There are no test-norms for the OHQ.

Furthermore, they completed the Symptom Checklist 90-S (SCL-90-S; Franke, 2014), which is one of the most common instruments to assess physical and psychiatric symptom load in clinical practice (in Germany). Participants indicate how strongly they suffered from 90 physical and psychiatric symptoms during the last week on a scale from 0 ("not at all") to 4 ("very strongly"). These symptoms are grouped into categories, such as somatic symptoms (e.g., headaches, pain, vertigo, trembling etc.), but also psychiatric symptoms for all common diagnostic clusters (e.g., paranoid thinking as an indicator of psychosis, or feelings of hopelessness as an indicator of major depression). There are test norms from large representative samples for the frequency of all of these symptom clusters. Table 1 shows an overview over the sub-scales of the SCL—90S.

2.3. Sample

Participants were $N = 101$ individuals from Würzburg and its surrounding area ($n = 82$ female; $n = 18$ male; $n = 1$ missing: age: $M = 24.60$, $SD = 4.59$). Due to technical difficulties, $n = 4$ data points were lost. Additionally, we deviated from the pre-registration and excluded $n = 1$ participant who indicated unrealistically high heartrates (>400 heartbeats/min) during the heartbeat counting task (HCT). For $n = 10$ participants, IAw could not be computed as they always indicated the same level of IS. The final sample size thus was $N = 96$ for all analyses except IAw ($N = 86$). Sample means and reliabilities for all subscales on all questionnaires are displayed in Table 1.

Table 1
Participants' mean raw and normed scores (and standard deviations) and reliability of the questionnaires of this study.

Questionnaire and scale	Mean raw score	Mean normed score	Reliability (CR-α)
LOT-R optimism	8.30 (2.19)	48.72 (8.79)	.65
LOT-R pessimism	4.38 (2.52)	42.99 (8.82)	.73
LOT-R total scale	15.92 (4.20)	52.07 (10.81)	.79
NEO-FFI neuroticism	1.78 (0.65)	50.53 (9.96)	.84
NEO-FFI extraversion	2.42 (0.52)	53.13 (9.66)	.76
NEO-FFI openness	2.60 (0.60)	52.65 (11.36)	.80
NEO-FFI agreeableness	2.68 (0.55)	53.54 (12.39)	.81
NEO-FFI conscientiousness	2.80 (0.53)	51.68 (10.50)	.81
OHQ total scale	4.41 (0.59)	–	.89
SCL-90-S subscale additional items	4.13 (3.68)	–	.66
SCL-90-S subscale aggression/hostility	2.47 (2.50)	52.95 (9.11)	.59
SCL-90-S subscale anxiety	4.23 (4.48)	54.16 (8.91)	.81
SCL-90-S subscale compulsiveness	6.34 (5.17)	53.06 (8.99)	.81
SCL-90-S subscale depression	7.68 (6.34)	53.67 (7.90)	.84
SCL-90-S subscale paranoid thinking	2.37 (2.88)	50.32 (8.23)	.70
SCL-90-S subscale phobic anxiety	1.19 (1.92)	51.82 (8.26)	.54
SCL-90-S subscale psychoticism	2.41 (4.00)	51.80 (8.76)	.82
SCL-90-S subscale somatization	4.43 (4.26)	48.08 (8.81)	.75
SCL-90-S subscale social uncertainty	5.06 (4.82)	53.69 (8.94)	.81

Notes. Sample size for all statistics: $N = 100$. Normed scores are T-scores ($M = 50$; $SD = 10$).

3. Results

3.1. Data preparation and analysis

3.1.1. Predictors for confirmatory analyses

Cardiac IAc was calculated using the following formula and served as a predictor in all confirmatory analyses:

$$Cardiac\ IAc = \frac{1}{4} * \sum \left(1 - \frac{|recorded\ heartbeats - counted\ heartbeats|}{recorded\ heartbeats}\right)$$

Participants' raw scores on the personality measures were first transformed into normed scores. Then, difference scores between the normed extraversion/optimism and normed neuroticism/pessimism scores were calculated with higher scores indicating higher extraversion/optimism, compared to neuroticism/pessimism. Difference scores were calculated to depict whether a person is predominantly extraverted or neurotic. This was necessary as these personality traits are not two end-points of one construct, but rather distinguishable individual traits. Normed scores were used to inoculate our observed results against sample characteristicts. This normed difference describes whether a person is more likely to ascribe positive or negative meaning to events, both in relative to a norming sample and relative to the respective other explanatory style.

The same was done for the LOT-R (i.e., optimism and pessimism scores were normend and then subtracted), although there is also a total scale score for this measurement instrument. We decided against using the total scale score, because Glaesmer et al. (2008) questioned its reliability and demonstrated that the LOT-R clearly has a two-factorial structure. These difference scores were positively correlated, $r(94) = .67$, $p < .001$, but they were not combined, because a correlation of $r > .70$ (50% shared variance) was pre-registered as the threshold for this. Thus, both difference scores were added as separate predictors in all analyses.

3.1.2. Predictors for exploratory analyses

Participants' confidence ratings from the HCT were averaged as a measure of IS. IAw was computed as the correlation between IAc and IS across trials. Both were used in exploratory analyses.

3.1.3. Criteria for confirmatory analyses

Since there are no test norms for the OHQ, participants' mean scores on the OHQ served as the criterion for the first confirmatory analysis, with higher scores indicating higher global well-being.

As pre-registered, participants' raw scores on the sub-scales anxiety, somatization, and phobic anxiety of the SCL-90-S were transformed into normed scores and then averaged. We used these sub-scales in particular because they refer to symptoms that are associated with interoceptive perceptions. All the other scales refer to psychiatric problems such as hearing voices or anhedonia, which we did not deem immediately relevant for our hypothesis (but see below). Thus, this average score served as a measure of physical symptom load (with higher scores indicating lower physical well-being).

3.1.4. Criteria for exploratory analyses

As a measure of psychiatric symptom load, we also averaged their means of the other (more psychiatric) symptom subscales of the SCL-90S (see Table 1). This score was used as a criterion for exploratory analyses (with higher scores indicating lower psychiatric well-being).

3.1.5. Analysis

Since our regression model included interaction terms, all variables were z-standardized prior to analysis. The all predictors as well as interactions between them, were regressed on global and physical well-being for confirmatory, as well as psychiatric well-being for exploratory analyses. These regressions were repeated with IS and IAw for further exploratory analyses. We predicted significant two-way interactions between IAc and the two personality difference scores. Since there were $k = 7$ predictors, the alpha level for individual predictors was set to $\alpha = 0.05/7 = 0.007$ to avoid alpha inflation. Simple slopes for the confirmatory analyses were tested with one-tailed tests as pre-registered. The results of all regression analyses are summarized in Table 2.

3.2. Confirmatory analyses

3.2.1. Global well-being

For global well-being, the regression model explained a significant proportion of variance, $F(7, 88) = 29.86$, $p < .001$, $R^2 = .70$. The only significant predictors were the two personality difference scores and their interaction. In line with previous research (Hills & Argyle, 2002), extraverted participants exhibited higher SWB. Simple slope analyses indicated that this was true for both optimists and pessimists (simple slopes both $\beta > 0.37$, both $ts > 3.24$, both $ps \leq .002$), although the relationship was stronger for the latter.

3.2.2. Physical symptoms

For physical symptoms, the regression model explained a significant proportion of variance, $F(7, 88) = 4.28$, $p < .001$, $R^2 = .25$. Contrary to

Table 2
Regression results for all confirmatory and exploratory analyses including cardiac IAc.

	OHQ (global well-being)			SCL-90S (physical symptoms)			SCL-90S (psychiatric symptoms)		
Predictor	β	*t*	*p*	β	*t*	*p*	β	*t*	*p*
Intercept	0.14	1.86	.067	−0.06	−0.53	.597	−0.16	−1.50	.138
IAc	0.02	0.26	.792	0.22	1.79	.076	0.24	2.22	.029
OP-PE	0.26	2.96	.004	0.12	0.85	.398	0.13	1.03	.307
EX-NE	0.55	6.99	<.001	−0.43	−3.46	.001	−0.54	−4.79	<.001
IAc * OP-PE	0.25	0.55	.583	−0.39	−2.92	.005	−0.35	−2.91	.005
IAc * EX-NE	−0.02	−0.24	.814	0.13	1.04	.301	0.13	1.10	.275
OP-PE * EX-NE	−0.20	−3.03	.003	0.02	0.22	.827	0.19	1.98	.051

Notes. Sample size for all statistics: $N = 96$. All variables were z-standardized for the analyses. IAc = cardiac IAc. OP-PE = Optimism-Pessimism difference. EX-NE = Extraversion-Neutoricism difference. SCL-90S physical = score on the subscales scales anxiety, somatization, and phobic anxiety. SCL-90-S psychiatric = score on the remaining subscales of the SCL—90S. For details on all calculations, see Sections 2.2 and 3.2.

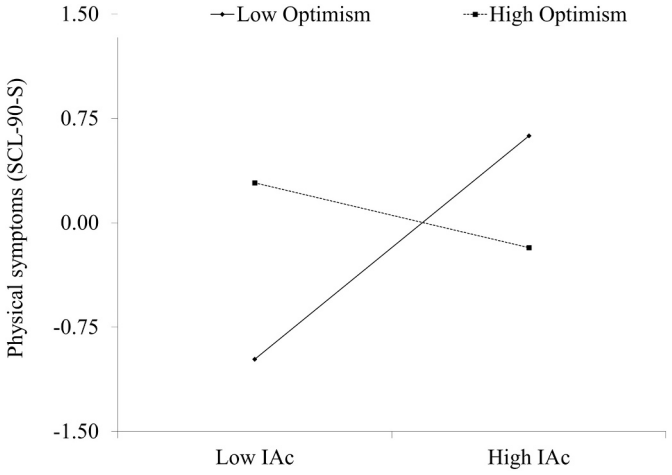

Fig. 1. Physical symptoms as a function of cardiac IAc and Optimism. Simple slopes are plotted at $M \pm 1$ *SD*.

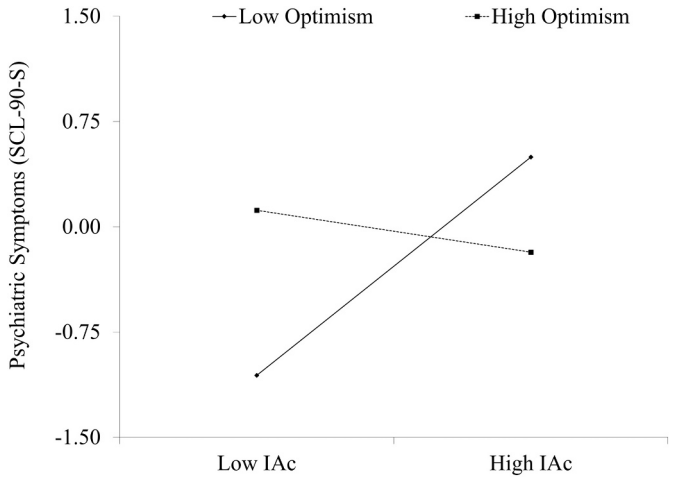

Fig. 2. Psychiatric symptoms as a function of cardiac IAc and Optimism. Simple slopes are plotted at $M \pm 1$ *SD*.

our expectation, there was no interaction between the Extraversion-Neuroticism difference and IAc.

For the Optimism-Pessimism difference, a significant interaction between Optimism-Pessimism and cardiac IAc was observed, see Fig. 1. In line with our hypothesis, for participants with low optimism, high cardiac IAc positively predicted the number of physical symptoms, that is, lower physical well-being, $\beta = 0.80$, $t = 3.01$, $p = .002$. For highly optimistic participants, the opposite was true, although non-significantly, $\beta = -0.23$, $t = -1.12$, $p = .132$.

3.3. Exploratory analyses

3.3.1. Interoceptive sensitivity and awareness

We also computed exploratory analyses, exchanging IAc with IS and IAw, respectively. These analyses were motivated by recent research showing a positive linear relation between IS and SWB (Ferentzi, Horváth, & Köteles, 2019). In our study, however, neither any main effect of IS, nor any interaction with this predictor significantly predicted any of the criteria for SWB (all $|\beta|$s < 0.13, all $|t|$s < 1.04, all $ps \geq .305$). The same was true for IAw (all $|\beta|$s < 0.24, all $|t|$s < 1.76, all $ps \geq .083$).

3.3.2. Psychiatric symptoms

As for physical symptoms, there was a significant interaction between cardiac IAc and the Optimism-Pessimism difference, see Table 2 and Fig. 2. For participants with low optimism, high cardiac IAc predicted more psychiatric symptoms (i.e., lower well-being), $\beta = 0.78$, $t = 3.31$, $p = .001$. For highly optimistic participants, the opposite was true, although non-significantly, $\beta = -0.15$, $t = -0.80$, $p = .428$.

4. Discussion

The main results of the present study are that, first, cardiac IAc was unrelated to participants' global well-being. Second, cardiac IAc positively predicted physical and psychiatric symptoms and thus lower physical and psychiatric well-being for predominantly pessimistic individuals, but there was no positive correlation for optimists. Third, although we assumed the same pattern for neurotic/extraverted individuals, we did not observe such an interaction. Finally, IS and IAw, as predicted, were unrelated well-being. These findings provide partial support for the predicted relations between cardiac IAc, SWB, and personality.

First, the results for global well-being did not confirm our hypothesis as only personality traits and not cardiac IAc predicted global well-being. In retrospect, the most likely explanation for this finding is that, as discussed by Kashdan (2004, p. 1225), "items of the OHQ tap into self-esteem, sense of purpose, social interest and kindness, sense of humor, and aesthetic appreciation". These dimensions are not affected by the proposed moderating mechanisms of the IAc-SWB relation. Sense of purpose, for example, seems unrelated to perceptions of interoceptive signals. Thus, future research should use measures that are more closely tied to the presently proposed mechanism to conclusively test the effects of IAc on global well-being.

Second, the impact on (psychiatric and physical) symptom load or well-being differed between extraversion/neuroticism and optimism/pessimism. Similarly to what was said for global well-being, a potential explanation for this discrepancy is that neuroticism and extraversion do not map as directly onto appraisals of life events as optimism and pessimism. While neuroticism and extraversion involve appraisals and

expectations, they encompass other aspects as well, such as assertiveness or sociability (see Borkenau & Ostendorf, 1993, p. 40). Optimism and pessimism, on the other hand, are exclusively tied to expectations and appraisals of live-events, and we suggest that future research should focus on optimism/pessimism.

Finally, the interactive effect of optimism/pessimism and cardiac IAc on physical and psychiatric well-being provided the strongest support for our hypothesis. These results indeed demonstrated that individuals with specific attributional styles for life events in general, also apply these styles to interoceptive perceptions. Especially pessimistic participants suffer from perceiving their heartbeat more frequently, that is, from higher IAc. Comparatively, optimists' physical and psychiatric well-being benefited less from higher IAc. There are two likely explanations for this asymmetry. First, our power analyses might have overestimated the effect sizes, and thus future studies should directly replicate our work with larger samples. Second, there is an inherent asymmetry between positive and negative life events as they relate to an organism's functioning. Based on the mobilization-minimization hypothesis (Taylor, 1991), negative events evoke stronger physiological, cognitive, and behavioral responses than positive or neutral events. Thus, potentially the proposed interaction is indeed not symmetric, but rather the detrimental effect of IAc is stronger than its beneficial counterpart.

However, there are also alternative explanations for these findings. For example, Murphy et al. (2019) recently proposed a model of interoceptive abilities that distinguishes between interoceptive accuracy and attention. Whereas accuracy comes close to IAc, attention refers only to how much an individual pays attention to interoceptive signals, independent of accuracy. Thus, alternatively, pessimists could simply pay more attention to interoceptive signals without any appraisal. While the present data speak against this explanation as there was no correlation between subjectively perceived heartbeats during the HCT and pessimism (all $rs < .23$, all $ps \geq .036$; Bonferoni-adjusted alpha, $p = .010$), it should be noted that our study was not designed to test this and further research is needed to conclusively reject this alternative explanation.

Our results also seemingly contradict the findings by Ferentzi, Horváth, and Köteles (2019), which found no relation between various indicators of IAc and SWB, but instead a positive correlation between IS and SWB. However, we believe that these findings can be reconciled. First, we also predicted no zero-order correlation between cardiac IAc and SWB and therefore, our results rather beg the question whether Ferentzi, Horváth, and Köteles (2019) would have observed the same interactions, had they measured optimism/pessimism. Second, while we assessed IS via confidence ratings during the HCT, Ferentzi, Horváth, and Köteles (2019) used the Body Awareness Questionnaire (BAQ; Shields et al., 1989). While confidence ratings are related to competency only in completing the HCT, the BAQ assesses more domain-general competency. Participants scoring high on the BAQ likely are generally confident, which might contribute to higher SWB. While plausible, this is independent of the present mechanism.

To reiterate, we predicted that high cardiac IAc increases the frequency with which heartbeats are perceived and that their meaning is subsequently construed, which we believe is guided by predispositions, resulting in higher/lower SWB. For this mechanism, neither subjective beliefs about one's cardiac IAc (our measure of IS), nor their correspondence to IAc (our measure of IAw) are relevant. But it should be noted that our measure of IAw was based on the correlation of only a few data points per participant, which questions the feasibility of this analysis and highlights the importance of future investigations on the role of IS and IAw in the present context.

Moving from basic to applied implications of our work, although obtained in healthy adults, our findings could be instrumental for clinical psychological research and practice. Many studies investigated whether it is possible to improve IAc, albeit with mixed results (e.g., Bornemann & Singer, 2017; Fischer et al., 2017). While additional research is needed to determine how trainable IAc is, in the light of the present findings, a more important question is whether such training is generally advisable. Training IAc could be a health resource or a risk factor, depending on who is trained. Pessimistic individuals, for example, should benefit from lower, rather than from additional attention to interoceptive signals as for these individuals higher IAc was related with higher symptom load.

However, higher symptom load could also be adaptive if participants who complain more often seek help. Due to its cross-sectional design, our study cannot answer this question. Future research with longitudinal follow-ups is needed to establish whether lower levels of physical and psychiatric well-being continue or whether eventually, well-being improves for participants with high cardiac IAc and pessimistic personalities. Thus, it is an important open research question to assess the effects of training IAc on well-being over time.

Despite contributing to interoception research on basic and applied levels, there are also noteworthy limitations of the present study. We already mentioned that the observed results are correlational in nature. It is alternatively possible that people with high symptom severity or low SWB develop specific personalities or that the presence of severe symptoms colors how a person views interoceptive signals. Similarly, we could have neglected theoretically important third variables that are also associated with the presently assessed personality traits. Such variables could provide alternative explanations for our results. Thus, experimental research is needed to clarify the exact roles of interoceptive processes for mental and physical health.

Finally, there is an ongoing debate about the validity of the HCT as a measure of interoception (Ring & Brener, 2018) as well as the validity of HCT scores (see Zamariola et al., 2018; but see also Zimprich et al., 2020). While it is probably the most used measure of IAc in interoception research, critics have argued that performance on the HCT is associated with variables other than cardiac IAc. For example, studies demonstrated that the HCT is affected by participants' ability to accurately estimate the time of HCT trials or beliefs about their heart rate (Ring et al., 2015; Ring & Brener, 1996). Given these concerns, it is important to conceptually replicate our research and to combine our multi-method approach to SWB with a multi-dimensional measurement of IAc, for example, following the protocol of Ferentzi, Horváth, and Köteles (2019), who, in addition to the HCT, also used measures of gastric and respiratory IAc.

These limitations notwithstanding, the present study tells a cautionary tale about the role of cardiac IAc for subjective health and well-being. Although nowadays, attention to one's body is recommended in many self-help books, the people who are most likely to seek self-help, those with a negative outlook on life, might be ill-advised to attend to their bodies. Clearly, more research on the causal mechanisms underlying the present results, their generalizability, and on the question of whether these findings might represent a precursor of future clinical problems is needed to warrant a universal call for more interoception.

CRediT authorship contribution statement

Thorsten M. Erle: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Vanessa Mitschke:** Methodology, Software, Validation, Investigation, Writing - review & editing, Supervision. **Dana Schultchen:** Conceptualization, Methodology, Resources, Writing - review & editing, Supervision.

Declaration of competing interest

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