Personality and Individual Differences 125 (2018) 14–20

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

Relationship between interoceptive accuracy, interoceptive sensibility, and alexithymia

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ARTICLE INFO

Keywords:
Bodily awareness
Interoceptive accuracy
Interoceptive sensibility
Alexithymia

ABSTRACT

Interoception is the ability to feel one's internal bodily sensations and it is related to emotional experience and the processing of emotional stimuli. Alexithymia is defined by difficulties in identifying and describing one's emotions and externally oriented thinking. Additionally, it is linked to impairments in emotional awareness and the regulation of emotions. It is largely assumed that alexithymia relates negatively both to subjective and objective interoception. However, evidence is scarce for the latter relation. The relationship between Interoceptive Accuracy (IAcc, as measured with the heartbeat tracking task), Interoceptive Sensibility (IS, self-report measure of interoception assessed via questionnaires), and alexithymia (i.e., TAS-20) was examined across ten studies (total $N = 998$). Results showed a weak negative correlation between alexithymia and IS but no correlation between alexithymia and IAcc.

1. Introduction

Early theories of emotions already suggested that interoception, i.e., the ability to feel internal bodily sensations, is a central antecedent of the conscious experience of emotions (Damasio, 1994; James, 1884). Herbert, Herbert, and Pollatos (2011) report findings that confirm that higher abilities in interoception are associated with greater intensity of emotional experience. Moreover, interoception has been linked to more detailed processing of emotionally arousing stimuli (Pollatos, Herbert, Matthias, & Schandry, 2007). Consistent with this view, past research has assumed a negative association between interoception and alexithymia. In the present research, we conducted a more comprehensive empirical test of the latter association. In the Introduction, we define subjective and objective abilities in interoception, as well as alexithymia and the links between these three constructs. We then report and discuss results collected across ten studies.

1.1. Interoception

Two components of interoception are distinguished for the purpose of the present research; Interoceptive Sensibility (IS) and Interoceptive Accuracy (IAcc). IS is the subjective, self-reported, measure of interoception. It assesses via questionnaires to which extent individuals report to perceive their internal sensations, such as their heartbeats, hunger, or respiration. In contrast, IAcc refers to people's objective ability in perceiving their internal (bodily) signals and states (Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015). The most widely used measure of IAcc is the heartbeat tracking task. In this task, individuals are asked to silently count their heartbeats, without taking their pulse. They are asked to do so for different time intervals (usually of 25, 35 and 45 s) and to report the number of counted heartbeats. Throughout the task, the actual number of heartbeats is recorded, allowing for performance measures and their further comparison to self-reported measures.

1.2. Alexithymia

Alexithymia is a personality construct that involves difficulties in identifying feelings, verbalizing them and an externally oriented thinking style. Alexithymia was originally introduced by Sifneos (1973) to indicate a group of cognitive and affective characteristics found in patients with psychosomatic disorders. This personality trait has been associated with a variety of somatic and psychiatric disorders, such as substance abuse disorders, posttraumatic stress disorder, somatoform disorders, panic disorder, depression, and eating disorders (Frewen, Dozois, Neufeld, & Lanius, 2008; Montebarocci et al., 2006; Taylor, Bagby, & Parker, 1999; Zackheim, 2007). Alexithymia is associated with deficits in the cognitive processing and regulation of emotions (Hsing, Hofelich Mohr, Brent Stansfield, & Preston, 2013; Laloyaux,

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https://doi.org/10.1016/j.paid.2017.12.024
Received 30 September 2017; Received in revised form 8 December 2017; Accepted 17 December 2017
Available online 21 December 2017

Fantini, Lemaire, Luminet, & Larøi, 2015; Lane et al., 1996) and is related to poor emotional awareness (Da Silva, Vasco, & Watson, 2017; Lane, 2000).

1.3. Theoretical links between interoception and alexithymia

Early theoretical models of alexithymia implied deficits in interoception, both at the subjective and objective levels (Taylor et al., 1999). For instance, the presence of high alexithymia was found in patients with eating disorders who, according to classic conceptual models (Bruch, 1973), are characterized by interoceptive deficits. Likewise, the presence of alexithymia and low interoception is reported in depression (Honkalampi, Hintikka, Tanskanen, Lehtonen, & Viinamäki, 2000).

The association between alexithymia and interoception is also illustrated in the original construction of the TAS-20 (see Taylor et al., 1999, Chapter 3, p. 55). Five factors were initially involved, comprising a total of 41 items. A factor called "Difficulty in distinguishing between feelings and the bodily sensations that accompany states of emotional arousal" was originally included and, for the scale construction, four items were directly borrowed from the Interoceptive Awareness subscale of Eating Disorder Inventory (EDI; Garner, Olmstead, & Polivy, 1983). Even if later scale developments excluded these specific items, the original design of the TAS speaks to the conceptual link between alexithymia and interoceptive abilities.

More recent theoretical (Murphy, Brewer, Catmur, & Bird, 2017) and experimental (Brewer, Cook, & Bird, 2016; Herbert et al., 2011; Shah, Hall, Catmur, & Bird, 2016; Sowden, Brewer, Catmur, & Bird, 2016) work also relate alexithymia to poor interoception. As Murphy et al. (2017) recently noted: "alexithymia is a marker of atypical interoception" (p. 48). In addition to the studies mentioned above, neuropsychological research revealed the presence of a relationship between damages of the anterior insula and interoceptive impairment and alexithymia (e.g., Ibañez, Gleichgerrcht, & Manes, 2010). The anterior insula is a crucial brain area where interoceptive signals arising from the body merge, providing information on the bodily state. Insular cortex lesions can result in deficits in body awareness and difficulties in recognizing emotions.

Finally, another theoretical argument supporting the assumed negative link between alexithymia and interoception is the presence of alexithymia in different physical and psychiatric disorders, i.e., diabetes, obesity, eating disorders, and depression, in which low interoceptive abilities are also reported (e.g., Cochrane, Brewerton, Wilson, & Hodges, 1993; Herbert & Pollatos, 2014; Honkalampi et al., 2000; Pinna et al., 2011; Pollatos et al., 2008). Alexithymia and impaired interoception might be related to eleven disorders and symptoms highlighted in Caspi and colleagues' p-factor model: dependence from alcohol, cannabis, hard drugs, tobacco, conduct disorders, major depression, generalized anxiety disorder, fears and phobias, obsessive-compulsive disorder, mania, and positive and negative schizophrenia symptoms.

1.4. Empirical links between interoception and alexithymia

Whereas both original and contemporary work confidently point to a theoretical link between interoception and alexithymia, empirical evidence for such association, however, is scare and points to opposite directions. A co-occurrence of high alexithymia and high interoception has been reported in the literature. Specifically, anxiety may be characterized by high alexithymia and high interoceptive accuracy (Domschke, Stevens, Pfleiderer, & Gerlach, 2010). Interpretation of the latter association, however, is mitigated by the use of a heartbeat tracking task for assessing IAcc. Anxious individuals are highly focused on changes in their heartbeats to detect signals of alarm. Therefore, they may be good heartbeat perceivers, but this interoceptive advantage may not extend to other bodily sensations.

It is also worth underling that no relationship between alexithymia and IAcc was observed by Bornemann and Singer (2017). These authors found no correlation between the heartbeat tracking task and the TAS-20 at baseline. A significant negative relationship was only detected after a 9 months of contemplative mental training, which increased IAcc and decreased alexithymia.

Turning to supportive evidence, a study by Brewer et al. (2016) found alexithymia to be related to poor IS ($r = 0.43$, $p < 0.001$), assessed using two newly developed questionnaires (i.e., the Interoceptive Confusion Questionnaire and the State–Emotion Similarity Questionnaire). Studies by Herbert et al. (2011) and Shah et al. (2016) found alexithymia to be negatively correlated with IAcc, as measured by the heartbeat tracking task ($r = -0.37$, $p < 0.01$ and $r = -0.36$, $p = 0.025$ respectively). These supportive studies, however, present limitations, including the use of non-validated questionnaires and in some cases of very low sample sizes (only 38 participants in Shah et al., 2016).

Given the widespread assumption for a strong negative relation between interoception and alexithymia, and considering the important theoretical and practical implications of such association, it is most surprising that only a few empirical studies addressed this question. Of note too, and perhaps even more important, to the best of our knowledge, no prior study explored this association using both objective and subjective measures of interoception. Considering the paucity of empirical data available, we decided to proceed to a more comprehensive and rigorous test of how both subjective and objective interoception is empirically linked to alexithymia. We did so by using larger samples and validated measures. Following previous theorization, we hypothesized a negative correlation (i) between alexithymia and interoceptive accuracy, as measured via the heartbeat tracking task, and (ii) between alexithymia and interoceptive sensibility, assessed with three different validated questionnaires. As a second step, we conducted regression analyses in order to explore the independent contributions of IAcc and IS to alexithymia.

2. Method

2.1. Participants

All participants were students at two Belgian Universities, one in the French-speaking part and one in the Dutch-speaking part of the country. They were all recruited using a Facebook page dedicated to paid studies at the Psychology research institute or using advertisements at the Faculty. All participants were tested one-by-one. Table 1 provides an overview of the descriptive statistics of the sample and measures used in each study. The studies received the approval from the Ethics Committee of both research institutes.

2.2. Material and measures

2.2.1. Heartbeat tracking task

Participants' heart rate was assessed using the Polar Watch RS800CX heart monitor (which derives heart rate from the placement of the wrists on electrode areas) or via ECG measurement (NeXus-10, Mind Media B.V.). Polar products have been used in previous studies, showing excellent validity and reliability in measuring heart rate and R-R interval data (e.g. Kingsley, Lewis, & Marson, 2005; Nunan et al., 2008; Quintana, Heathers, & Kemp, 2012; Weippert et al., 2010). Following the well-validated Mental Tracking Method by Schandry (1981), data were recorded during three randomly presented time intervals (25 s, 35 s, 45 s), each separated by a pause of 20 s. The software Polar ProTrainer5 or custom made R-peak detection Matlab scripts were used to extract the actual number of heartbeats. One acoustic start cue was presented at the beginning of each time interval and another acoustic stop cue indicated the end of the interval. Throughout the experiment, they were instructed to silently count their own heartbeats. At the end of each time interval, participants were asked to verbally report how

Table 1
Descriptive statistics of the whole sample.

Study	Sample size	Language spoken	Mean age (SD)	Females (%)	Males (%)	Measures
1	99	French	22.25 (4.84)	50 (50.5)	49 (49.5)	IAcc, TAS-20
2	158	French	21.85 (3.52)	118 (74.7)	40 (25.3)	IAcc, BAQ, TAS-20
3	157	French	22.24 (2.94)	118 (75.2)	39 (24.8)	IAcc, BAQ, TAS-20
4	64	Dutch	22.76 (4.46)	42 (65)	22 (35)	MAIA, TAS-20
5	48	Dutch	21.91 (3.58)	33 (69)	15 (31)	MAIA, TAS-20
6	151	Dutch	20.05 (4.64)	130 (86)	21 (14)	MAIA, TAS-20
7	161	Dutch	20.03 (5.16)	126 (78)	35 (22)	IAQ, TAS-20
8	59	Dutch	21.38 (4.74)	49 (78.5)	10 (21.5)	IAcc, IAQ, TAS-20
9	56	Dutch	20.37 (2.40)	42 (73.4)	14 (26.6)	IAcc, IAQ, TAS-20
10	45	Dutch	19.86 (3.43)	27 (58.9)	18 (41.1)	IAcc, IAQ, TAS-20
Total	998		21.27	735 (73.6)	263 (26.3)	

Note.
IAcc = Interoceptive Accuracy.
BAQ = Body Awareness Questionnaire.
TAS-20 = Toronto Alexithymia Scale.
MAIA = Multidimensional Assessment of Interoceptive Awareness.
IAQ = Interoceptive Awareness Questionnaire.

many heartbeats they counted. No feedback on the length of the counting phases or the quality of their performance was given.

In order to quantify the IAcc from the heartbeat tracking task the following formula was used: $1/3 \Sigma (1 - (|\text{recorded heartbeats} - \text{counted heartbeats}|) / \text{recorded heartbeats})$. The interoceptive accuracy score can vary between 0 and 1, with higher scores indicating higher IAcc, and lower scores indicating lower IAcc.

2.2.2. Toronto Alexithymia Scale (Bagby, Parker, & Taylor, 1994)

The TAS-20 is the most psychometrically valid and commonly used self-report measurement of alexithymia. It is constituted of 20 items rated on a 5-point scale from strongly disagree to strongly agree. It includes three subscales: difficulties in identifying feelings (DIF), e.g., "I am often confused about what emotion I am feeling", difficulties in describing feelings (DDF), e.g., "It is difficult for me to find the right words for my feelings", and externally oriented thinking (EOT), e.g., "I prefer to just let things happen rather than to understand why they turned out that way". Both the full scale and the subscales were used in the analyses. The French (Loas, Fremaux, & Marchand, 1995) and Dutch (Kooiman, Spinhoven, & Trijsburg, 2002) versions of the questionnaire were used.

2.2.3. Body Awareness Questionnaire (Shields, Mallory, & Simon, 1989)

The BAQ is an 18-item scale developed to measure self-reported attentiveness to normal non-emotional body processes, i.e., sensitivity to body cycles and rhythms, ability to detect small changes in normal functioning, and ability to anticipate bodily reactions. Examples of items are: "I notice differences in the way my body reacts to various foods", "I notice distinct body reactions when I am fatigued", "I notice specific reactions to being overhungry". Responses to the 18 items are given on a Likert scale going from 1 (not at all true about me) to 7 (very true about me), resulting in one body awareness score. The French version of the questionnaire was used (Shankland, Guillaume, & Carré, 2016).

2.2.4. Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012)

This 32-item questionnaire is a multidimensional self-report measure of interoceptive body awareness. It includes eight subscales, which were treated separately in the analyses: 1) Noticing: awareness of uncomfortable, comfortable, and neutral body sensations, e.g., "When I am tense I notice where the tension is located in my body"; 2) Not-Distracting: tendency not to ignore or distract oneself from sensations of pain or discomfort, e.g., "I do not notice (I ignore) physical tension or discomfort until they become more severe" (reverse-scoring); 3) Not-Worrying: tendency not to worry or experience emotional distress with sensations of pain or discomfort, e.g., "When I feel physical pain, I become upset" (reverse-scoring); 4) Attention Regulation: ability to sustain and control attention to body sensations, e.g., "I can pay attention to my breath without being distracted by things happening around me"; 5) Emotional Awareness: awareness of the connection between body sensations and emotional states, e.g., "I notice how my body changes when I am angry"; 6) Self-Regulation: ability to regulate distress by attention to body sensations, e.g., "When I feel overwhelmed I can find a calm place inside"; 7) Body Listening: active listening to the body for insight, e.g., "I listen for information from my body about my emotional state"; 8) Trusting: experience of one's body as safe and trustworthy, e.g., "I am at home in my body". The Dutch version of the questionnaire was used (Courtois, 2012, retrieved from www.osher.ucsf.edu/maia/).

2.2.5. Interoceptive Awareness Questionnaire (IAQ, Bogaerts et al., in preparation)

This questionnaire aims to evaluate the discrepancy between interoceptive sensations of neutral and negative valence. It includes nineteen items divided in two subscales: 1) Awareness of neutral bodily sensations, e.g., "During physical activity I can always tell when my heart rate accelerates"; 2) Attention to unpleasant bodily sensations, e.g., "When I'm short of breath, I focus my attention on this". The two subscales were treated separately in the analyses. The Dutch version of the questionnaire was used (Bogaerts et al., in preparation). Table 2 displays reliability analyses (Cronbach's alphas) for each measure in each study.

2.3. Procedure

After signing the consent form, IAcc was assessed in studies 1, 2, and 3 and 8, 9, and 10. In a second step, participants were asked to complete the questionnaires. Finally, participants were fully debriefed on the purpose of the study and they received 5 euros or a credit course as compensation.[2] Table 1 summarizes all the measures used for each study.

[2] These data were collected in the framework of a study that used an experimental manipulation. The heartbeat tracking task, the TAS-20 the IAQ, and the MAIA were administered before the manipulation, therefore they are not influenced by it. The TAS-20 and the BAQ in studies 1, 2, and 3 were administered after, but analyses on the potential effect of the manipulation on these measures showed nonsignificant results.

Table 2
Cronbach's alphas of all the questionnaires used in the studies.

Studies scales	1	2	3	4	5	6	7	8	9	10
IAcc	0.93	0.89	0.93	–	–	–	–	0.89	0.88	0.88
BAQ	–	0.79	0.82	–	–	–	–	–	–	–
MAIA1	–	–	–	0.26	0.62	0.58	–	–	–	–
MAIA2	–	–	–	0.53	0.46	0.58	–	–	–	–
MAIA3	–	–	–	0.62	0.65	0.52	–	–	–	–
MAIA4	–	–	–	0.78	0.84	0.87	–	–	–	–
MAIA5	–	–	–	0.68	0.62	0.81	–	–	–	–
MAIA6	–	–	–	0.71	0.75	0.79	–	–	–	–
MAIA7	–	–	–	0.86	0.78	0.82	–	–	–	–
MAIA8	–	–	–	0.89	0.85	0.84	–	–	–	–
IAQ_F1	–	–	–	–	–	–	0.72	0.64	0.74	0.67
IAQ_F2	–	–	–	–	–	–	0.71	0.64	0.71	0.67
DIF	0.73	0.76	0.75	0.83	0.75	0.85	0.80	0.75	0.79	0.79
DDF	0.77	0.73	0.79	0.83	0.84	0.78	0.73	0.80	0.74	0.78
EOT	0.59	0.62	0.59	0.22	0.45	0.53	0.58	0.65	0.51	0.67
TOT	0.80	0.77	0.80	0.82	0.81	0.84	0.79	0.82	0.71	0.78

Note.
IAcc = Interoceptive Accuracy.
BAQ = Body Awareness Questionnaire.
MAIA = Multidimensional Assessment of Interoceptive Awareness.
1. Noticing: Awareness of uncomfortable, comfortable, and neutral body sensations.
2. Not-Distracting: Tendency not to ignore or distract oneself from sensations of pain or discomfort.
3. Not-Worrying: Tendency not to worry or experience emotional distress with sensations of pain or discomfort.
4. Attention Regulation: Ability to sustain and control attention to body sensations.
5. Emotional Awareness: Awareness of the connection between body sensations and emotional states.
6. Self-Regulation: Ability to regulate distress by attention to body sensations.
7. Body Listening: Active listening to the body for insight.
8. Trusting: Experience of one's body as safe and trustworthy.
IAQ – F1: Interoceptive Awareness Questionnaire - Awareness of neutral bodily sensations.
IAQ – F2: Interoceptive Awareness Questionnaire - Attention to unpleasant bodily sensations.
DIF = Toronto Alexithymia Scale, Difficulty Identifying Feelings.
DDF = Toronto Alexithymia Scale, Difficulty Describing Feelings.
EOT = Toronto Alexithymia Scale, Externally Oriented Thinking.
TOT = Toronto Alexithymia Scale, Total score.

3. Results

3.1. Relationship between IAcc, IS, and alexithymia

3.1.1. Correlation analyses

Correlational analyses on the relation between IAcc and the TAS-20 across six studies revealed no significant associations (all $p > 0.05$), as shown in Table 3. Pearson correlations between the BAQ and the TAS-20 in studies 2 and 3 ($n = 316$) showed a significant negative correlation between the BAQ and the subscales DDF ($r = -0.15$, $p = 0.01$), EOT ($r = -0.22$, $p < 0.001$), and alexithymia total scores ($r = -0.20$, $p < 0.001$), as displayed in Table 4. Correlational analyses in studies 4, 5 and 6 where the MAIA was used as measures of IS, revealed the presence of a significant negative relationship between the TAS-20 (three subscales and total score) and the eight subscales of the MAIA. As shown in Table 5, the strongest correlations were found for the subscales "Not-Worrying", "Attention Regulation", and "Trusting". Lastly, results from studies 7, 8, 9, and 10 where the IAQ was administered, showed a variety of findings. Study 7 revealed a positive correlation between Attention to unpleasant bodily sensations and DIF ($r = 0.22$, $p = 0.01$) and a negative correlation between Awareness of neutral bodily sensations and DDF ($r = -0.16$, $p = 0.04$) and EOT ($r = -0.29$, $p < 0.001$). On the contrary, the correlational analysis on studies 8, 9 and 10 revealed only the presence of a negative correlation between Awareness of neutral bodily sensations and the total TAS-20 score ($r = 0.18$, $p = 0.01$), as shown in Table 6.

Table 4
Correlations between alexithymia (subscales and total scores), IAcc, and Interoceptive Sensibility (measured by the BAQ) in studies 2 and 3.

	Study 2 BAQ $n = 158$	Study 3 BAQ $n = 157$	Studies 2 + 3 BAQ $n = 316$
DIF	− 0.08	− 0.06	− 0.07
DDF	− 0.11	− 0.17*	− 0.15*
EOT	− 0.23**	− 0.15	− 0.22**
TOT	− 0.19**	− 0.15	− 0.20**
IAcc	0.23**	0.16*	0.18*

Note.
DIF = Toronto Alexithymia Scale, Difficulty Identifying Feelings.
DDF = Toronto Alexithymia Scale, Difficulty Describing Feelings.
EOT = Toronto Alexithymia Scale, Externally Oriented Thinking.
TOT = Toronto Alexithymia Scale, Total score.
IAcc = Interoceptive Accuracy.
BAQ = Body Awareness Questionnaire.
** $p < 0.001$.
* $p < 0.05$.

3.1.2. Regression analyses

IAcc and BAQ total scores in studies 2 and 3 were entered in a hierarchical regression to check, first, the contribution of IAcc and, second, the contribution of IS. Four regression analyses were performed with IAcc and IS as independent predictors and DIF, DDF, EOT, and the total score of the TAS as dependent variables. Results indicated that the BAQ significantly predicted DDF ($\beta = -0.17$, $p = 0.003$), EOT ($\beta = -0.22$, $p < 0.001$), and the total TAS score ($\beta = -0.21$, $p < 0.001$), but not DIF ($\beta = -0.08$, $p = 0.15$). On the contrary, IAcc

Table 3
Correlations between alexithymia (subscales and total scores) and IAcc in studies 1 to 3 and 8 to 10.

	Study 1 IAcc $n = 99$	Study 2 IAcc $n = 158$	Study 3 IAcc $n = 157$	Studies 1 + 2 + 3 IAcc $N = 414$	Study 8 IAcc $n = 59$	Study 9 IAcc $n = 56$	Study 10 IAcc $n = 45$	Studies 8 + 9 + 10 IAcc $N = 160$
DIF	− 0.12	0.14	− 0.12	− 0.02	− 0.10	− 0.09	− 0.09	− 0.09
DDF	− 0.14	0.10	0.03	0.01	− 0.09	0.04	0.13	0.01
EOT	0.04	− 0.10	− 0.003	− 0.04	0.01	0.02	0.10	0.03
TOT	− 0.10	0.07	− 0.05	− 0.02	− 0.08	− 0.03	0.06	− 0.03

Note.
DIF = Toronto Alexithymia Scale, Difficulty Identifying Feelings.
DDF = Toronto Alexithymia Scale, Difficulty Describing Feelings.
EOT = Toronto Alexithymia Scale, Externally Oriented Thinking.
TOT = Toronto Alexithymia Scale, Total score.
IAcc = Interoceptive Accuracy.
** $p < 0.001$.
* $p < 0.05$.

Table 5
Correlations between alexithymia subscales and total score, and Interoceptive Sensibility (measured by the eight MAIA subscales 1 = Noticing, 2 = Not-Distracting, 3 = Not-Worrying, 4 = Attention Regulation, 5 = Emotional Awareness, 6 = Self-Regulation, 7 = Body Listening, 8 = Trusting) in studies 4, 5, and 6.

Studies 4 + 5 + 6 (n = 263)	1	2	3	4	5	6	7	8
DIF	− 0.20**	− 0.17**	− 0.45**	− 0.32**	0.02	− 0.28**	− 0.11	− 0.40**
DDF	− 0.10	− 0.06	− 0.15*	− 0.20*	− 0.05	− 0.20**	− 0.21**	− 0.26**
EOT	− 0.23**	0.03	− 0.09	− 0.20**	− 0.19**	− 0.16**	− 0.24**	− 0.20**
TOT	− 0.23**	− 0.11	− 0.33**	− 0.33**	− 0.07	− 0.28**	− 0.23**	− 0.39**

Note.
DIF = Toronto Alexithymia Scale, Difficulty Identifying Feelings.
DDF = Toronto Alexithymia Scale, Difficulty Describing Feelings.
EOT = Toronto Alexithymia Scale, Externally Oriented Thinking.
TOT = Toronto Alexithymia Scale, Total score.
MAIA = Multidimensional Assessment of Interoceptive Awareness.
1. Noticing: Awareness of uncomfortable, comfortable, and neutral body sensations.
2. Not-Distracting: Tendency not to ignore or distract oneself from sensations of pain or discomfort.
3. Not-Worrying: Tendency not to worry or experience emotional distress with sensations of pain or discomfort.
4. Attention Regulation: Ability to sustain and control attention to body sensations.
5. Emotional Awareness: Awareness of the connection between body sensations and emotional states.
6. Self-Regulation: Ability to regulate distress by attention to body sensations.
7. Body Listening: Active listening to the body for insight.
8. Trusting: Experience of one's body as safe and trustworthy.
** $p < 0.001$.
* $p < 0.05$.

Table 6
Correlations between alexithymia (subscales and total scores), IAcc, and Interoceptive Sensibility (measured by the IAQ) in studies 7, 8, 9, and 10.

	Study 7 IAQ F1/F2 n = 161	Study 8 IAQ F1/F2 n = 59	Study 9 IAQ F1/F2 n = 56	Study 10 IAQ F1/F2 n = 45	8 + 9 + 10 IAQ F1/F2 n = 160
DIF	0.07/0.22**	− 0.05/ 0.04	− 0.18/0.15	− 0.17/ 0.18	− 0.14/0.13
DDF	− 0.16*/ − 0.03	− 0.07/ − 0.17	− 0.08/ − 0.02	− 0.21/ − 0.17	− 0.12/ − 0.11
EOT	− 0.29**/ − 0.13	− 0.01/ 0.12	− 0.14/ − 0.22	− 0.22/ − 0.11	− 0.13/ − 0.07
TOT	− 0.14/0.06	− 0.06/ − 0.01	− 0.21/0.03	− 0.29*/ − 0.02	− 0.18*/ − 0.01
IAcc		0.39**/ − 0.14	− 0.03/ − 0.32**	0.11/0.06	0.16*/ − 0.14

Note.
DIF = Toronto Alexithymia Scale, Difficulty Identifying Feelings.
DDF = Toronto Alexithymia Scale, Difficulty Describing Feelings.
EOT = Toronto Alexithymia Scale, Externally Oriented Thinking.
TOT = Toronto Alexithymia Scale, Total score.
IAcc = Interoceptive Accuracy.
IAQ – F1: Interoceptive Awareness Questionnaire - Awareness of neutral bodily sensations.
IAQ – F2: Interoceptive Awareness Questionnaire - Attention to unpleasant bodily sensations.
** $p < 0.001$.
* $p < 0.05$.

was never a significant predictor of alexithymia.

In studies 8, 9, and 10, four hierarchical regression analyses were conducted with IAcc (first step), the factor Awareness of neutral bodily sensations of IAQ (second step), and the factor Attention to unpleasant bodily sensations of IAQ (third step) as predictors and DIF, DDF, EOT, and the total score of the TAS as dependent variables. Results revealed that the Awareness of neutral bodily sensations factor of IAQ significantly predicted EOT ($\beta = -0.16$, $p = 0.04$) and the total TAS score ($\beta = -0.17$, $p = 0.03$), but not DIF ($\beta = -0.06$, $p = 0.41$) and DDF ($\beta = -0.13$, $p = 0.11$). Conversely, the Attention to unpleasant bodily sensations factor and IAcc were not significant predictors of alexithymia.

3.2. Relationship between IAcc and IS

In order to examine if objective and subjective measures of interoception were related, analyses focused on the correlation between IAcc and IS. In studies 2 and 3, a relatively weak but significant positive correlation between IAcc and the BAQ was found ($r = 0.18$, $p = 0.001$). Additionally, analysis on the relationship between IAcc and the IAQ in studies 8, 9, and 10 showed a relatively weak positive correlation between Awareness of neutral bodily sensations and IAcc ($r = 0.16$, $p = 0.04$).

4. Discussion

The aim of the present study was to investigate the relationship between interoceptive accuracy, interoceptive sensibility, and alexithymia. As explained in the Introduction, this association is strongly assumed in both early and contemporary theorizing on alexithymia, but evidence for it has been relatively scarce and inconclusive, so far. The present research endeavor provided a more rigorous and comprehensive test for these associations. Results revealed a weak positive correlation between objective and subjective components of interoception. More precisely, a positive correlation was found between IAcc and the BAQ and the factor Awareness of neutral bodily sensations of the IAQ related to the Awareness of neutral bodily sensations. Findings additionally revealed that self-reported alexithymia correlates negatively with self-reported interoception (IS), but not with the objective measure (IAcc). In particular, the strongest correlation were found between alexithymia (total score and subscales) and the subscales Not-Worrying, Attention Regulation, and Trusting of the questionnaire MAIA. This finding might suggest that individuals with high alexithymia focus less on their body sensations, while they tend to be more sensitive to pain and discomfort. Moreover, they lack of self-confidence in their bodily signals, reporting to not feel their body as trustworthy. An important implication raised by this finding might be to promote a training among alexithymic people aimed to increase the attention and confidence related to internal states.

Regarding the IAQ, a negative correlation was found between the subscales DDF, EOT, and the total score of the TAS-20 and the factor Awareness of neutral bodily sensations. In other words, individuals with high alexithymia, specifically with a difficulty in describing their

feelings and externally oriented thinking, show deficits in their ability of being aware of neutral bodily sensations. Interestingly, a positive correlation between the subscale DIF and the factor Attention to unpleasant bodily sensations of the IAQ was also found, revealing that individuals with difficulties in identifying feelings pay more attention to negative sensations arising from the body, such as pain. This is in line with previous studies on alexithymia and pain perception which highlighted that the pain threshold is lower in individuals who score high in DIF, thus suggesting a hypersensitivity towards negative symptoms (Huber, Suman, Biasi, & Carli, 2009; Nyklíček & Vingerhoets, 2000).

The present findings question the assumed relationship between interoception and alexithymia, at least at the objective level. This result speaks against the idea that alexithymia is a marker of poor interoception (Murphy et al., 2017) and fails to provide support to the 'p-factor' hypothesis (Caspi et al., 2014). Even if at the theoretical level this association seems valid and plausible, the data collected here failed to support it. This may either suggest that theoretical assumptions are invalid or that the measures used here lacked sensitivity for validating these hypotheses.

If the first interpretation is correct (i.e., faulty theorization), it would suggest that high alexithymia scorers have difficulties in identifying emotions, but do not experience deficits in recognizing their internal bodily states. Alternatively, it may be that they believe they are not able to feel the internal sensations at the subjective level (IS), while in practice they are at the objective level (IAcc).

If the second account is correct (i.e., faulty measurement), new and more advanced techniques should be implemented. For instance, high alexithymia scorers may have no deficit in heartbeats detection but may experience other types of interoceptive deficits, such as in respiration or gastro-intestinal functioning. Another possibility is that interoceptive deficits are limited to clinical groups; that is, to individuals scoring higher than 61 on the TAS-20. Finally, while the present research involved subjective and objective measure of interoception, alexithymia was examined only through self-reports. Therefore, another important endeavor for future research is to develop a performance measure of alexithymia and/or to use observer-rating scales, such as the Toronto Structured Interview for Alexithymia (TSIA; Bagby, Taylor, Parker, & Dickens, 2006). In addition, alternative ways of measuring IAcc should be explored (see Murphy, Catmur, & Bird, 2017 for new tests), since the mental tracking method, even if widely used, has been criticized (e.g., potential influence of beliefs about one's resting heart rate; Ring, Brener, Knapp, & Mailloux, 2015).

5. Conclusion

In conclusion, we found here a weak negative association between alexithymia and subjective interoception, and no association between alexithymia and objective interoceptive performance. This suggests that high alexithymia scorers tend to underestimate their interoceptive abilities, while they show no actual interoceptive deficit. Alternatively, such deficits may be limited to clinical groups or may be operating on bodily sensations different from those examined here (or both). Because of the critical theoretical and practical implications of these research questions, it is important that future research addresses associations between alexithymia and interception using different operationalization of the current constructs.

Acknowledgements

This research was supported by an Excellence research grant funded by the Walloon region (Belgium), (FOOD4GUT: Innovative nutrition research on obesity based on colic nutriments. Biological, behavioral and societal aspects, project # 1318148).

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