Review

Differentiating attention styles and regulatory aspects of self-reported interoceptive sensibility

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Based on prior research, multiple discriminable dimensions of interoception have been defined: awareness, accuracy and sensibility. Some investigators defined *interoceptive awareness* as metacognitive awareness of interoceptive accuracy, assessed as correspondence between subjective confidence in and objective accuracy of one's heartbeat detection. However, metacognitive awareness has been understood quite differently: 'a cognitive set in which negative thoughts/feelings are experienced as mental events, rather than as the self' or as 'error awareness'. *Interoceptive sensibility*, defined as self-reported interoception, distinguishes self-reported interoception from objective *interoceptive accuracy*, but does not differentiate between anxiety-driven and mindful attention styles towards interoceptive cues, a distinction of key clinical importance: one attention style is associated with somatization and anxiety disorders; the other has been viewed as healthy, adaptive, resilience-enhancing. The self-report Multidimensional Assessment of Interoceptive Awareness was developed to differentiate these attention styles. It has been translated into 16 languages and applied in cross-sectional and longitudinal studies. Findings from these applications suggest that differentiating interoceptive sensibility according to attention style and regulatory aspects (i) provides insights into the psychology of interoceptive awareness, (ii) differentiates between clinically maladaptive and beneficial interoceptive attention, and (iii) helps elucidate therapeutic approaches that claim to provide health benefits by training mindful styles of bodily awareness.

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1. Introduction

To further scientific research and discourse, several well discriminable dimensions of interoception (e.g. awareness, accuracy and sensibility) have been defined through recently published taxonomies [1,2]. Yet, as different research groups approach interoception from quite different fields of research and experiential backgrounds, it comes as no surprise that we encounter various terminologies while we try to find a common language. For example, one group of investigators defined *interoceptive awareness* as metacognitive awareness of interoceptive accuracy, understood and assessed as the correspondence between subjective confidence in and objective accuracy of one's heartbeat detection [1]. However, metacognitive awareness is a difficult term and has been understood in different ways that barely overlap. From the viewpoint of psychologists interested in studies of the mind or working in behavioural clinical care, metacognitive awareness is commonly viewed as 'a cognitive set in which thoughts/feelings are experienced as mental events, rather than as the self' [3]. The term is a key concept in current psychotherapeutic approaches to chronic depression, anxiety and borderline personality disorder. These approaches are sometimes summarized as the so-called 'third wave of psychotherapy' [4] and include acceptance and commitment treatment, dialectical behavioural therapy, metacognitive therapy, mindfulness-based cognitive therapy (MBCT) and

others. Within these psychotherapeutic approaches, metacognitive awareness is understood as a mental condition that allows individuals to disidentify and disengage from their own emotions and related bodily feelings, enabling them to observe these as dynamic phenomena within their personal experience, without thinking or believing that these emotions and feelings are self-defining. It is a recognition, an awareness that one is aware of something, thus meta-awareness [5].

Conversely, when the term metacognition is used as defining (and operationalizing) the concept of *interoceptive awareness*, both are referred to as 'the correspondence between objective interoceptive accuracy and subjective report, i.e. metacognition, ... a quantified measure of the degree to which accuracy of (objective) heartbeat detection is predicted by subjective confidence in the task judgment, e.g. using area under an ROC curve' [1]. Metacognition in this context is viewed as 'error awareness' [6]. According to this view, interoceptive awareness—metacognition of interoceptive accuracy—is operationalized as the degree of error, the quantifiable difference between (i) self-reported judgement about one's interoceptive accuracy and (ii) objectively assessed interoceptive accuracy. The former is assessed by questionnaire, the latter, e.g. with the heartbeat tracking task. This may well be a useful quantification and operationalization of an aspect of interoceptive awareness, but it is substantially different from the more clinical psychological conceptualization of metacognitive awareness noted above and—most notably—stays conceptually bound to interoceptive accuracy.

The conceptualization of different aspects of interoception and the differentiation of interoceptive accuracy from interoceptive awareness is of major importance, as the earlier literature was relatively vague and potentially confusing regarding the term 'interoceptive awareness'. In 2004, in a seminal paper, Critchley *et al.* [7] used the term synonymously with what was later labelled interoceptive accuracy. In 2009, Bud Craig related the broad concept of human awareness to interoception and emotional awareness, which included feelings—a formulation that appears to be much broader than error awareness: 'all stimuli, incentives, intentions and cognitions that have salience are represented by feelings, a crucial neuropsychological construct composed of nested sets of integrative associations that are elaborated on an interoceptive template and endowed with characteristic homeostatic sequelae . . . . In this model, feelings are the computational common currency of awareness' [8, p. 68]. In the same article, Bud Craig explicitly refers to error awareness as just one element of awareness, which has been shown to be processed in the insula [9,10] and which appears to be intriguingly close to the way Sarah Garfinkel *et al.* [1] recently conceptualized the construct they labelled interoceptive awareness. In the author's view, their conceptualization of interoceptive awareness could potentially be operationalized as the complement of error awareness and might, therefore, be more appropriately labelled 'interoceptive confidence'.

To the author, the error awareness definition thus represents quite a radical reduction of a much broader, multidimensional construct, which in other publications has been defined as 'the conscious perception of sensations from inside the body that create the sense of the physiological condition of the body, such as heartbeat, respiration, satiety, and the autonomic nervous system sensations related to emotions', but also pain and sensual touch [11]. Sensations include symptoms of an underlying medical condition when they are disease-related. The author's broad conceptualization includes key behavioural and cognitive aspects well known in perception and psychological pain research, such as appraisal and beliefs (e.g. catastrophizing), attention regulation (e.g. ignoring, distraction), behaviour (e.g. acceptance and avoidance; coping styles), future anticipation, and past experience and experiential impressions associated with and modifying perceptions from inside the body [11]. The apparent multi-dimensionality of this latter definition—a definition that includes regulatory aspects of interoception and choices in attentional styles—does not easily map onto a single quantitative objective measure. The psychological context in which we process stimuli from the internal milieu shapes our perception and how we relate and respond to these stimuli. Attention regulation, skills in applying attention regulation for sensations that we experience (Self-Regulation), a context of Trusting and a willingness to 'Listen to Body Sensation' for behavioural decisions, may be—and have been—summarized as regulatory aspects of interoception, by which we recognize, organize, make sense of, respond to and use these sensations [12].

However, the inclusive, multidimensional definition appears to be closer to what the formerly quoted renowned research group labelled as *interoceptive sensibility* and defined as self-reported interoception, gauged using interviews or questionnaires [1,13]. Interestingly, originating in British philosophical, scientific and—later—literary writing, the term *sensibility* has its own history and—importantly—its own ambiguity: at times 'considered a physical and/or emotional *fragility*, sensibility was also widely perceived as a *virtue*' [14,15]. Although clearly helpful in offering a much needed distinction between self-reported interoception and objective *interoceptive accuracy*, the term interoceptive sensibility is still ambiguous and does not differentiate clearly an anxiety and hypervigilance-driven attention style (associated with emotional fragility) versus a more mindful attention style (potentially a virtue) towards interoceptive cues. Yet, this particular distinction appears to be of key importance to clinical care, as one attention style is associated with hypochondriasis, somatization and anxiety disorders (very well exemplified in the items of Steven Porges' Body Perception Questionnaire, 1993; PBPQ) [16], whereas another attention style has been viewed as healthy, adaptive and resilience-enhancing [13,17–21]. The term 'sensibility' encompasses both attention styles and may have to be disambiguated for the needs of clinical psychologists. Perceptions, be they exteroceptive or interoceptive, are powerfully regulated by psychological processes [22] which include a variety of attention processes [5] now known to be reflected in distinct brain activities [23,24].

The self-report Multidimensional Assessment of Interoceptive Awareness (MAIA) was systematically developed to help differentiate beneficial and maladaptive attention styles [11]. Since its publication in November 2012, it has been translated into 16 languages (http://www.osher.ucsf.edu/maia/) and applied in numerous cross-sectional and longitudinal studies. This paper reviews some of the findings from published and unpublished applications. The review is narrative and attempts to explore the following three questions: can differentiating interoceptive sensibility according to attention style and regulatory aspects (i) provide valuable insights into the psychology of interoceptive awareness [12],

(ii) differentiate between clinically maladaptive and beneficial interoceptive attention, and (iii) potentially aid in understanding therapeutic approaches that claim to provide benefits for various health conditions by training a mindful style of bodily awareness. A more comprehensive systematic review has to be postponed at this time, as several interesting studies, in which the MAIA was applied, are still awaiting publication.

The MAIA was developed in a stepwise process through reviewing the current literature [17], specifying a multidimensional conceptual framework analysing input from focus groups, evaluating prior instruments, and developing items by instructors and patients of body awareness-enhancing therapies [25]. Subsequently refined by cognitive interviews, items were field-tested in students and instructors of mind–body approaches and in participants of a cohort study with primary care patients followed up 2 years after a new episode of low back pain. Field test data were submitted to an iterative process using multiple validation methods, including exploratory and confirmatory factor analyses, comparison between known groups, and correlations with established measures of related constructs [11]. The resulting 32-item multidimensional instrument is composed of eight scales: (i) Noticing: the awareness of uncomfortable, comfortable and neutral bodily sensations; (ii) Not-Distracting: the tendency to not ignore or distract oneself from sensations of pain or discomfort; (iii) Not-Worrying: the tendency to not react with emotional distress or worry to sensations of pain or discomfort; (iv) Attention Regulation: the ability to sustain and control attention to bodily sensation; (v) Emotional Awareness: the awareness of the connection between bodily sensations and emotional states; (vi) Self-Regulation: the ability to regulate psychological distress by attention to bodily sensations; (vii) Body Listening: actively listening to the body for insight; and (viii) Trusting: experiencing one's body as safe and trustworthy (table 1).

One key motivation for the development of the MAIA was the clinical necessity of being able to distinguish—at least by self-report—between beneficial and maladaptive forms of interoceptive sensitivity. To this end the scale Noticing can be viewed as a scale that does not distinguish between these polar aspects of interoceptive sensibility, similar to earlier measures of bodily awareness [17]. Emotional Awareness may also be ambiguous if it is not positively interacting with Self-Regulation and Trusting. Distraction from unpleasant chronic symptoms has been viewed as a nonmindful style of attention and as maladaptive [26–28]. Worry is closely associated with anxiety and hypervigilance, whereas higher scores in Attention Regulation, Self-Regulation, Body Listening and Trusting may reflect beneficial, more mindful styles of attention to, and self-regulation of, interoceptive symptoms.

2. Validation studies

Following the original validation in two samples [11,29] the MAIA has been applied in numerous studies which have provided data on *convergent and discriminatory validity* with various standard questionnaires. Validation studies of the original English language version have included: Revised NEO Personality Inventory (NEO PI-R. BR[*1]); Checklist Generalized Anxiety Disorder (BR*); Checklist Panic

Disorder (BR*); Checklist Social Anxiety Symptoms (BR*); Checklist Obsessive Compulsive Disorder Symptoms (BR*); Defense Style Questionnaire (DSQ; [30]. BR*); Toronto Alexithymia Scale (TAS-20) (BR*; MA*); Glasgow Sensory Questionnaire (GSQ) (MA*); Somatosensory Amplification Scale (SAS. MA*); Autism Quotient (AQ. MA*); Pain Catastrophizing Scale (PCS. GT*); Attachment styles by Experiences in Close Relationships Revised (ECR-R; [31]. LE*); Demographics of Adverse Childhood Experiences Study (ACE; [32]. LE*); Spielberger State-Trait Anxiety Inventory (STAI; [33]. M-BN*); Beighton clinical exploration of hypermobility ([34]. M-BN*). For the German version, convergent and discriminatory validity were assessed by the Five Factor Mindfulness Inventory (FFMQ; [35]); STAI-T from the State-Trait Anxiety Questionnaire [33]; and Private Body Consciousness Scale [12,36]. For the Polish version, construct validity was assessed with the Body Awareness Questionnaire (BAQ; [37]); the Physical Self-Description Questionnaire [38]; and the Body Attitude Test [39,40]. The Persian version used positive affect and fear of injury (AM*). The Swedish version used the Attachment Style Questionnaire (ASQ) and EuroQol Quality of Life Questionnaire (EQ-5D. NV*). The Italian version used the Emotional Susceptibility Scale [41,42].

A consistent key finding from these construct validity examinations is that the MAIA scales are differentially correlated with trait anxiety measures: Emotional Awareness shows the weakest correlation with trait anxiety, while Attention Regulation, Not-Worrying and Trusting exhibit the strongest negative correlations. In the German sample, correlations between trait anxiety and Noticing, Emotional Awareness and Body Listening were all between $r = -0.10$ and 0.10. Mallorqui-Baque *et al.* [13] reported negative correlations between Attention Regulation or Trusting and state anxiety with associations being amplified in individuals with greatest state anxiety. The construct, assessed by the MAIA, is clearly not positively related to anxiety or anxiety-associated hypervigilance. This is important, as historically, heightened bodily awareness was viewed in medical settings as an undesired and problematic patient characteristic associated with somatization and hypochondriasis [43] and previous studies often used proxy-measures of anxiety as self-report measures for interoceptive sensibility (review in [17]).

Data on *internal consistency reliability* are also available from numerous studies for the original English MAIA and its Spanish, German, Hebrew, Italian, Polish, Chinese and Persian versions. These studies strongly agree that two of the eight MAIA scales have relatively weak Cronbach's alphas: Not-Distracting and Not-Worrying, often between 0.60 and 0.70 and at times even lower. Cronbach's alpha is strongly dependent on the number of scale items, and these two scales are the shortest with only three items each. For the six items of these two scales, five are the only reverse-scored MAIA items. Effort is currently underway to improve these scales. However, despite their low internal consistency, the positive construct validity results suggest that these scales should not be dismissed: they have shown strong associations with several validity scales and have been able to distinguish between known subgroups of primary care pain patients [29].

Factor analyses have been conducted for the Spanish [44], German [12], Italian [42], Persian [45] and Chinese [46] versions and generally confirmed the eight-factor structure of

Table 1. MAIA scales and items.

Noticing

    1. When I am tense I notice where the tension is located in my body.

    2. I notice when I am uncomfortable in my body.

    3. I notice where in my body I am comfortable.

    4. I notice changes in my breathing, such as whether it slows down or speeds up.

Not-Distracting

    5. I ignore physical tension or discomfort until they become more severe.[a]

    6. I distract myself from sensations of discomfort.[a]

    7. When I feel pain or discomfort, I try to power through it.[a]

Not-Worrying

    8. When I feel physical pain, I become upset.[a]

    9. I start to worry that something is wrong if I feel any discomfort.[a]

    10. I can notice an unpleasant body sensation without worrying about it.

Attention Regulation

    11. I can pay attention to my breath without being distracted by things happening around me.

    12. I can maintain awareness of my inner bodily sensations even when there is a lot going on around me.

    13. When I am in conversation with someone, I can pay attention to my posture.

    14. I can return awareness to my body if I am distracted.

    15. I can refocus my attention from thinking to sensing my body.

    16. I can maintain awareness of my whole body even when a part of me is in pain or discomfort.

    17. I am able to consciously focus on my body as a whole.

Emotional Awareness

    18. I notice how my body changes when I am angry.

    19. When something is wrong in my life I can feel it in my body.

    20. I notice that my body feels different after a peaceful experience.

    21. I notice that my breathing becomes free and easy when I feel comfortable.

    22. I notice how my body changes when I feel happy/joyful.

Self-Regulation

    23. When I feel overwhelmed I can find a calm place inside.

    24. When I bring awareness to my body I feel a sense of calm.

    25. I can use my breath to reduce tension.

    26. When I am caught up in thoughts, I can calm my mind by focusing on my body/breathing.

Body Listening

    27. I listen for information from my body about my emotional state.

    28. When I am upset, I take time to explore how my body feels.

    29. I listen to my body to inform me about what to do.

Trusting

    30. I am at home in my body.

    31. I feel my body is a safe place.

    32. I trust my body sensations.

[a]Reversed scored items. All items scored on scale from 0 for 'never' to 5 for 'always' in response to: 'Indicate how often each statement applies to you generally in daily life'.

the MAIA, using established fit indices Root Mean Square Error of Approximation (RMSEA) and Comparative Fit Index (CFI; table 2). However, we can expect that in non-English languages a few items will load differently according to cultural differences [44], which will have to be further explored in future studies.

Scale–scale intercorrelations reported from German, Persian, Italian and Spanish versions reached values of up to 0.57 [42,45], 0.62 [12], and 0.68 [44] for a few of these correlations. The highest value in the original English version was published as 0.60 [11]. However, for the original MAIA the pattern of correlations with validity measures was explored

Table 2. Fit Indices of Confirmatory Factor Analyses. RMSEA, Root Mean Square Error of Approximation; CFI, Comparative Fit Index; SRMR, Standard Root Mean Square Residual.

	factors	n	sample	RMSEA	CFI	SRMR
English original	8	325	mind–body experienced	0.060	0.886	0.056
German	8	1076	healthy volunteers	0.059	0.901	n.a.
Spanish	8	470	healthy volunteers	0.056	0.905	0.059
Italian	8	321	university students	0.023	0.974	0.057
Persian	8	425	university students	0.072	0.940	0.067
Chinese	8	294	healthy volunteers	0.065	0.940	n.a.

in detail, and it was shown that the MAIA scales differentially correlated with scales of other constructs [11], an approach that was also taken for the German [12] and Italian [42] versions.

3. The heartbeat detection task and self-reported interoceptive sensibility

Is interoceptive sensibility as assessed by the MAIA or other self-report instruments related to interoceptive accuracy? Until recently, several cross-sectional and longitudinal [47] studies comparing meditators with non-meditators were unable to find differences in the heartbeat detection task. However, two recent and not yet fully published longitudinal studies reportedly found such an association [48]. As interoceptive awareness is purportedly trained in mindfulness approaches, and as the heartbeat detection task was historically often thought of as an objective measure for interoceptive awareness—rather than interoceptive accuracy—some researchers had expected that the MAIA scales would be associated with the heartbeat detection task. Numerous efforts have been made to determine their expected correlations [42,49]. In the study by Cali *et al.* [42], the interoceptive accuracy score assessed by the heartbeat tracking task was weakly but statistically significantly correlated with only one MAIA scale: Attention Regulation ($r = 0.20$, $p = 0.02$, $n = 135$). All other scales were not correlated (r between −0.10 and 0.10). Similarly and consistently, none of the published or not yet peer-reviewed or fully published attempts have shown a clear correlation between heartbeat detection accuracy and MAIA scales [42,49] (unpublished data, personal communication by Adam Middleton, Glasgow, UK, 2014; Carolyn Durlik, London, UK, 2014; Boris Bornemann, Leipzig/Berlin, Germany, 2016; Camilla Valenzuela Moguillansky, Valparaiso, Chile, 2016). Interoceptive accuracy as measured by the heartbeat detection task apparently does not relate to parameters assessed with the MAIA. However, it needs to be noted that the only published data for this comparison from the study by Cali *et al.* [42] showed—similar to other studies [50]—relatively poor mean accuracy scores between 0.5 and 0.6 for the heartbeat tracking task, estimating the heart rate more than 40% lower than the actual rate.

These findings are in line with studies that did not apply the MAIA but assessed interoceptive accuracy and interoceptive sensibility, 'an individual's personal account of how they experience internal sensations'. Interoceptive sensibility is viewed by their authors [1] as a 'subjective, self-evaluated

characterological trait (from questionnaire measures) to be interoceptively focused'. Sarah Garfinkel *et al.* explicitly addressed this question—among other relationships—in a study comparing heartbeat tracking and discrimination with interoceptive sensibility assessed using the awareness section of the PBPQ [16] in healthy university staff and students. The PBPQ has been applied in the past in numerous interoception studies as a general self-report measure of interoceptive awareness or sensibility. On a five-point scale from 'never' to 'always', this questionnaire solicits statements to 45 symptoms: 'During most situations I am aware of: e.g. swallowing frequently; my mouth being dry; my skin itching; an urge to urinate; sweat in my armpits; feeling constipated', and others, virtually all of which are anxiety or distress-related symptoms. Self-rated sensibility did not independently predict interoceptive accuracy. Correlation coefficients between questionnaire-based interoceptive sensibility (here the Awareness section of the PBPQ) and heartbeat tracking or discrimination task measures were $r = 0.06$ and 0.006, respectively [1]. Similarly, Fairclough and Goodwin [51] reported a $r = −0.03$ correlation with the Awareness section but found a correlation of $r = 0.45$ between the Autonomic Nervous System Reactivity section of the PBPQ and the auditory Whitehead method for heartbeat perception. Correlations appear to be inconsistent, as Schulz *et al.* [52] found a correlation of $r = 0.31$ between the PBPQ scale 'Awareness' and one method of heartbeat perception, the Whitehead visual, but not with the Whitehead auditory or Schandry method, and no correlation of any of these methods with Autonomic Reactivity, whereas Hugo Critchley *et al.* [7] found no correlation of heartbeat perception with either scale. To the author's knowledge, no study correlated the MAIA scales with the PBPQ, which at face value appears to be a proxy measure for anxiety and anxiety-related hypervigilance rather than a measure for potentially beneficial interoceptive skills.

To the author's knowledge, other modalities of interoception, e.g. for respiratory or gastrointestinal symptoms and sensations, have not been explored in any similar way. In studies of these modalities, the assessment measures could best be conceptualized as measuring interoceptive accuracy. Within interoceptive accuracy, a distinction has been made between measuring the *detection threshold* for the lowest perceptible intensity of a sensation, e.g. pressure from an inflatable balloon in the gastrointestinal tract or resistances in the airways, and measuring the *ability to discriminate* between different intensities [53–55].

If a measure such as the PBPQ only assesses the trait of perceptual awareness of anxiety-related bodily symptoms, it may be questionable in its appropriateness and usefulness

to quantify interoceptive sensibility, unless we define interoceptive sensibility as a one-dimensional construct, comparable to a single dimension and the first MAIA scale, Noticing, although the PBPQ does not include any items assessing potentially beneficial aspects of bodily awareness or bodily symptoms associated with positive emotions. This lack of any correlation does not come as a surprise at all, as nobody would expect that—if such comparison may be permitted—visual acuity would have anything to do with our trait of seeing a glass as half empty.

4. The value of differentiating dimensions within the construct of interoceptive sensibility

In a study by Boris Bornemann et al. [12] self-reported interoceptive sensibility was assessed longitudinally. The study showed that several aspects of this construct are modifiable by an intervention that trains individuals in bodily and breath awareness through 'Breathing Meditation' and a 'Body Scan'. Interoceptive bodily awareness was viewed as an individual's capacity, a skill that can be trained by mind–body-focused interventions, rather than as a characterological personality trait. Compared to controls, they found differential changes over time in specific dimensions of interoceptive sensibility measured by the MAIA scales. Scores for the MAIA scale most similar to the PBPQ, Noticing, showed the least growth from that training. It needs to be noted, however, that Noticing is not assessing anxiety-related symptom perception, as detailed below. The finding that the Noticing scale did not change with the intervention may indicate that observed changes were not due to desirability bias. The strongest changes were seen in Self-Regulation, measured by a four-item scale for the ability to regulate psychological distress by attention to bodily sensations (for items, see table 1). Scores for Attention Regulation, the ability to sustain and control attention to bodily sensation, had the second-largest growth. Between-group Cohen-d effect sizes were 0.72 and 0.56, respectively. The practices employed in this study appeared to have strengthened the participants' abilities to direct their attention towards their bodies (Attention Regulation) and led them to make use of these abilities to regulate distress (Self-Regulation). In line with other studies that correlated the MAIA scales with measures for trait anxiety [11,13,29], all MAIA scales were either negatively or not correlated with trait anxiety.

The multi-dimensionality of the MAIA allowed testing which aspects of interoceptive awareness or sensibility are primarily affected by the type of interoceptive, body-focused meditation training intervention in the study of Bornemann et al. [12]. Participants showed no changes on the Noticing scale for the subjective evaluation of the ability to accurately perceive bodily events, a kind of undifferentiated general assessment of interoceptive sensibility. However, the study showed moderate to large changes (Cohen's $d = 0.40-0.72$) for the interoceptive sub-components of Self-Regulation, Attention Regulation and Body Listening, which collectively could be described as regulatory aspects and skills of interoceptive awareness or as attention styles of interoceptive sensibility. In the development of the MAIA scales, focus groups had defined several other dimensions as aspects of interoceptive bodily awareness, two of which also showed positive changes over time: a heightened sense of awareness

of the connection between bodily and emotional states (Emotional Awareness), the basis for the deliberate use of the body for insight and decision-making (captured in the Body Listening scale), and a higher sense of trust in one's own body, i.e. experiencing one's body as a safe place and its sensations as trustworthy, indicated by increases on the MAIA Trusting scale.

Differentiating attention styles towards pain is a topic of major discussion in the pain research literature and appears to be of major clinical importance. Pain is an element of interoception [56], and modifying one's attention style towards that object of interoception has been shown to be of key importance in the trajectory of pain and in pain management [57–61]. Comparing MAIA scale scores from a cohort of primary care patients who had experienced low back pain with those from a group of mind–body therapy-trained individuals showed the largest difference in the Non-Distracting scale. The pain patients apparently saw more value in a distraction style of coping with pain and discomfort. Conversely, yoga and/or meditation-trained individuals may have learned a new coping style for pain, namely a mindful attention style rather than one of ignoring pain and distracting oneself from it. For research in pain management, a differentiation and disambiguation of interoceptive sensibility into distinct dimensions through the MAIA scales has the potential of supporting pain research.

The capacity of the MAIA for differentiating specific aspects of interoceptive sensibility is further corroborated by similar findings from a recent study by Tim Gard's team [62]. The MAIA scales were included in a trial of MBCT for patients with chronic back pain and co-morbid depression. Self-Regulation and Not-Distracting improved in the intervention group more than in controls, whereas Noticing did not. Despite the weakness of the Not-Distracting scale regarding its internal consistency, these results showed that the positive effect of MBCT on depression severity was mediated by Not-Distracting. Again, training interoceptive sensibility as an adjunct approach in pain and depression management makes sense only if we are able to discriminate different aspects of interoceptive sensibility.

For the topic of anxiety, Mallorqui-Bague et al. [13] found that higher anxiety was associated with higher interoceptive accuracy in the heartbeat tracking task, but specific attention skills or styles towards body symptoms, namely those assessed by Attention Regulation and Trusting, were negatively correlated with state anxiety. Importantly, that association was the strongest in people with higher anxiety levels. As a diminished confidence in the interpretation and control of physiological arousal symptoms is characteristic of individuals with high-state anxiety, usually combined with increased emotional reactivity and enhanced perceptual sensitivity to or accuracy of physiological arousal [63], improving a compromised capacity to control bodily changes may be a promising approach to treating anxiety disorders. The investigators suggested, therefore, that enhancing awareness of bodily processes, e.g. through mindfulness approaches, may be used therapeutically for managing anxiety.

Also related to emotions and behavioural health, Guiseppe Cali et al. [42] explored associations between (i) the construct of emotional susceptibility [41], the tendency to experience feelings of discomfort and vulnerability when facing emotionally laden stimuli (real or imagined) and

(ii) interoceptive accuracy and the many facets of self-reported sensibility [42]. The analyses showed an intriguing pattern of relationships between emotional susceptibility and the different dimensions of interoceptive sensibility. Participants with higher emotional susceptibility reported more emotional distress or worry with sensations of pain or discomfort (Not-Worrying), higher awareness of the connection between body sensations and emotional states (Emotional Awareness), and were either less able to sustain and control attention to body sensations (Attention Regulation) or less prone to experience their own body as a safe and trustworthy place (Trusting). The strongest predictor of participants' emotional susceptibility was the interaction between Attention Regulation and Trusting. Participants who had a rather low score in at least one of these scales were more prone to experience feelings of discomfort, help-lessness, inadequacy and vulnerability due to the inability to control their reactions in negative situations, irrespective of their score in the other scale; conversely, only participants who showed high scores in *both* these scales were reported to have low emotional susceptibility or vulnerability.

Another revealing example of the complex relationships within the construct of interoceptive sensibility was described by Mehling *et al.* [11]: in a sample of mind–body experienced individuals, Emotional Awareness assessed by the MAIA was negatively related to trait anxiety (T-STAI) when taken alone, but this relation became positive after removing the portion of variance it shared with Self-Regulation. This suggests that the Emotional Awareness scale may assess distinct aspects of interoceptive sensibility that may be negatively and positively related to anxiety (respectively, those shared with the Self-Regulation scale and those that are specific to the Emotional Awareness). This interpretation led Mehling *et al.* to conclude that 'mere awareness of how body sensations correspond to emotional states [i.e., the Emotional Awareness], without the ability to use awareness of those sensations to reduce distress [i.e., the Self-Regulation], could actually increase anxiety' [11]. Training and increasing interoceptive sensibility is not a panacea. It requires distinguishing these regulatory or attention-related processes within the construct of interoceptive sensibility, which appears to be of major clinical relevance.

Taken together, these findings of differential changes within dimensions of interoceptive sensibility and their complex interplay can help us to better understand the complex psychology of interoceptive awareness.

5. Findings from clinical research

As already discussed in §§3 and 4, assessing interoceptive sensibility in a clinical setting warrants a more differentiated view of the multiple dimensions concealed by the general construct. The MAIA scales have so far been applied in a limited variety of clinical settings where it is so apparently important to differentiate dimensions of interoceptive sensibility. The author is aware of several completed controlled clinical trials that are still awaiting completed peer review and journal publication: a trial of MBCT for co-morbid chronic low back pain and depression (as mentioned in §4); trials of yoga for patients with chronic low back pain [64], a tai chi-inspired low-injury running style for individuals with pre-hypertension [65], yoga and mindfulness-inspired

fitness training as 'integrative exercise' for war veterans with post-traumatic stress symptoms [66], and a course of Mindfulness-Based Childbirth and Parenting in pregnant women to alleviate fear and pain in childbirth [67]. All of these studies showed differential changes in individual aspects of interoceptive sensibility. Changes were never significant for the global Noticing aspect of interoceptive sensibility. Significant score increases generally were seen in the realm of Self-Regulation, Attention Regulation, Emotional Awareness and/or Body Listening, and were associated with changes in clinical outcomes.

6. Application in clinical care

The MAIA has found a limited use in clinical settings for the evaluation of the therapeutic progress in physical therapy (Viveka Nyman, Stockholm, Sweden) and psychiatric (Rustin Berlow, MD, San Diego, USA) outpatient care. From these clinicians, large datasets are available awaiting further analyses. According to these clinicians, the MAIA appears to be useful for clinical evaluations. Interestingly, it is used in part to introduce new patients to elements of the therapeutic approach, thereby already using the MAIA itself as an early part of the intended intervention. Using the language of a questionnaire as an intervention raises psychometric concerns, as it implies that repeated measures may include an effect from learning the language and conceptual understanding of psychological parameters, an effect from learning a different understanding of the concept rather than from changes in these parameters. However, in the study by Bornemann *et al.* [12] repeated application of the MAIA scales over three months did not show any scale score increases when used without any intervention.

It should be noted that the factor structure of the various MAIA translations has generally been confirmed in healthy volunteers; only one was evaluated in a clinical population with low back pain. For clinical applications in patients with specific medical conditions, confirmatory factor analyses in these populations are strongly recommended.

7. MAIA for studies of mind–body approaches

Interoception has become a research field where researchers from a broad variety of disciplines are trying to find a common language. Researchers from neuroscience and biological psychology meet with researchers of contemplative practices and engage in discourse coming from different experiential backgrounds. In the field of integrative medicine, in which the author is involved by practising and researching non-pharmacological approaches for various medical conditions (particularly for pain), the term *bodily awareness* has emerged in the past decades and has been endowed with new meaning. Enhancing bodily awareness, previously viewed by physicians as associated with somatization and hypochondriasis, has more recently been proposed as a common mechanism of action for many mind–body therapies, such as mindfulness-based therapeutic approaches, meditation, yoga, tai chi, Feldenkrais method and many others [20,25,68]. Physiologically, bodily awareness is the awareness of proprioceptive and interoceptive signals from inside the body. Researchers have begun to submit these mind–body approaches with their therapeutic claims to

rigorous research and find themselves in dialogue with other scientists in the interoception field [2]. As previous measures were unable to appropriately capture the changes that patients undergoing mind–body therapies may experience [17], the MAIA was developed in order to facilitate such research. The MAIA has now been used in research on the potential therapeutic benefits from mindfulness-based approaches (such as MBSR, Mindfulness-Based Stress Reduction; MBCT, Mindfulness-Based Cognitive Therapy; MABT, Mindful Awareness in Body-oriented Therapy and MBCP, Mindfulness-Based Childbirth and Parenting), the body scan, breath meditation, yoga, Feldenkrais, tai chi-inspired running and Integrative Exercise (an integration of traditional resistance and aerobic fitness training with elements from yoga and mindfulness). The findings from this research support the notion that enhancing interoceptive bodily awareness can be beneficial if specific conditions are met. One of the most important conditions (laid out in more detail in [2]) is the specific style of mindful interoceptive attention as opposed to a style driven by anxious hypervigilance and biased by catastrophic expectations. The author believes that differentiating these attention styles and perceptive attitudes in self-report measures of interoceptive sensibility can contribute to a better understanding of mind–body approaches.

8. Limitations/shortcomings of MAIA

Naturally, the key limitation of the MAIA is its reliance on self-report with its well-known advantages and disadvantages [69]. Interoceptive awareness is one of those constructs that are invisible, not easily observable by a second person, multidimensional, and not easily matched with objective measures or tasks on which performance is measurable. To suggest an analogy to the importance of interoceptive accuracy for interoceptive awareness: how would one want to measure and characterize the variety of reactions of museum visitors to a modern art painting, component of their exteroceptive awareness? Can we measure the change in visitor responses produced by changes in the painting's presentations, e.g. with introductions and background information, placement in different room environments, the price of admission tickets, the fame of the painter, time allotment for the visit, or variations in visitors taste and attitudinal traits? Visual accuracy of the visitor may be but one important outcome, but probably not the most interesting one. Using self-report measures in psychological research, as notoriously vulnerable to bias as these are, when keeping their limitations in mind, may still be necessary where appropriate objective measures are not (yet) available.

Related to this limitation is the above-mentioned effect that a questionnaire, when applied repeatedly, may lead to a new understanding of the underlying constructs and may therefore measure the effect of conceptual learning rather than a change in this dimension. This inherent limitation has been encountered with other self-report measures, such as the FFMQ, and has already been discussed in detail [11].

Another weakness of the MAIA is that two of its eight scales have suboptimal internal consistency: the scales for Not-Distracting and Not-Worrying each include only three items, and five of these are the only negatively worded ones within the MAIA. Although in some samples

Cronbach's alpha for these two scales reached 0.67 and 0.71, respectively, most samples reported lower values, reaching as low as 0.53. Cronbach's alphas depend on the number of items (Cronbach's alpha for all 32 items was 0.91 in the same sample), and item redundancy increases alpha. Although it has been argued that internal consistency of a parsimonious scale may be less important if one wants to capture different aspects of a parameter with as few items as possible [70], efforts are currently underway to improve internal consistency by adding a few items to these scales for an improved version of the MAIA. In a new longitudinal study, for which recruitment is currently underway, three preliminary items were added to each of the Non-Distracting and Non-Worrying scales. It is planned to conduct exploratory factor analysis to determine which of these items are best suited to improve the scales' reliability.

A few scale–scale intercorrelations with coefficients around 0.60 may be viewed as moderately high, raising the issue of their independence. However, no agreed-upon standard for intercorrelations being too high or too low exists. Further, these scales were clearly distinguishable by (i) separate factor loadings and (ii) differential patterns of correlations with validation measures [11,42].

Finally, the validation studies for foreign-language translations have been done in healthy volunteers, such as psychology students. Factor analyses may have different results in different, e.g. clinical, populations. Only the original English version was assembled of scales and items for which iterative factor analyses provided the best fit for healthy volunteers *and* primary care patients who had suffered from low back pain [11,28].

9. Conclusion

The purpose of this article was to add to the discussion of interoceptive terminology. This narrative review supports three arguments: (i) Through recent research by the team around Garfinkel *et al.* [1], as well as by numerous researchers who used the heartbeat detection task as a measure for interoception research, it has become increasingly apparent that interoceptive awareness can no longer be considered equivalent to interoceptive accuracy. Consequently, self-report measures for interoception, now conceptualized as interoceptive sensibility, e.g. by using the MAIA, barely correlate with measures of interoceptive accuracy. Similarly, mind–body therapeutic approaches claiming to enhance interoceptive skills may not show changes in interoceptive accuracy, but rather with self-report measures that incorporate scales for capturing attention regulation and top-down regulatory elements of interoceptive processes. (ii) Confidence about one's interoceptive accuracy—the opposite of error awareness—can be labelled 'interoceptive confidence' and thereby would be one quantifiable element of interoception, rather than being synonymous with interoceptive awareness. Interoceptive awareness—in the author's view—may maintain its much broader and more inclusive conceptualization as forwarded by Bud Craig, Oliver Cameron [71] and others [2]. (iii) It may be advantageous to disambiguate the construct of interoceptive sensibility. Interoceptive sensibility—in keeping this recent terminology—is a more general concept that does not discriminate between beneficial and maladaptive attention styles. However, this

discrimination is of key importance for clinical care. Differentiating multiple dimensions within interoceptive sensibility has been shown to aid in better understanding of interoceptive processes and can elucidate mechanisms of action for mind–body therapies. Self-reported interoceptive sensibility, as assessed by either the MAIA or the awareness section of the PBPQ, is not related to interoceptive accuracy. Interoceptive sensibility has previously been assessed by the PBPQ, a well-established measure for negative emotion-related physical symptoms. However, the PBPQ is unidimensional, measures a parameter partially related to a single dimension of the MAIA, and may be of limited meaning and usefulness in this context [17].

Despite their obvious problems, self-report questionnaires have the advantage that they more easily allow a broader first-person assessment of interoceptive sensibility and awareness, covering not only sensibility to body signals, but also perception-related regulatory aspects, beliefs, attitudes, thoughts and emotions. The MAIA is an initial step to make such a self-report instrument available for the scientific study of interoceptive sensibility. Limitations of its current version are described, and efforts for its improvement are underway. Despite psychometric shortcomings in a few of its eight scales, it has shown that interoceptive sensibility can be viewed as a trait that includes dimensions with potential plasticity, rather than standing for a stable unidimensional character trait.

The MAIA has already provided longitudinal data that showed the possibility of differential changes within defined dimensions of interoceptive sensibility and has elucidated a complex interplay of its elements. In summary, findings from its applications suggest that differentiating interoceptive sensibility according to attention styles and regulatory aspects (i) provides insights into the complex psychology of interoceptive awareness, (ii) differentiates between clinically maladaptive and beneficial interoceptive attention, and (iii) helps in elucidating therapeutic approaches that claim to provide health benefits by training a mindful style of bodily awareness.

Endnote

[1]*AM: Maryam Abassi, Iran; BR: Rustin Berlow, USA; GT: Tim Gard, USA/The Netherlands; LE: Elizabeth Lutz, USA; LJ: Justin Leiter, USA; MA: Adam Middleton, UK; M-BN: Nuria Mallorqui-Baque, UK/Spain; NV: Viveka Nyman, Sweden.

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