



Making sense of what you sense: Disentangling interoceptive awareness, sensibility and accuracy



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ABSTRACT

Garfinkel and Critchley (2013) recently proposed a three level model of interoception. Only few studies, however, have empirically tested this theoretical model thus far. The present study aimed at investigating (1) the central assumptions of this model, i.e. that Accuracy, Sensibility and Awareness are distinguishable facets of interoception and that Interoceptive Accuracy is the basic level of interoception, and (2) whether cardiovascular activation (as indexed by heart rate) is differentially related to the three facets of interoception. Analyses were conducted on a total sample of $N = 159$ healthy participants (118 female [74.2%]; mean age = 23.9 years, $SD = 3.3$, range = 19–45) who performed either the heartbeat tracking task, the heartbeat discrimination task or both. The results suggest that Accuracy, Sensibility and Awareness are empirically distinct facets of interoception, showing no correlation when based on heartbeat tracking, but moderate correlations when based on heartbeat discrimination. The assumption that Interoceptive Accuracy is the basic level of interoception could only be partially confirmed. Instead, we conclude that the level of objective physiological states should be considered as the most basic level of interoceptive signal processing.

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1. Introduction

Interoception, i.e. the sense of the physiological condition of the body (Craig, 2003), is related to various mental and behavioral processes, such as emotion processing, emotion regulation, and intuitive decision-making (Bechara and Naqvi, 2004; Pollatos and Schandry, 2008; Fustos et al., 2013; Sütterlin et al., 2013; Terasawa et al., 2013). Previous research on interoception, however, often suffered from conceptual vagueness. Only recently, Garfinkel et al. (2015) suggested clear and concise definitions for terms such as “interoceptive awareness” and “interoceptive accuracy”, which previously were often used interchangeably (Dunn et al., 2010; O'Brien et al., 1998; Terhaar et al., 2012), whereas others treated these terms separately, which may impede comparisons between outcomes of different studies (Ceunen et al., 2013). Moreover, Garfinkel and Critchley (2013) proposed a multi-level conceptualization of interoception that distinguishes between three facets of the construct: 1. Interoceptive Sensibility, 2. Interoceptive Accuracy and 3. Interoceptive Awareness.

Interoceptive Sensibility refers to a dispositional tendency to be internally focused. This term captures self-reported beliefs about body sensations, which are typically assessed via self-report measures such as questionnaires (Mehling et al., 2012; Porges, 1993). Garfinkel et al. (2015) also use the mean of individual confidence ratings in interoceptive accuracy tasks as indicator of interoceptive sensibility. The second level of Garfinkel and Critchley's (2013) model is named *Interoceptive Accuracy*, which refers to “objective” behavioral tests of interoception. There are two main approaches for the assessment of Interoceptive Accuracy: a) the tracking method, originally proposed by Schandry (Dunn et al., 2007; Herbert et al., 2012; Schandry, 1981), which assesses a person's accuracy in detecting their heartbeats by counting them in a given time interval, and b) the signal discrimination method, which presents a series of external stimuli (tones, lights or tactile stimuli) and asks the participant to judge whether the stimuli are simultaneous or delayed relative to one's own heartbeat (Whitehead and Drescher, 1980; Whitehead et al., 1977). The tracking task has been criticized for its results being influenced by expectancies or guesses about heart rate or other factors such as attention or motivation (e.g., Windmann et al., 1999; Ring et al., 2015). Even though both established heartbeat perception tasks involve different processes (e.g. attention focusing on visceral sensations to perform heartbeat tracking, but attention focusing on visceral and external sensations to perform heartbeat discrimination;

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Schulz et al., 2013), many studies have found moderate correlations between indices derived from both tasks (Knoll and Hodapp, 1992; Schaefer et al., 2012; Hart et al., 2013).

In addition to Interoceptive Sensibility and Interoceptive Accuracy, Garfinkel and Critchley (2013) consider *Interoceptive Awareness* as a third level. This aspect of interoception can be assessed via metacognitive judgments on Interoceptive Accuracy and refers to the extent of an individual's confidence ratings predicting their own actual interoceptive performance (Garfinkel and Critchley, 2013). Garfinkel and Critchley (2013) point out that most of the existing literature refers to the first or second facet of interoception (Sensibility or Accuracy), and particularly Interoceptive Accuracy has been demonstrated to be related to several mental disorders such as eating disorders (Pollatos et al., 2008), panic disorder (Ehlers and Breuer, 1996), depersonalization/derealization disorder (Schulz et al., 2015) and depression (Terhaar et al., 2012). Recently, Yoris et al. (2015) have reported that metacognitive beliefs and worries about interoception and not interoceptive performance in a heartbeat detection task discriminated between patients with panic disorder and healthy controls, pointing at the importance of metacognitive interoceptive processing for the understanding of the role of interoception in mental disorders.

There are only two studies so far which have investigated the question as to whether the three facets of the model are distinguishable and how they relate to each other empirically. The authors of the model themselves investigated the relationship between the three facets of interoception in a sample of 80 healthy participants (Garfinkel et al., 2015). In a stepwise forward linear regression analysis, Interoceptive Sensibility and Awareness predicted Interoceptive Accuracy, and these associations were lowered when Interoceptive Awareness was entered as the dependent variable instead. The authors interpreted their results as underpinning the potential independence of the three facets of interoception as proposed in their model and as in line with their assumption of the primacy of Interoceptive Accuracy: only after a basic accuracy threshold is overcome, a correspondence between the different facets of interoception would emerge (Garfinkel et al., 2015). A second study ($N = 25$) by Meessen et al. (2016) found the three facets of interoception to be uncorrelated. The generalizability of the results of this study, however, may be limited because the sample investigated was small and no data on heartbeat discrimination paradigms was assessed.

Taken together, both studies suggest a partial independence of the three facets of interoception as proposed by the model introduced by Garfinkel and Critchley (2013), and larger associations between these facets in people high in Interoceptive Accuracy. Several unresolved issues remain, however. Firstly, with only two published studies the empirical evidence is sparse. Additional studies with reasonably sized datasets on the relation between different facets of the model are, therefore, needed. Particularly data on the association between Interoceptive Accuracy assessed using a heartbeat discrimination paradigm and Interoceptive Awareness are lacking.

Secondly, neither Garfinkel et al. (2015) nor Meessen et al. (2016) controlled whether the three facets of interoception were related to indices of visceral-afferent neural signal transmission, which represent a necessary prerequisite for its perception (Vaitl, 1996). Cardiovascular activation by exercise (Pollatos et al., 2007; Schandry et al., 1993) or laboratory stressors (Fairclough and Goodwin, 2007; Schulz et al., 2013) has been shown to affect Interoceptive Accuracy, which may be due to altered transmission of visceral-afferent neural signals during cardiovascular activation (e.g., as indexed by increase of heart rate, blood pressure, etc.). Furthermore, interoception is affected by indices of baseline cardiovascular activation, in that lower resting heart rate is associated with higher Interoceptive Accuracy (Knapp-Kline and Kline, 2005). If empirical results support the assumption that visceral-afferent signal transmission is related to higher levels of interoception, the objective physiological state or process (such as resting heart rate) may constitute the most basic level underlying the processing of internal signals, which

is required for interoception, and could, therefore, be integrated as the fourth element in the model introduced by Garfinkel and Critchley (2013).

The present study investigated the relationship between Interoceptive Accuracy, assessed with both a heartbeat tracking and a heartbeat discrimination task, Interoceptive Sensibility and Interoceptive Awareness. As primary hypothesis we expected (I) to replicate previous findings (Garfinkel et al., 2015) in support of the three-facet model of interoception (Garfinkel and Critchley, 2013). Support for this model would be found in three distinguishable facets of interoception with Interoceptive Accuracy as basic construct. In line with Garfinkel et al. (2015), distinctness is indicated by zero to mild correlations. In hypothesis (Ia) we, therefore, expected zero to mild correlations between the three facets and higher correlations between “Accuracy” and “Sensibility” than between “Accuracy” and “Awareness”. As we expected “Accuracy” as the most basic construct, we hypothesized (Ib) associations between interoceptive facets (Accuracy, Sensibility and Awareness) to be higher in individuals high in Interoceptive Accuracy compared to individuals low in Interoceptive Accuracy. Thus, Interoceptive Accuracy is expected to act as moderator of these associations. According to hypothesis (Ic) we expected Interoceptive Sensibility and Awareness to predict Interoceptive Accuracy in a linear regression analysis and that these relations should be weakened when a reversed regression model was calculated. In hypothesis (II), we expected heart rate (as an index of cardiovascular activation) to be differentially related to the three facets of interoception. If significant relations between these variables would emerge, implications for a potential integration of heart rate into the model proposed by Garfinkel and Critchley would be discussed. As secondary hypotheses, we expected (III.) accuracy and sensibility to be related across tasks (heartbeat tracking and heartbeat discrimination) and (IV.) that the use of a specific formula to calculate Interoceptive Accuracy would not affect outcome. For this purpose, we compared the formula proposed by Hart et al. (2013), that was used by Garfinkel et al. (2015) with the formula proposed by Schandry (1981).

2. Material and methods

2.1. Participants

Participants were 159 healthy individuals (118 female [74.2%]; mean age = 23.9 years, $SD = 3.3$, range = 19–45) who took part in the five separate experiments contributing to this study. See Table 1 for details on the demographic characteristics of the subsamples.

Data from experiments three and four have been published previously, addressing research questions other than the relationship between Interoceptive Accuracy and Awareness (Schulz et al., 2013; Michal et al., 2014).

The present study was conducted in accordance with the declaration of Helsinki and was approved by the local ethics committees of the Universities of Trier and Mainz (Germany), where the studies were conducted. All participants gave written informed consent.

2.2. Interoceptive accuracy tasks

2.2.1. Heartbeat discrimination task

An interoceptive-exteroceptive discrimination task was initially developed by Brener and Jones (1974), but further elaborated by others (Brener and Kluitse, 1988; Katkin et al., 1981). Participants are asked to judge whether exteroceptive stimuli appear either “synchronously” or “delayed” to their own heartbeats. Exteroceptive stimuli were elicited with a latency of 230 ms ($S+$ trials, synchronous) or 530 ms ($S-$ trials, delayed) after the participants' actual R -wave. The task was implemented in an auditory version in which a sinus tone (440 Hz) of 80 ms duration was used. During each trial, six consecutive stimuli with the same latency were presented. Participants completed test trials

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