内受容感覚の性差：身体感覚・情動の未分化が女性の心拍知覚メタ認知の低下を予測する

Gender difference in interoception: Women with undifferentiated bodily/emotional feeling show decreased interoceptive metacognition

晴木 祐助[1, 2, *], 金子 景[1], 小川 健二[1]
Yusuke Haruki, Kei Kaneko, and Kenji Ogawa

[1]北海道大学, [2]日本学術振興会
Hokkaido University, Japan Society for the Promotion of Science
[*]haruki@let.hokudai.ac.jp

Abstract
Interoception refers to the perceptions arising from the internal body's physiological processes. Researchers have suggested a gender difference in interoception, with women more likely to report somatic symptoms in association with mental disorders, possibly due to reduced metacognitive ability in interoception. In this study, we examined gender differences in three interoceptive aspects and their link to individual interoception tendencies using behavioral tests and questionnaires. Our findings revealed no statistically significant gender differences in perceptual accuracy, confidence, or metacognitive ability in interoception. However, we did observe a decline in interoceptive metacognition among women who strongly linked bodily sensations to emotional experiences in daily life, a pattern not observed in men. These results empirically support the idea that women may be more vulnerable to impaired interoceptive metacognition associated with bodily/emotional feelings, which could lead to inaccurate evaluations of physiological states.

Keywords — interoception, metacognition, gender difference

1. Introduction

In recent decades, there has been a growing interest in interoception, which refers to the perception of bodily sensations. Researchers have focused on understanding individual differences in subjective awareness of interoception (i.e., interoceptive awareness) using various methods, including behavioral tests and questionnaires [1]. One potential factor influencing interoceptive awareness is gender, as women tend to experience greater physiological (especially hormonal) changes [2]. Moreover, from the clinical perspective, there are much more risks of common mental disorders in women, particularly with somatic symptoms (i.e., atypical interoceptive awareness) [3]. In line with this, recent meta-analyses regarding behavioral tests have shown that women generally exhibit more moderate perceptual accuracy in interoception compared to men [4, 5].

However, beyond perceptual accuracy, other aspects of interoceptive awareness, such as subjective confidence and metacognitive ability (insight) [1], have not been thoroughly explored in relation to gender differences. In this study, we aimed to investigate gender disparities in interoceptive accuracy, confidence, and insight using a modified heartbeat counting task that provided a more robust statistical evaluation of interoceptive insight. Additionally, we assessed individual tendencies in day-to-day interoception experiences using a questionnaire, which served as a potential modulator of gender differences in interoception. We hypothesized that men would exhibit higher interoceptive accuracy and insight and also that reduced interoceptive insight may be associated with individual dispositions toward interoception in women.

2. Materials and methods

A total of 78 volunteers (41 women, 37 men) participated in the study. All participants were undergraduate students at Hokkaido University, with an average age of XX years. Each participant received a 1000 yen Amazon gift card upon completion of the one-hour experiment. Five participants (four women, one man) were excluded from the statistical analysis due to excessive noise in the physiological recordings, which prevented accurate calculation of their heart rate. Consequently, our final sample included 73 participants (37 women,

36 men), which met the minimum sample size requirement (n = 34) needed to achieve sufficient statistical power (1 - β = .80) for detecting medium to large effect sizes of correlation coefficients (ρ = .40) at a given type-1 error probability (α = .05) for both genders. Prior to participating in the study, all participants provided written informed consent. The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments, and the experimental protocol was approved by the Ethics Committee of Hokkaido University.

To assess participants' interoceptive accuracy, confidence in their accuracy, and insight into their interoceptive abilities, we utilized a heartbeat counting task. During each trial, participants silently counted the number of their heartbeats that occurred within specific durations (15 s, 25 s, 35 s, or 45 s), focusing on the sensations of their heartbeat. Immediately after each trial, participants reported the counted number using a visual slider with a digit scale. Additionally, participants rated their confidence in their interoceptive accuracy on a visual slider ranging from 0 (no perception of heartbeats) to 100 (complete perception). Participants were explicitly instructed to count only the heartbeats they were unquestionably able to detect, prohibiting the use of strategies unrelated to heartbeat detection (e.g., estimating time or the number of heartbeats), as such strategies have been shown to inflate interoceptive accuracy.

A total of 20 trials were completed by participants, with each duration presented in a randomized order, consisting of five trials for each duration. Every five trials, participants were given a break to rest as needed. The increased number of trials was intended to quantify the robust relationship between interoceptive accuracy and confidence (i.e., interoceptive insight). Previous studies, such as the work by Garfinkel and colleagues [1], calculated Pearson's correlation coefficient between interoceptive accuracy and confidence based on only six trials. However, this approach is problematic due to the high level of uncertainty and potential bias associated with such a small sample, which can result in inaccurate estimates of the true correlation. Specifically, computing the correlation coefficient based on six pairs, assuming a medium-to-large population correlation coefficient (ρ = .50), yields a standard error of .43.

The photoplethysmography (PPG) signals obtained during the task trials were analyzed using the Heartpy module in Python. To ensure the integrity of the recorded PPG signals for each participant, we first applied a third-order low-pass filter to the PPG time series to reduce noise. Subsequently, we meticulously examined each trial to identify any erroneous or missing peak detections. During this examination, we identified two or more unreliable PPG time series in four out of the 77 participants, rendering it impossible to accurately calculate the number of heartbeats. Consequently, these four participants were excluded from further analyses. For the remaining participants, the number of heartbeats and heart rate were calculated using the preprocessed PPG time series for each trial. Subsequently, we determined the interoceptive accuracy, confidence, and insight for each participant based on the recorded and reported number of heartbeats across the 20 trials. The formulations used for these calculations are as follows:

$$Interoceptive\ accuracy = \frac{1}{20}\sum_{i=1}^{20}\left(1 - \frac{|Recorded\ Nbeats_i - Reported\ Nbeats_i|}{Reported\ Nbeats_i}\right)$$

$$Interoceptive\ confidence = \frac{1}{100}\frac{1}{20}\sum_{i=1}^{20} Interoceptive\ confidence_i$$

$$Interoceptive\ insight = \frac{Cov(Interoceptive\ accuracy, Interoceptive\ confidence)}{SD(Interoceptive\ accuracy)SD(Interoceptive\ confidence)}$$

Following the completion of the heartbeat counting task, participants were administered a questionnaire: the Japanese version of the Multidimensional Assessment of Interoceptive Awareness (MAIA) to evaluate interoceptive sensibility. The MAIA questionnaire comprises 32 statements that capture various aspects of daily experiences related to interoception [6]. For example, participants are asked to rate statements such as "When I am tense, I notice where the tension is located in my body." Responses to these statements

are given on a 5-point Likert scale, ranging from 0 (never) to 5 (always). Interoceptive sensibility is assessed across eight independent factors represented by the MAIA: noticing, not distracting, not worrying, attention regulation, emotional awareness, self-regulation, body listening, and trusting. All questionnaires were administered through an online form. The order of the statements within the questionnaire was randomized to minimize order effects. Interoceptive sensibility was calculated as multidimensional components based on the eight factors assessed by the MAIA questionnaire.

In our statistical analyses, we first compared interoceptive accuracy, confidence, and intensity between genders using tow sample t-tests. Moreover, we tried to compare the relationship between interoceptive insight and participants' disposition about interoception across genders. To this end, we calculated correlation coefficients between interoceptive insight and each factor of MAIA for both genders. Then it was statistically tested if there was a gender difference in these correlations, by using Lenhard's method [7]. We conducted multiple comparison corrections using the Bonferroni method for our t-tests ($\alpha = .05/3 = .017$) and correlational tests ($\alpha = .05/8 = .006$), respectively.

3. Results and discussion

First of all, we did not find any significant gender difference in interoceptive accuracy, confidence, and metacognitive insight (Figure 1, all ps > .18). Particularly, our data did not show the gender difference in interoceptive accuracy that has been

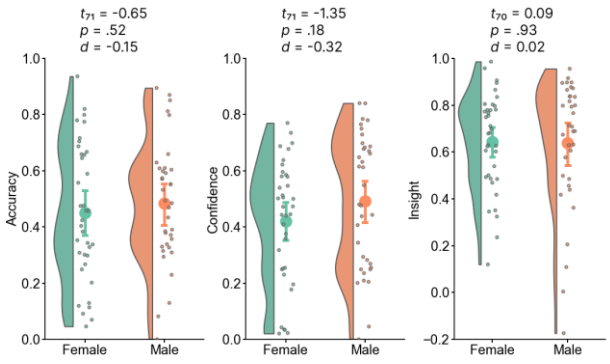

Figure 1. Mean differences in interoceptive accuracy, confidence, and insight between genders.

emphasized by two recent meta-analyses [4, 5]. In addition, there was no mean difference in interoceptive insight, the individual consistency between perceptual accuracy and its subjective confidence. These results were somewhat unexpected, given previous research indicating that women tend to have lower interoceptive accuracy while reporting heightened bodily awareness, especially related to symptoms, more frequently than men [3].

Instead for the mean difference, we found a gender difference in the relationship between interoceptive insight and individual dispositions to interoception (Figure 2, $p < .001$). There was a negative correlation between individual interoceptive insight and emotional awareness scale in the MAIA in women ($r_{women} = -.54$, $p < .001$; $r_{men} = .14$, $p = .43$), suggesting that women who tend to consider their bodily fluctuation as more emotional than perceptual had decreased interoceptive insight. This result might elaborate the gender difference in interoceptive awareness frequently observed in clinical settings, with women often reporting somatic symptoms in mental illness.

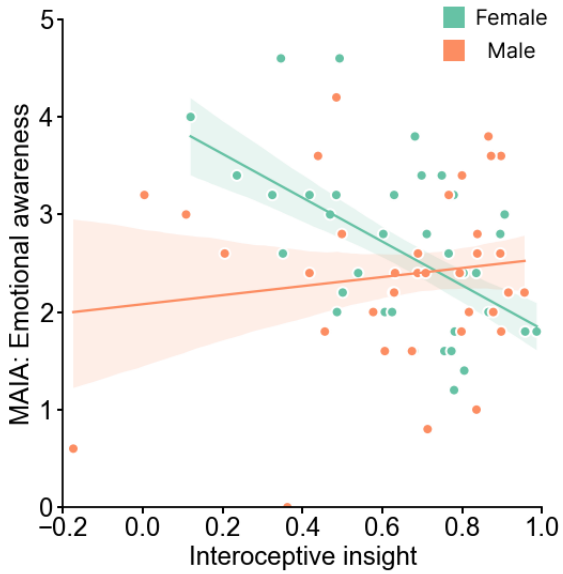

Figure 2. Gender differences in the relationship between interoceptive insight and individual tendency to discriminate their bodily feelings from emotional ones.

Taken together, the present study revealed that women with undifferentiated bodily/emotional

feeling show decreased interoceptive insight while group-level gender differences in interoceptive awareness were not observed.

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