The relationship between interoceptive sensibility and tactile localisation: a cross-sectional study

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Abstract

Background: The perception of our body (i.e. somatoperception) is under the influence of multisensory information (e.g. touch) and internal representations of our body in the brain (i.e. body representations). The integrity of body representations seems important since distortions range from tactile mislocalisation to loss of body ownership. Body representations have been linked to perceiving the internal bodily state (i.e. interoception) as well as perceiving the surrounding environment (i.e. exteroception). However, the inter-relationship between interoception and exteroception remains unclear, but could be hypothesised based on the overlap of the interoceptive and exteroceptive neural networks. In particular touch as exteroceptive modality seems of clinical interest since touch is relatively strongly related to pain.

Aim: Investigating the relationship between interoceptive sensibility and tactile localisation in a non-clinical sample

Methods: In this cross-sectional study, interoceptive sensibility was assessed with the Multidimensional Assessment of Interoceptive Awareness, version 2 (MAIA-2). Tactile localisation was assessed with the imprinted Tactile Acuity Device, with the overall accuracy score as outcome. Multiple linear regression was used to perform multiple partial correlations between the MAIA-2 subscales and the overall accuracy score, after all variables were adjusted for age and gender. Additionally, zero-order correlations and semi-partial correlations were obtained.

Results: Sixty-nine participants were included. The multiple partial correlation showed an adjusted R^2 of .19 ($p < .000$), with MAIA-2 *body listening* and MAIA-2 *trusting* included. MAIA-2 *body listening* had a zero-order correlation ($r = -.378$, $p = .001$) and a semi-partial correlation ($r = -.447$, $p < .000$) to the overall accuracy score. MAIA-2 *trusting* only had a semi-partial correlation ($r = .261$, $p = .020$) to the overall accuracy score.

Conclusion and key findings: Participants who reported higher scores on whether they actively listen to their body for insight showed lower overall accuracy scores. Also, participants who reported higher scores on whether they experience their body as safe and trustworthy showed higher overall accuracy scores. These findings suggest that interoception and exteroception seem to inter-relate, which could be helpful to increase our understanding of distortions in body representations in clinical samples.

Keywords: interoception, interoceptive sensibility, exteroception, tactile localisation, body representations.

INTRODUCTION

The perception of our body (i.e. somatoperception) is a product of the integration of multisensory information (e.g. vision and touch) and an internally stored representations of our body in the brain (i.e. body representations) (1,2). Within this complex integration, body representations act as a frame of reference on which a somatoperception is generated (1). Distortions in body representations have been linked to clinical disorders such as anxiety, depression and chronic pain (3–5), with perceptual distortions ranging from tactile mislocalisation to loss of body control as well as body ownership (3,6–9). This implies the importance for the functional integrity of body representations. Especially since body representations have been suggested to be modifiable, as treatments targeting body representations have shown some effect in chronic pain conditions (10,11).

Body representations have been associated with both interoception and exteroception (3). Interoception is the ability to perceive the internal state of the body (5). This refers to the perception of internal sensations arising from physiological parameters (5,12), which monitor the bodily homeostatic stability (4,13). Interoception consists of three distinct dimensions, namely interoceptive accuracy, interoceptive sensibility and interoceptive metacognitive awareness (14). Exteroception is the ability to perceive the surrounding environment (3). This refers to the perception of sensory information from outside the body (3). Although, interoception and exteroception have been individually linked to body representations (3,7–9,15) their inter-relationship remains unclear.

An inter-relationship between interoception and exteroception seems plausible, as there is considerable overlap in the neural network responsible for interoception as well as exteroception. The overlapping neural networks includes the anterior cingulate cortex, the insular cortex, the inferior frontal gyrus and the sensorimotor cortices (12). Moreover, interoception as well as exteroception seem negatively affected in chronic pain conditions (3,7–9,15). However, only few studies have directly investigated their relationship. One study observed that decreased interoceptive accuracy related to stronger distortions of body ownership during a bodily illusion based on exteroceptive stimulation (15). Another study found correlations between interoceptive accuracy and exteroceptive awareness ($r = -0.291$, $p = 0.05$), as well as between interoceptive sensibility and exteroceptive awareness ($r = -0.355$, $p = 0.001$) (16). These studies show that interoception and exteroception do not seem to operate independently.

However, previous literature on the inter-relationship between interoception and exteroception predominantly focused on vision as exteroceptive modality. Yet, touch as exteroceptive modality could be of particular interest, since both interception and touch fall within the same somatosensory domain (17). Additionally, touch may be of further interest from a clinical point of view. The processing of both nociceptive and mechanoreceptive information shows a strong, near indistinguishable, overlap in cortical activation. Especially when compared to the cortical activation of other exteroceptive modalities such as vision (18,19).

In order to investigate the relationship between interoception and touch both will be assessed as somatoperceptions. Since stronger functional interactions are expected when interoception and touch are assessed on the same somatoperceptual level (1). Of the interoceptive dimensions, interoceptive sensibility measures interoception as somatoperception (14). Furthermore, touch can be quantified by measuring tactile acuity. Tactile acuity assesses somatoperception by tactile localisation (1,2).

Therefore, the aim of this study is to investigate the relationship between interoceptive sensibility and tactile localisation in a non-clinical sample. This study is conducted in a non-clinical sample since the relationship between interceptive sensibility and tactile localisation has not yet been investigated. However, investigation this relationship may help our understanding of how body representations are formed or even altered, which could help to better interpret changes found in clinical populations. More importantly, improving our understanding could be beneficial for interventions targeting distortions in body representations.

MATERIALS AND METHODS

Design and participants

This cross-sectional study was conducted to investigate the relationship between interoceptive sensibility and tactile localisation. Participants were recruited between May 2019 and March 2020, using a convenience sample from the general public in South East Queensland, Australia. Participants were eligible for inclusion if they, 1) were aged 18 and above, 2) were currently pain free in the back, neck, arms and head, 3) had normal or corrected to normal vision, 4) understood the English language and 5) were able to confidently use a tablet. Participants were excluded when they, 1) used medical or recreational drugs in the past seven days that would interfere with perception, 2) had a history of any chronic pain (i.e. pain persistent for more than three months without a clear clinical diagnose) in the past five years for more than four days a week, 3) had a history of severe neck or head trauma, 4) had a history of neurological disorders as confirmed by a clinician and 5) had a history of psychological disorders as confirmed by a clinician. The study was approved by Griffith University Human Research Ethics Committee and this paper written in accordance to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (20).

Interoceptive sensibility

Interoceptive sensibility was assessed with the Multidimensional Assessment of Interoceptive Awareness, version 2 (MAIA-2) questionnaire (21). The MAIA-2 covers multiple dimensions of self-perceived interoceptive sensibility (14), and has been suggested as the most adequate measure of interoceptive sensibility (14,21,22). The MAIA-2 consists of 37-items divided into eight subscales, *noticing, not-distracting, not-worrying, attention regulation, emotional awareness, self-regulation, body listening* and *trusting* (21). Individual items were answered on a scale ranging from 0 (never) to 5 (always) (23). The score for each subscale was calculated by averaging the summed scores of each item within the subscale. Higher scores indicated higher interoceptive sensibility (23). The internal consistency of the subscales were moderate to robust (24) with Cronbach's Alphas ranging from 0.64 to 0.83 (21). The construct validity of the MAIA-2 has been established with other validated scales (25) and through detecting differences in known group comparisons (25,26).

Tactile localisation

Tactile localisation was assessed with the imprinted Tactile Acuity Device (iTAD). The iTAD measures tactile localisation in the neck by assessing localisation- and orientation accuracy using vibrotactile stimuli (27). The percentage correct scores of the localisation- and the orientation test were averaged into the ITAD overall accuracy score (0-100%). Higher scores indicated better tactile localisation. The overall accuracy score of the iTAD has moderate intra-rater reliability with an Intraclass Correlation Coefficients (ICC) model 2,1 of 0.69 (95% CI: 0.54-0.8) (27). In addition to good internal consistency with an ICC model 2,4 of 0.84 (95% CI: 0.75-0.9) (27). The overall score of the ITAD has demonstrated some construct validity in a known-group comparison study (27).

Potential confounders

Both interoceptive sensibility (22) as well as tactile localisation are influenced by age (28,29) and gender (30,31). To better approach the unique relationship between interoceptive sensibility and tactile localisation, age and gender were recorded as potential confounders and adjusted for in the analysis (32).

Procedures

Measurements were conducted in a closed distraction free room. Participant received an information sheet and provided written informed consent. Age and gender were recorded, and the MAIA-2 questionnaire was completed. To perform the iTAD assessments, participants were positioned on an armless chair with their feet flat on the ground. Participants held a tablet in their hands, while their forearm(s) rested on a desk. Participants were asked to remain in a fixed sitting position while minimizing neck movement. First, the iTAD familiarisation and fitting protocol were conducted after which the localisation- and orientations tests were performed to collect the ITAD overall accuracy score.

Statistical Analysis

The statistical analysis was performed using multiple linear regression in IBM SPSS Statistics 24. Multiple linear regression was used to perform Pearson's multiple partial correlations. The Pearson's multiple partial correlations were obtained by partialing out the effects of age and gender from the MAIA-2 subscales as well as the ITAD overall accuracy score (33,34). The remaining residual values of the MAIA-2 subscales and the ITAD overall accuracy score were considered the independent variables and the dependent variable, respectively. The residuals values of the MAIA-2 subscales were added in the analysis by 'forward'-method. Variables with a P-value of <0.05 were included in the model. After running the multiple linear regression, the adjusted R^2 value was considered the Pearson's multiple partial correlation coefficients (33,34). The assumptions for multiple linear regression were checked (35). The Shapiro-Wilk test and P-P plots were used to check for normality of the residuals. Linearity and homoscedasticity were checked using standardized residuals plots. Multicollinearity was checked using the tolerance and Variance Inflation Factor (VIF) statistics. A tolerance statistic of >0.2 and a VIF statistic of <10 were considered acceptable (35). The Durban-Watson test was used to check for independence of errors and Cook's distance was used to check the influence of individual cases. A Durban-Watson test statistic of >1 and <3 as well as a Cook's distance value <1 were considered acceptable (35). In addition to the Pearson's multiple partial correlation, both the Pearson's zero-order correlations as well as the Pearson's semi-partial correlations were obtained. The sample size was calculated in G-Power 3.1, using the statistical test for multiple linear regression, fixed model, significant R^2 deviation from zero. With 10 possible predictors, a level of significance of $p = 0.05$ and 90% power, 69 participants were needed to demonstrate a large effect ($f^2 = 0,35$).

RESULTS

Study characteristics

A total of 69 healthy participants were included in this study, of which 33 males (47.8%). Patient characteristics, the MAIA-2 subscale scores and ITAD overall accuracy scores are presented in table 1.

TABLE 1 | Patient and measurement characteristics

Participants, n (%)	69 (100)
Sex, n (%)	
Male	33 (47.8)
Female	36 (52.2)
Age, mean (SD)	
Years	42.4 (14.9)
MAIA-2 subscales, mean (SD)	
Noticing	3.2 (1.0)
Not-distracting	2.3 (1.5)
Not-worrying	2.9 (0.9)
Attention regulation	3.0 (0.8)
Emotional awareness	3.3 (0.9)
Self-regulation	2.9 (0.9)

Body listening	2.3 (1.2)
Trusting	3.5 (1.0)
iTAD, mean (SD)	
Overall accuracy score	50.5 (13.5)

n: sample size; SD: Standard Deviation; MAIA-2: Multidimensional Assessment of Interoceptive Awareness version 2; iTAD: imprinted Tactile Acuity Device;

Multiple partial correlation

The multiple regression analysis resulted in a significant ($F(2, 66) = 8.84$, $p < .000$) model, which included MAIA-2 *body listening* and MAIA-2 *trusting* (see table 2). The adjusted multiple partial correlation of this model was 0.19 ($p < .000$), indicating a shared variance of 19% between interoceptive sensibility and tactile localisation after adjusting for age and gender.

TABLE 2 | Multiple partial correlation to the iTAD overall accuracy score

Variables	R^2	Adjusted R^2	p-value
MAIA-2 *body listening,* MAIA-2 *trusting*	.21	.19	.000

MAIA: Multidimensional Assessment of Interoceptive Awareness version 2;

Zero-order correlations and semi-partial correlations of individual subscales

The MAIA-2 *body listening* had a significant inverse zero-order correlation and semi-partial correlation to the ITAD overall accuracy score (see table 3). Remarkable, MAIA-2 *trusting* did not have a significant zero-order correlation ($r = 0.106$, $p = .388$) to the ITAD overall accuracy score but did have a significant semi-partial correlation ($r = .261$, $p = .020$) (see table 3).

TABLE 3 | Zero-order and semi-partial correlations to the iTAD overall accuracy score

	Zero-order correlations		Semi-partial correlations	
Variables	r	p-value	r	p-value
MAIA-2				
Body listening	-.378	.001	-,447	.000
Trusting	.106	.388	.261	.020

r: Pearson's Correlation Coefficient; MAIA-2: Multidimensional Assessment of Interoceptive Awareness version 2;

DISCUSSION

The aim of this study was to investigate the relationship between interoceptive sensibility and tactile localisation in a non-clinical sample. The results showed a multiple partial correlation of .19 i.e. the MAIA-2 *body listening* and MAIA-2 *trusting* share 19% of their variance with the ITAD overall accuracy score after adjusting for age and gender. The MAIA-2 *body listening* showed a significant inverse zero-order correlation as well as a significant inverse semi-partial correlation to the ITAD overall accuracy score i.e. participants who reported higher scores on whether they actively listen to their body for insight showed lower overall accuracy scores and vice versa. The MAIA-2 *trusting* showed a significant semi-partial correlation i.e. participants who reported a higher score on whether they experience their body as safe and trustworthy showed higher overall accuracy scores and vice versa. The effect sizes of the multiple partial correlation as well as the zero-order correlation and the semi-partial correlation of the MAIA-2 *trusting* are small (36). The effect sizes of the zero-order correlation as well as the semi-partial correlation of the MAIA-2 *body listening* are medium (36)

The results of this study correspond to the results of Tsakiris et al. (2011) who observed that distortions in body-ownership following exteroceptive visuo-tactile stimulation were significantly predicted ($r^2 = 0.06$, $b = -3.56$, $p < 0.05$) by lowered interoceptive accuracy (15). This demonstrates that participants with less interoceptive accuracy had a stronger sense of non-body ownership, which seems to suggest that the representation of one's body relies on the integrative effects of interoceptive as well as exteroceptive information (15). Additional corresponding results are from Valenzuela et al. (2017) who also reported an inverse correlation between the MAIA-2 *body listening* and exteroceptive body awareness ($r = -.355$, $p = .001$), indicating that participants who reported higher scores on whether they actively listen to their body for insight showed higher exteroceptive body awareness scores (16). However, the interpretation of the relationship in the study of Valenzuela et al. (2017) is opposite to this study, since higher scores indicated lower exteroceptive body awareness in the study of Valenzuela et al. (2017). In addition, the study sample consisted of chronic pain as well as non-clinical cases. On baseline, the chronic pain group showed significantly ($t = 2.209$, $p = 0.03$; $d = 0.61$) higher exteroceptive body awareness scores compared to the non-clinical cases (16). This could also have influenced the relationship, since it has been demonstrated that exteroception seems lowered in chronic pain condition (7–9).

In contrast to the results of this study, Valenzuela et al. (2017) observed no correlation between the MAIA-2 *trusting* and exteroceptive body awareness (16). This may be because in this study, the MAIA-2 *trusting* is acting as a suppressor variable between the MAIA-2 *body listening* and the ITAD overall accuracy score (37,38). The MAIA-2 *trusting* individually is unrelated to the ITAD overall accuracy score. However, the MAIA-2 *trusting* seems to explain a significant proportion of the MAIA-2 *body listening*, which is unrelated to the ITAD overall accuracy score (37,38). This reduces the proportion of unrelated variance in the MAIA-2 *body listening* to the ITAD overall accuracy score. As a result, the proportion of shared variance between the MAIA-2 *body listening* and the ITAD overall accuracy score is increased. In essence, the MAIA-2 *trusting* enhances the relationship between MAIA-2 *body listening* and the ITAD overall accuracy score (37,38). Additional contrasting results are from Ainley et al. (2012, 2013), who demonstrated a significant improvement in interoceptive accuracy after various visual self-observations methods i.e. mirror self-observation ($F(1,107) = 6.70$, $p = .01$), bodily self-condition ($t(40) = 2.51$, $p = .02$) as well as narrative self-condition ($t(40) = 2.77$, $p = .01$) (39,40). These results suggest that participants who focus their attention on visual self-observation showed an increase in interoceptive accuracy. A possible explanation for this result is that interoceptive accuracy as well as visual self-observation seem to be processed in the insular cortex (39–41), which is considered part of the interoceptive network (12). This may have allowed for the attentional focus to be directed towards the interoceptive modality, instead of both the interoceptive and the exteroceptive modality. Which may have resulted in the increase in interoceptive accuracy, since attentional focus did not have to be divided between two modalities.

The aforementioned studies, including this study, collectively suggest that there seems to be a relationship between interoception and exteroception. However, the direction of the relationship is not straightforward and possibly bidirectional. Yet, the MAIA-2 *body listening* subscale seems to be a relevant subscale since it has been significantly correlated to exteroception in both a non-clinical as well as a partially clinical sample. This may support the idea that actively listening to the body for insight might be an important interoceptive dimension in the relationship between interoception and exteroception. A potential explanation for the relationship between the MAIA-2 *body listening* and the ITAD overall accuracy score could be based on the 'competition of cues' hypothesis (42,43). The competition of cues highlights that when attentional focus is directed to one source of information, the other sources of information may receive less attention (42,43). Although this is based on the perception of physical symptom and fatigue (42,43), the essence could apply to this study. When attentional focus is directed towards either actively listening to the body for insight or localizing tactile stimuli, it seems plausible that the other modality may receive less attention and thereby may be perceived less accurate. This line of thought could also apply for a clinical population such as chronic pain, in which has been demonstrated that interoception (22) and exteroception (7–9) are individually lowered. This may be because that the attentional focus in chronic pain cases is directed towards pain or pain-related thoughts, which could result in less accurately perceiving interoceptive as well as exteroceptive information. This highlight the possible difference in forming somatoperceptions in non-clinical and clinical populations

This study contains strengths, first that both interoceptive sensibility and tactile localisation are somatoperceptions. This could have resulted in measurements more closely linked to body representations in comparison to measurements of somatosensation (e.g. tactile stimuli detection). Second, that touch was used as exteroceptive modality. Touch relates relatively strongly to pain, which may be more clinically relevant compared to vision as exteroceptive modality. Third, the multiple partial correlation has enabled to adjust for the effects of age and gender on the MAIA-2 subscales as well as the ITAD overall accuracy score, retaining the shared variances between the MAIA-2 subscales. This may have contributed to more accurate presentation of the underlying relationship. This study also contains some limitations. First, the sample size of this study could have affected the statistical power. Since one subscale demonstrated a small to medium correlation which was nearly significant. A larger sample size may have significantly added this subscale. Second, interoceptive sensibility is an invisible construct, which is difficult to observe and compare to other objective measures (25). This raises the question whether individuals have enough self-knowledge to accurately perceive their internal bodily state using self-reporting measures. However, adding the objective measure of interoception (i.e. interoceptive accuracy by heartbeat detection) would have resulted in measuring two different and not inter-related interoceptive dimensions (14). In addition, interoceptive accuracy may be considered a somatosensation (1,14).

The findings of this study could potentially have clinical benefits. Since patients who experience high-degrees of pain and pain behaviour may benefit from interventions targeting distortions in body representations (e.g. cognitive-behavioural treatments). If patients are focussed on the experience of pain and pain behaviours, the patient could be elicited to redirect attentional focus towards e.g. interoceptive or exteroceptive signals or other relevant bodily sources of information. The results could be twofold, by diverting the attentional focus away from pain and pain-behaviour the degree of pain experience could become less. Additionally, by diverting the attentional focus towards perceiving interoceptive or exteroceptive signals, patients may more accurately perceive these signals. This could allow for the patient to better distinguish between painful and non-painful.

Future research should continue to explore the relationship between interoception and touch in a chronic pain population with a prospective longitudinal study design in order to increase our understanding of the direction of the relationship. In other words, if distortions in body representations result from distorted interoception and exteroception or if distortions in interoception and exteroception result from distorted body representations. Additionally, future research should measure interoceptive sensibility (i.e. the MAIA-2 questionnaire) as well as interoceptive accuracy (i.e. heartbeat detection tasks) in order to obtain multiple measures of interoception, which would strengthen the validity of measuring the interoceptive construct.

CONCLUSION

In conclusion, this study aimed to investigate the relationship between interoceptive sensibility and tactile localisation in a non-clinical sample. The results demonstrate that participants who reported higher scores on whether they actively listen to their body for insight showed lower overall accuracy scores. Also, participants who reported higher scores on whether they experience their body as safe and trustworthy showed higher overall accuracy scores. These findings, combined with current literature, suggest that interoception and exteroception seem to inter-relate, which could potentially be helpful to increase our understanding of distortions in body representations in non-clinical and clinical samples.

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