



Gender differences in interoceptive accuracy and emotional ability: An explanation for incompatible findings

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ABSTRACT

Most theories of emotion describe a crucial role for interoceptive accuracy, the perception of the body's internal physiological signals, in emotional experience. Despite support for interoceptive accuracy's role in emotion, findings of gender differences in emotional and interoceptive processing are incompatible with theory; women typically show poorer interoceptive accuracy, but women often outperform men on measures of emotional processing and recognition. This suggests a need to re-evaluate the relationship between interoceptive accuracy and emotion considering sex and gender. Here we extend Pennebaker and Roberts' (1992) theory of gender differences in the use of interoceptive signals for emotional experience, proposing that language socialisation may result in gender differences in the propensity to label internal state changes as physiological or emotional, respectively. Despite outstanding questions concerning the fractionation of interoceptive and emotional domains, this theory provides a plausible explanation for seemingly incompatible findings of gender differences in interoceptive and emotional abilities.

Interoception is a multidimensional construct that refers to the processing of internal bodily sensations (e.g., from the heart, stomach, lungs) at various levels (Craig, 2002; Suksasilp and Garfinkel, 2022), including accuracy (perception; performance on objective tests), attention (engagement) and insight (metacognition; Khalsa et al., 2018; Suksasilp and Garfinkel, 2022). Interoception, particularly interoceptive accuracy, has long been linked to emotional ability,¹ with almost every theory of emotion ascribing a fundamental role to the perception of interoceptive signals in emotional experience (Critchley and Nagai, 2012; Damasio, 1994; Damasio et al., 1991; Gendron and Barrett, 2009; James, 1894; Schachter and Singer, 1962; Seth, 2013). Whilst early theories suggested that emotions arise from changes in the body's physiological state (e.g., James, 1984), later theories highlighted that it is the combination of both physiological arousal and interpretation of the context that determines emotional labelling (Schachter and Singer, 1962). Most contemporary theories are in line with this tradition; for example, contemporary constructivist approaches highlight a role for "sensory stimulation from inside the body" in addition to cognitive

components (see Gendron and Barrett, 2009 for a review). Similarly, predictive coding models suggest that emotions arise from active inference regarding the likely internal and external cause(s) of changes in the body's physiological state (Seth, 2013). Whilst these theories differ in some respects, all propose that perceiving a change in the body's internal state is crucial for emotional experience, suggesting that individuals who have difficulties perceiving internal bodily states (poor interoceptive accuracy) should have difficulties with emotion.

1. Interoceptive accuracy and emotional processing

Consistent with these theoretical proposals, evidence suggests a positive association between interoceptive accuracy and emotional ability (e.g., Critchley and Garfinkel, 2017; Füstös et al., 2013; Koch and Pollatos, 2014; Terasawa et al., 2014; Wiens et al., 2000; although this may vary with age, i.e., Schaan et al., 2019). In terms of emotional processing, better cardiac interoceptive accuracy correlates with enhanced emotional self-regulation (Weiss et al., 2014), the use of more

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¹ Emotional ability encompasses both processing and regulation of one's own emotions (hereafter referred to as 'emotional processing') and recognition of others' emotions (hereafter 'emotional recognition').

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reappraisal and suppression strategies (Kever et al., 2015), and appears to facilitate the downregulation of emotional arousal through the use of reappraisal strategies (Füstös et al., 2013). Those with greater cardiac interoceptive accuracy also demonstrate more arousal in response to emotional images or film clips (Dunn et al., 2010; Wiens et al., 2000), indicating a positive relationship between interoceptive accuracy and emotional intensity. In terms of emotion recognition, evidence suggests cardiac interoceptive accuracy is also positively associated with emotional intelligence (in children; Koch and Pollatos, 2014) and the recognition of others' facial expressions (Terasawa et al., 2014, 2021). Whilst recent evidence highlights a possible role for other aspects of interoception (e.g., interoceptive insight; Mulcahy et al., 2019; Schuette et al., 2021), overall it is interoceptive accuracy *specifically* that has been routinely linked with various aspects of emotional ability, in line with theoretical proposals.

2. Gender differences in interoceptive accuracy and emotion

Whilst both theory and evidence indicate a positive association between interoceptive accuracy and emotional ability, these findings appear inconsistent with results concerning gender differences² in interoceptive and emotional ability. Compared to men, women exhibit worse interoceptive accuracy across numerous domains (blood glucose levels: Cox et al., 1985; respiration: Harver et al., 1993; blood pressure: Pennebaker and Watson, 1988; nicotine: Perkins, 1999; sexual concordance: Suschinsky and Lalumière, 2012; gastric: Whitehead and Drescher, 1980), with findings being most conclusive for cardiac and respiratory interoceptive accuracy (for a review and meta-analysis see Prentice and Murphy, 2022). Conversely, women tend to show an advantage over men in the processing and recognition of their own and other's emotions (e.g., Thompson and Voyer, 2014); women outperform men on the decoding of nonverbal communications, especially in the recognition of others' facial expressions (DePaulo et al., 1982; Hall, 1978; McClure, 2000; Thompson and Voyer, 2014) and emotional vocalisations (Hall, 1978; Thompson and Voyer, 2014). Women also self-report more engagement by their own emotions, demonstrating higher scores for emotional self-awareness (Barrett et al., 2000; Meshkat and Nejadi, 2017), and on measures of 'emotional intelligence' (Fischer et al., 2018).

Findings that women have greater emotional ability than men, despite poorer interoceptive accuracy, are inconsistent with the aforementioned theoretical proposals and empirical evidence that better interoceptive accuracy relates to improved emotional processing and recognition. Indeed, based on the described theory and evidence we would expect that difficulties perceiving interoceptive signals would relate to poorer emotional ability. This suggests a need for further examination of the relationship between interoceptive accuracy and emotional ability, and gender differences within it.

3. Pennebaker and Roberts (1992) theory of gender differences in emotion

By way of an explanation for gender differences in interoceptive accuracy, Pennebaker and Roberts (1992) hypothesised that men and women may rely on different cues when gauging their internal states; men use more internal physiological cues, while women use more external situational ones. For example, when gauging hunger, men may be more likely to use internal sensations in the stomach, while women may rely on cues such as the time of day or when they last ate. Consistent

with this idea, they observed that men outperformed women on tasks of interoceptive accuracy in controlled experimental environments, but that gender differences were absent in more naturalistic settings where external cues could be relied upon (Cox et al., 1985; Pennebaker and Watson, 1988). Pennebaker and Roberts (1992) argued that whilst these findings suggest that women may be able to compensate for difficulties perceiving interoceptive states by relying on external cues (e.g., blood glucose level; Cox et al., 1985), such processing biases may also influence the information men and women use to decode their own and others' emotional states. While men may rely on their physiological signals to detect emotional changes in themselves and others (i.e., James, 1894), women may primarily search for situational cues, with internal signals being of secondary importance (i.e., Schachter and Singer, 1962). Pennebaker and Roberts (1992) therefore suggested that theories of emotion that ascribe a fundamental role for the perception of physiological cues (interoceptive accuracy; e.g., Damasio, 1994; Damasio et al., 1991; Gendron and Barrett, 2009; James, 1894; Schachter and Singer, 1962; Seth, 2013) may only apply to men.

Consistent with the idea that interoceptive accuracy may only relate to emotional ability in men, recent evidence suggests that interoceptive accuracy is positively related to certain emotional regulation strategies in men but is unrelated to emotional regulation in women (Lischke, Pahnke et al., 2020; but see Lischke, Weippert et al., 2020 for conflicting evidence for emotion contagion). In men, interoceptive accuracy was positively correlated with suppression strategies, which are thought to occur at a more 'autonomic and behavioural level', but not more cognitive reappraisal strategies. Suppression strategies have been shown to involve greater engagement of the insula (Giuliani et al., 2011; Goldin et al., 2008; Hayes et al., 2010), an area thought to be important for interoception (Critchley et al., 2004), which may be more active in men compared to women during emotional recognition tasks (Lee et al., 2005). This supports Pennebaker and Roberts (1992) proposal that men may use their interoceptive signals more than women when regulating their emotions.

Whilst evidence is consistent with the idea that men and women rely on different cues for gauging emotional states in themselves and others, the cause(s) of these gender differences remains unknown. Pennebaker and Roberts (1992) explored several possible explanations for these gender differences in the use of physiological cues for emotion, which were primarily biological or social/psychological. In terms of biology, males have been shown to be more physiologically reactive than females (Rauste-von Wright et al., 1981), with arousal often taking longer to return to baseline levels (Sapolsky et al., 1977). The authors suggested that these physiological differences may result in males having a stronger interoceptive signal from which to recognise their internal physiological state which, in turn, may support the use of these signals for emotional processing and recognition. This idea is consistent with more contemporary active inference models of interoception where having an internal signal of a greater magnitude or duration would lead to greater modification of prior expectations about interoceptive signals and therefore more accurate predictions about future states (i.e., less prediction error; Paulus et al., 2019).

In terms of biological explanations, we have proposed that gender differences in interoceptive accuracy and the use of internal versus external cues may be explained, in part, by the increased amount of physical and hormonal change females experience across development that would likely result in greater discrepancies between actual and expected bodily states (i.e., a prediction error; Murphy et al., 2019; Prentice and Murphy, 2022). This is consistent with the absence of gender differences in interoceptive accuracy before early puberty (Koch and Pollatos, 2014; Schaan et al., 2019). If males are, therefore, more accurate at perceiving interoceptive states, then a tendency for males to rely more on interoceptive signals for emotional processing and recognition, is perhaps unsurprising.

Alternatively, Pennebaker and Roberts (1992) proposed that gender differences in interoceptive accuracy and emotion may be the

² Throughout this paper we refer to 'gender differences' as opposed to 'sex differences' unless we are talking specifically about biological or physiological differences between the sexes. Similarly, the terms 'men' or 'boys' and 'women' or 'girls' are used except from when sex differences are discussed, where 'males' and 'females' are referred to.

consequence of different socialisation experiences when learning to understand one's bodily signals. Specifically, they suggest that girls' experiences with menstruation and social attitudes towards menstruation as shameful, unpredictable, and ambiguous may teach girls to mistrust their body's internal signals (Steiner-Adair, 1986; Johnston-Robledo and Chrisler, 2013). Pennebaker and Roberts (1992) also highlight that the historical power imbalance between men and women may result in women needing to demonstrate greater perception of social and emotional cues as a survival mechanism. It is therefore possible that the superior emotional recognition of women compared to men is partially mediated by women having lower social status on average than men (Frieze and Ramsey, 1976; Guterres, 2020). This idea is supported by a study involving leader-subordinate dyads in which subordinates were consistently found to be more attentive to the leader's emotions, with this effect particularly enhanced when the subordinates were women, and the leaders were men (Snodgrass, 1985). Whilst these ideas have not been explored by contemporary research, as stigma surrounding menstruation and gender differences in power and status still exist today (e.g., Guterres, 2020; Johnston-Robledo and Chrisler, 2013), they remain plausible explanations for gender differences in emotional ability.

Whilst the aforementioned explanations are intuitive and provide an explanation for gender differences in interoceptive accuracy and the use of interoceptive signals in emotional processing and recognition (Pennebaker and Roberts, 1992; Murphy et al., 2019), these explanations fail to fully account for women's superior emotional ability in the context of their poorer interoceptive accuracy. Given that all the aforementioned theories of emotion posit a positive relationship between emotion and interoceptive accuracy, women's poorer interoceptive accuracy would be expected to result in poorer emotional ability. Although it is possible that the above theories do not apply to women, and that the positive relationship between interoceptive accuracy and emotional ability is specific to men only (Pennebaker and Roberts, 1992), this seems unlikely given that a positive correlation between interoceptive accuracy and emotional ability has been found in studies where most participants were women (e.g., between interoceptive accuracy and emotional regulation; Weiss et al., 2014). To fully reconcile these findings, theory must be able to explain why women have superior emotional ability despite poorer interoceptive accuracy, but also account for empirical evidence where interoceptive accuracy does relate to emotional ability in samples comprised predominantly of women.

4. The language socialisation hypothesis

One possible mechanism that might explain women's superior emotional ability, despite poorer interoceptive accuracy, is language and specifically an individuals' tendency to interpret their internal state changes as having physiological (i.e., 'purely interoceptive') or emotional causes. As most internal states are ambiguous and overlapping (e.g., a racing heartbeat may indicate excitement, anxiety, the consumption of too much caffeine or exercise) a (potentially pre-conscious) decision must be made about how to interpret these physiological changes. This idea is in line with theories of emotion that posit that once an internal state change is detected it must be interpreted or appraised and inferences are made regarding the likely cause(s) of changes in the body's internal state (Seth, 2013). Importantly, however, most research focusing on interpretation processes has distinguished between the labelling of different emotional states (e.g., excitement, anxiety; Ekman and Friesen, 2003; Thompson and Voyer, 2014), not considering that individuals may also make physiological interpretations (e.g., caffeine consumption, exercise) depending on the context. As such, we argue that in addition to emotional interpretations (e.g., labelling of a racing heartbeat as excitement or anxiety), individuals may also attribute the same physiological change to a physiological cause (e.g., caffeine consumption, exercise). Crucially, as individuals may interpret the same physiological change differently, this

raises the possibility of processing biases. Indeed, it is well accepted that individuals may hold certain biases in the interpretation of their internal states (for example, those with panic disorder are more likely to interpret ambiguous internal signals as threatening; Clark et al., 1997; McNally, 1994). It is therefore plausible that individuals could also display biases in their propensity to label internal state changes as physiological or emotional.

Given this, one possible explanation for gender differences in interoceptive and emotional abilities is that they are the result of a bias in the interpretation of internal states, whereby women are more likely to label ambiguous internal states as emotional while men are more likely to label them as physiological; for example, when experiencing a racing heartbeat, males may be more likely to seek a physiological explanation ('I have drunk too much coffee today') whereas females may be more likely to attribute this internal state to an emotion ('I am stressed and anxious today'). Therefore, the same internal state change may be more likely to be interpreted as having a physiological or emotional cause, in men and women, respectively.

Whilst this theory provides one explanation for gender differences in interoceptive and emotional ability, a question remains regarding how these biases might develop. One plausible explanation is that these may arise during childhood, with the gendered use of language by parents and caregivers leading girls and boys towards more emotional and physiological interpretations of their internal states, respectively. For example, if when a child is crying, parents or caregivers are biased towards emotional interpretations for female children ('she is feeling upset or frustrated') and biased towards more physiological interpretations for male children ('he is feeling tired or unwell'), these differences may have consequences for children's emotional processing in later life. Indeed, if as has been proposed, parental language plays a role in refining and tuning the categorisation of emotional and interoceptive states (Hobson et al., 2019), it likely that children who are exposed to more emotional or physiological labelling of their internal states by caregivers will, in turn, make more emotional and physiological interpretations of their own internal states, respectively, as they will have a greater differentiation of these concepts.

The above theory posits that adults may tend to label boys' ambiguous internal states as physiological and girls' ambiguous internal states as emotional. Consistent with this idea, evidence suggests labelling of internal states is not gender-invariant; mothers interpret different behaviour as indicative of hunger depending on the gender of their child (Wright, 1986). Displays of distress are more likely to be labelled as pain in infant boys than girls, with adults also more likely to rate pain intensity as greater in boys (Cohen et al., 2014). This occurs even when the pain is elicited in identical circumstances and pain expression is identical across genders (Earp et al., 2019). When raters are men specifically, evidence suggests low-pitched cries (indicative of male sex) are labelled as expressing more discomfort than high-pitched cries (indicative of female sex; Reby et al., 2016). Conversely, in a study where women had to rate the reasons why an infant might be crying in a video clip, women made more emotional attributions when they believed the infant was a girl compared to a boy (Leerkes and Siepak, 2006). Similarly, evidence also suggests that at later developmental stages, parents use more emotional language when speaking to or about their daughters, compared to their sons, and this is the case for both mothers and fathers (Fivush et al., 2000; Kuebli and Fivush, 1992; Mascaro et al., 2017). In general, mothers tend to use a greater proportion of emotion terms than fathers (Aznar and Tenenbaum, 2015; Fivush et al., 2000), which is consistent with findings that women engage in more emotional talk in their everyday lives (Goldshmidt and Weller, 2000). The available evidence is therefore consistent with the idea that at early developmental stages girls and boys may receive more exposure to emotional and interoceptive language, respectively.

These differences in internal state labelling are likely to influence the development of the child's internal state language and concepts (e.g., MacCormack et al., 2020). Specifically, one might expect that the

forementioned labelling biases would result in greater complexity of interoceptive and emotional concepts in men and women, respectively. Consistent with this assertion, longitudinal evidence suggests that mothers' more frequent use of emotional language with girls than boys may result in more complexity of emotional language in girls at later developmental stages (Kuebli et al., 1995). Indirect evidence is also consistent with this possibility; for example, the rate of alexithymia (difficulties identifying and describing one's emotions) is higher in men than women (Kokkonen et al., 2001; but see Mason et al., 2005), with evidence that greater endorsement of 'traditional male ideologies' relates to increased alexithymia in men (Levant et al., 2003). This suggests that gender socialisation may contribute towards differences in how men perceive and describe their emotions. Furthermore, observational studies also suggest that girls use more emotional language (Buckner and Fivush, 1998) and display a greater understanding of complex emotions than boys (Bosacki and Moore, 2004), and that both boys and girls are more likely to label a gender-neutral character as female if the character is displaying a happy, sad, or fearful facial expression (Birnbau et al., 1980). These data are therefore consistent with the idea that exposure to emotional language influences a child's later emotional ability.

The contribution of language to interoception is yet to be directly examined. However, if, as has been proposed, the availability of such language concepts contributes towards the ability to recognise such internal states (Hobson et al., 2019), it may be that differences in socialisation contribute to gender differences in recognition (interoceptive accuracy) and interpretation of one's internal states. Specifically, if boys are socialized to use greater and more complex interoceptive language these concepts may be more accessible and well-defined to them. If in turn, these concepts are both better defined and more accessible to boys and men, they may show greater interoceptive accuracy and be more likely to make physiological interpretations of internal signals. This would therefore provide a possible explanation for men's superior interoceptive accuracy, and yet account for their poorer emotional ability compared to women.

Whilst the above focuses on the labelling of one's own internal states, the availability of language concepts, the ability to recognise internal states, and the interaction between these processes, is also likely to influence the recognition of others' emotions and interoceptive states, which can also be highly ambiguous. A body of evidence indicates a relationship between the ability to recognise one's own emotions and the ability to recognise emotions in others (Cook et al., 2013), with novel evidence suggesting a similar pattern for interoceptive states (Gajperia et al., 2022). If, as we propose above, gender differences in the labelling of children's internal states by adults results in gender differences in internal state concepts, these differences could be reflected in the labelling of others' internal states, particularly when these are ambiguous. Indeed, if we use our understanding of our internal states when interpreting the internal states of others, we might expect that men and women would show an advantage in recognising interoceptive and emotional states in others, respectively. Consistently, evidence suggests that female caregivers may be more accurate at perceiving emotional expressions (e.g., pleasure) in infants, compared to expressions of pain and hunger (Sagi, 1981). Conversely, men show higher percentage accuracy (though not significantly so) for expressions of infant pain than anger, compared to women, despite women showing an advantage overall (Wiesenfeld et al., 1981), and fathers appear more accurate than mothers at perceiving pain in children (Moon et al., 2008). Overall, this suggests that when internal states are ambiguous, they may be more likely to be labelled as emotional or physiological in girls and boys, respectively, which in turn may lead towards an advantage (or a bias) for women in recognising emotional states and an advantage (or a bias) for men in recognising interoceptive states in the self and others.

Importantly, such a theory does not rule out the possibility that some women may employ interoceptive signals during emotional processing and recognition. Whilst the available evidence suggests that, on average,

women appear to receive more exposure to emotional language than interoceptive language, experiences of language socialisation may vary across girls and women due to differences in socialisation potentially related to culture and family structure. In addition, it is likely that individual differences in interoceptive accuracy may also influence the relationship between interoceptive accuracy and emotional ability, and whether women and men are more likely to make emotional or physiological interpretations of their internal states. These individual differences may help to explain instances where positive associations between interoceptive accuracy and emotional ability have been reported in samples comprised mostly of women (Weiss et al., 2014). This theory can, therefore, still account for findings of a positive relationship between interoceptive accuracy and emotional ability in some women as it predicts that individual differences in language socialisation and interoceptive accuracy may result in different interpretations of internal signals between individuals of the same gender and/or sex.

Considering potential individual differences, it is notable that language socialisation is proposed to play a role in cross cultural differences in interoceptive and emotional ability (Ma-Kellams, 2014). As hypothesised for women by Pennebaker and Roberts (1992), it has been suggested that the poorer interoceptive accuracy observed in East Asians (Ma-Kellams, 2014; Ma-Kellams et al., 2012) may relate to observed biases towards contextual cues in these individuals (e.g., Kanagawa et al., 2001; Ma-Kellams et al., 2012). Whilst gender differences in interoceptive accuracy have not been examined across cultures, given cultural differences in interoceptive and emotional ability it remains to be seen whether gender differences are observed across all cultures. Indeed, cultural differences have been identified in interoceptive accuracy (Chentsova-Dutton and Dzokoto, 2014; Ma-Kellams et al., 2012), the use of somatic language (Tsai et al., 2004), language socialisation (Schieffelin and Ochs, 1986), adult-child interactions (Keller et al., 2011), and in gender roles and gender stereotypes of emotional expression (Fischer and Manstead, 2000). It is plausible that linguistic differences may play a role in whether gender differences arise; for example, differences may be less apparent in languages and cultures where emotional and interoceptive words are less differentiated (e.g., Tung, 1994). Gendered language socialisation may also be influenced by whether the language contains grammatical genders (e.g., French), is 'naturally gendered' (i.e., has gendered pronouns but not other noun, e.g., English) or is 'genderless' (e.g., Mandarin), with evidence suggesting that gender prejudice is more likely in gendered languages (DeFranza et al., 2020). Whilst more research is needed, it is possible that emotional and physiological interpretations of internal states are differently favoured in different cultures and that gender socialisation is influenced by factors such as language and gender norms.

In summary, gender differences in interoceptive accuracy and emotional ability are incompatible with theory and evidence positing a positive relationship between interoceptive accuracy and emotional ability. Whilst it remains a possibility that other aspects of interoception (attention and insight) and gender differences therein may shed light on seemingly incompatible findings, existing theory and evidence is not able to fully account for women's superior emotional ability in the context of their poorer interoceptive accuracy, compared to men. In this paper we present a novel theory that provides a plausible explanation for ostensibly incompatible gender differences in interoceptive accuracy and emotional ability, suggesting that gender differences may arise from a bias in the interpretation of ambiguous internal bodily states that stems from gender differences in language socialisation. Such a theory builds upon the explanation proposed by Pennebaker and Roberts (1992) which suggests the relationship between interoceptive accuracy and emotional ability may be gender-specific and goes further to highlight the possible role of language socialisation in gender differences. Incompatible findings raise questions regarding whether the established theory that interoceptive accuracy substantially contributes to emotional ability applies to women and highlights a need to examine this relationship across all sexes and genders, and to consider individual

differences therein. However, several outstanding questions remain, for example, whether this theory applies across different interoceptive domains, emotional valences, and cultures. For example, although some interoceptive signals may be positive (e.g., satiation or sexual arousal), more often an interoceptive signal involves a negative deviation from homeostasis. Given this, it may be that hypothesised biases are specific to 'negative' internal states. To fully test the language socialisation hypothesis, future research is needed that examines the relationship between the development of interoceptive and emotional abilities in the self and others and assesses the use of internal state language considering different interoceptive domains, emotional valences, and cultures. Nevertheless, this theory provides a novel framework for investigating the relationship between interoceptive accuracy and emotional ability. Such a framework is critical for understanding both typical and atypical interoceptive and emotional ability, with implications for social and emotional functioning and wellbeing.

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