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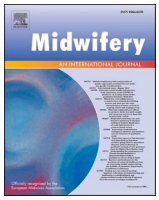

Bonding with bump: Interoceptive sensibility moderates the relationship between pregnancy body satisfaction and antenatal attachment

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ABSTRACT

Problem: There is limited understanding and contradictory results regarding the contribution of the pregnant bodily experience to antenatal attachment.
Background: Antenatal attachment is an important aspect of pregnancy, which has been linked with positive maternal and infant outcomes. Given the profound physical process of pregnancy, it is likely that bodily experience is implicated in antenatal attachment, with research supporting the involvement of pregnancy body (dis) satisfaction. However, previous research reveals conflicting results and has only focused on exteroceptive bodily experience (appearance) rather than internal physiological sensations (interoception).
Aim: To examine the relative contributions of both external and internal bodily experience in antenatal attachment.
Methods: This cross-sectional study collected online survey data from 159 pregnant participants with measures capturing interoceptive sensibility (subjective experience of interoception), pregnancy body dissatisfaction and antenatal attachment.
Findings: We replicated previous findings that pregnancy body dissatisfaction is related to antenatal attachment. However, the relationship between pregnancy body dissatisfaction and antenatal attachment was moderated by worry about interoceptive signals. The interoceptive construct of body trust was most strongly associated with antenatal attachment.
Discussion: The results suggest that interoception is important for antenatal attachment, particularly feelings of body trust. Moreover, for individuals who were less worried about bodily sensations, high levels of body dissatisfaction were associated with low attachment scores, whilst for those who were more concerned about these sensations, the relationship between body dissatisfaction and antenatal attachment was mitigated.
Conclusion: The results suggest that focusing on internal sensations may be a protective strategy against pregnancy body dissatisfaction to strengthen maternal bonds.

Introduction

Antenatal attachment (AA) represents the experience of a bond that a pregnant mother has with their unborn baby (Condon and Corkindale, 1997) and is thought to have beneficial effects for both mother and child. For example, there is a strong link between AA and perinatal depressive symptoms, with a suggestion that a strong bond is protective against developing postnatal depression (Rollè et al., 2020). Additionally, strong AA is associated with better pregnancy health and safety practices (Jussila et al., 2020), as well as stronger postnatal attachments (Trombetta et al., 2021). The experience of pregnancy is overwhelmingly physical, with the fetus growing within the maternal body and connecting to the mother through bodily sensations. Thus, there is an intuitive link between AA and the maternal bodily experience (Kirk and Preston, 2019). For this reason, previous studies have examined the role of pregnancy body satisfaction on AA. However, such studies have uncovered mixed results.

Huang, Wang, and Chen (2004) examined links between AA, body satisfaction and feeding choice in women during their third trimester. The authors found that those with a positive pregnancy body experience have a positive attitude toward the fetus. Conversely, Maïus et al. (2014) investigated women in their second trimester and found *dis*satisfaction

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with the pregnant body was related to stronger bonds. The authors suggested that feeling more dissatisfied with their pregnant body allowed the mother to focus more on the baby. A further study examining pregnant women at different stages during pregnancy did not find a direct relationship between body (dis)satisfaction and AA, instead suggesting that body dissatisfaction moderated the relationship between gestation and AA: those who were more satisfied with their bodily appearance had a strong link between gestational age and AA, whereas those who were dissatisfied with their pregnant body did not demonstrate this relationship (Haedt and Keel, 2007). A more recent study (Kirk and Preston, 2019) examining pregnancy specific body dissatisfaction alongside other known predictors of AA found weaker bonds related to higher body dissatisfaction, with no effect of gestation (on global AA scores). Overall, although bodily experience seems to be important to AA, exactly how this relationship works is unclear. One explanation for this unclear relationship may be because previous studies have focused on feelings towards body appearance, and therefore do not consider the full embodied experience of pregnancy.

When we think of a pregnant body, we typically think of external physical features; most obviously the growing baby bump. However, our bodily experience comprises both external (exteroceptive) and internal (interoceptive) signals (Pink et al., 2021). Interoceptive signals refer to sensations arising from within the body and can convey information about physiological state, such as hunger (Craig, 2002). Many of the physical changes that occur during pregnancy affect interoceptive signals (Shagana et al., 2018). For example, to meet the oxygen demands of the fetus, respiratory rate (i.e., breathing) increases (Jouanne et al., 2021), a sensation detected inside the body. Pelvic girdle pain, a signal that also arises from within the body, is felt due to relaxation of the pelvic ligaments (Larsen et al., 1999). To ensure sufficient oxygen and nutrient delivery to the fetus, cardiac output, (i.e. heart rate) increases (Meah et al., 2016), another sensation felt within the body and thus considered interoception. Movements of the fetus itself could also have direct effects on interoception, such as compromising the size of the bladder and lungs as well as engaging the mother's attention towards their body (Kirk and Preston, 2019). Thoughts, feelings, and interpretations of these signals could also change with pregnancy. For example, pelvic pain can be distressing outside of pregnancy (Young et al., 2015), but during pregnancy, mothers might be able to neutralise their feelings towards pelvic pain by appraising it as a normal part of pregnancy ((Close et al., 2016); page 4).

People vary on how attuned they are to their internal bodily signals and questionnaires have been developed to capture this variance. The subjective experience of interoception (interoceptive sensibility), which incorporates how we feel about and interpret interoceptive signals (Critchley and Garfinkel, 2017) is measured using questionnaires such as the Multidimensional Assessment of Interoceptive Awareness (MAIA; (Mehling et al., 2012). The MAIA captures eight different interoceptive constructs, some of which have potential links to AA. Longitudinal data suggests scores on the body-noticing subscale (subjective awareness of bodily sensations) decrease postnatally relative to pregnancy (Singh Solorzano et al., 2022). This may reflect a switch from awareness of fetus wellbeing (inside the body) to baby wellbeing (outside the body). Furthermore, pregnant people are found to distract less (not-distracting subscale) from bodily signals compared to those not in the perinatal period (Crossland et al., 2022), which could reflect a heightened responsiveness to the fetus's needs. Additionally, the subscale body trust might be important for AA due to its close relationship with body dissatisfaction (Crossland et al., 2022; Todd et al., 2019). Indeed, body trust was found to fully mediate observed differences in body (dis) satisfaction between people with and without children (pregnant and non-pregnant; (Crossland et al., 2022).

There is also a potential moderating effect of interoception on the relationship between body (dis)satisfaction and AA. The competition of cues hypothesis (Pennebaker and Pennebaker, 1982; Pennebaker, 2012) states that attentional resources are finite, such that more attention directed to internal signals leaves fewer resources available for external information, and vice versa. Thus, attention to interoceptive signals may moderate the relationship between body (dis)satisfaction and AA, with greater attention directed internally reducing the role of body (dis) satisfaction on AA. We predict that the most likely construct to drive such a moderation is the not-worrying MAIA subscale. Whilst greater worry about body signals in early pregnancy was found to be related to higher postpartum depression, the same study also found higher levels of worry during pregnancy compared to postpartum (Singh Solorzano et al., 2022) such that some increases in worry about body sensations could be fundamental to pregnancy. Postnatal attachments are thought to be related to increased worry about infant wellbeing (Dubber et al., 2015), which helps ensure appropriate caregiving behaviour and is linked to specific changes in brain regions associated with fear and arousal (Swain, 2008). Thus, during pregnancy, because the baby is developing inside the mother's body, an increase in worry about bodily sensations may be a normal component necessary for AA.

The current study will examine the contributions of interoceptive sensibility and exteroception (body dissatisfaction) on individual differences in AA. Firstly, we will examine whether the interoceptive constructs of trusting, noticing, not-worrying, and not-distracting play a role alongside body dissatisfaction in AA. These constructs were selected due to being implicated in pregnancy and bonding by previous research (Crossland et al., 2022; Singh Solorzano et al., 2022; Noda et al., 2022; Suga et al., 2022). Secondly, in line with the competition of cues hypothesis (Pennebaker, 2012), we predict that (not) worrying about bodily sensations will moderate the relationship between body dissatisfaction and AA, with greater worry about internal signals reducing the importance of body dissatisfaction and thus weakening the relationship.

Methods

The study utilised an Observational Cross-sectional design and is reported according to STROBE guidelines (von Elm et al., 2008).

Data collection procedure

Participants self-selected to participate by responding to advertisements to take part in an online survey hosted by Qualtrics (Provo, UT). The advertisements were distributed via social media sites (Twitter, Facebook), university staff newsletters, parenting websites, groups and classes, and local nurseries. The data were collected across two recruitment windows, both during the COVID-19 pandemic: the first being December 2020-February 2021 (inclusive) and the second being October–December 2021 (inclusive). Data were collected as part of two separate projects and thus two recruitment windows were used to ensure the study was sufficiently powered. The researchers distributing the survey were asked to do so using an approved poster, and to direct participants with questions to the project supervisor. Instructions given on how to complete the measures were copied from the manual of the measures, with clarification added to the MAIA instructions to ensure that participants were responding relative to how they feel during pregnancy.

Participants

To determine the appropriate sample size, we conducted a power analysis for regression in Rstudio (version 4.2.2) (package *pwr)* that suggested a minimum sample of 126 participants. We anticipated a medium effect size ($f2 = 0.15$) based on our previous findings (Crossland et al., 2022), an alpha of 0.05, power of 0.9 and maximum numerator of 9. Participants had to be at least 18 years old, currently pregnant, had not had a miscarriage in the last 12 months, and had no current or historic diagnosis of prenatal depression or an eating disorder. A total of 484 participants started the survey. A total of 119 were excluded for violating the inclusion criteria, 99 of which were eliminated for not

being currently pregnant as this data were collected for the first project addressing a different research question. In line with requirements from our ethical review board, participants were given an option to skip past individual questionnaires, such that 206 participants were removed for missing an entire measure of interest (see below). These participants were removed rather than imputing values due to full constructs being missing and missing data unlikely to be random. There were no missing data at the item level of the questionnaires. Omission of demographic data did not result in participant removal. The final sample consisted of 159 self-reporting pregnant participants, all of whom identified as female except one who identified as non-binary.

Ethical considerations

Ethical approval was granted by the University of York Psychology Department Ethics Committee (ref: 20113 and 21121). All participants gave informed consent on the same survey as the questionnaires before research data were collected from them. Confidentiality was ensured by sharing an anonymous link participants accessed the survey through. This does not collect location or IP address data. We also did not ask for any names or email addresses. Recent experience of miscarriage was included as an exclusion criteria, because although the role of previous pregnancy loss on subsequent attachment is unclear (Tiemeyer et al., 2020), we do know that these experiences can have lasting psychological effects, including anxiety (Farren et al., 2020) and thus could introduce confounding effects on both antenatal attachment and feelings towards the body. Having a historic or current eating disorder or prenatal depression diagnosis was included in the exclusion criteria based on previous research (Fogarty et al., 2018; Rollè et al., 2020) introducing concerns they might have confounding effects on antenatal attachment and the questions asked might be distressing to the participants. To avoid potential unnecessary participant distress, we removed the two items in the attachment questionnaire relating to feelings about wanting to punish the fetus and if the pregnancy was lost. Data were stored on a university-managed secure drive. Participants were given access to a debrief document which listed pregnancy-specific sources of support.

Measures

Multi-dimensional Assessment of Interoceptive Awareness (MAIA; (Mehling et al., 2012)): The original version was used to make results comparable to previous relevant studies in pregnancy (Kirk and Preston, 2019; Crossland et al., 2022; Singh Solorzano et al., 2022) Participants were instructed to answer the questions based on their bodily experience since becoming pregnant. The MAIA is a 32-item self-report questionnaire measuring independent constructs of interoceptive sensibility. Participants indicated how often each statement applies to them since becoming pregnant on a 6-point Likert scale (0 = *never*, 5 = *always*). Participants answered all subscales, but as the current study was focused on four of the subscales, only these are described: (1) *Noticing*, how much an individual is aware of their bodily sensations (4 items; e.g., "I notice when I am uncomfortable in my body."); (2) *Not-distracting*, the tendency not to distract oneself from sensations of pain or discomfort (3 items; e.g., "When I feel pain or discomfort, I try to power through it." [reverse scored]); (3) *Not-worrying*, the tendency not to experience emotional distress with sensations of pain or discomfort (3 items; e.g., "I can notice an unpleasant body sensation without worrying about it."); and (8) *Trusting*, the experience of one's body as safe and trustworthy (3 items; e.g., "I trust my body sensations."). The score for each scale is calculated by the mean of its items. The MAIA has good convergent and discriminant validity and acceptable internal consistency (α=0.66 – 82, Mehling et al., 2011) including with pregnant samples (α=0.66 - 0.90, (Kirk and Preston, 2019)). Using omega, the not-worrying (Ω=0.65) and noticing (Ω=0.68) subscales fell short of standardised cut offs. However, considering our directional hypotheses and that reliability measures are vulnerable to scale length (the not-worrying subscale only has three items), we decided to proceed with the planned analysis. The not-distracting (Ω=0.75) and trusting (Ω=0.81) subscales demonstrated good internal consistency.

The Maternal Antenatal Attachment Scale (MAAS; Condon, 1985): The MAAS is a 19 item self-report scale of AA, comprising two subscales: *Quality of Attachment* (10 items, e.g., "Over the past two weeks I have felt: Very emotionally distant from my baby, Moderately emotionally distant from my baby, Not particularly emotionally close to my baby, Moderately close emotionally to my baby, Very close emotionally to my baby") and *Strength of Intensity of Preoccupation* (8 items, e.g., "Over the past two weeks I have found myself talking to my baby when I am alone: Not at all Occasionally, Frequently, Very frequently, Almost all the time I am alone"). The current study used a Global Attachment Score, which is calculated from the sum of all 19 items (one item does not load on either subscale). Responses are provided on a 5-point likert scale. Condon (1993) reports good reliability with α=0.82 for the total scale. For ethical concerns the current study omitted two items (relating to feelings of wanting to punish the fetus and if the pregnancy were to be lost), but still had good internal consistency (Ω=0.83). Previously it was found that the variance of these excluded items is not significantly predicted by Global MAAS score (Rollè et al., 2020) suggesting these items are not fundamental for capturing AA and thus unlikely to affect the validity or measure reliability of the scale. This scale has been developed and validated for use in pregnant samples.

The Body Understanding Measure for Pregnancy Scale (BUMPs; (Kirk and Preston, 2019)): BUMPs is a 19 item self-report questionnaire designed to specifically capture pregnancy body satisfaction. BUMPs comprises three subscales, *Appearance* (9 items, e.g., "It upsets me when people comment on my changing body"), *Weight* (7 items, e.g., "I am worried about the amount of weight I am putting on") and *Physical* (3 items, e.g., "I get frustrated that I am less physically able than I was before I was pregnant"). Responses are recorded on a 5-point likert scale (1 = *strongly disagree*, 5 = *strongly agree*). Higher scores indicate higher levels of dissatisfaction. BUMPs has good internal consistency across all scales (α= 71 - 0.91; (Kirk and Preston, 2019)). This study used the global measure which is calculated by summing all 19 items and was found to have good internal consistency (Ω = 0.88). This scale has been developed and validated for use in pregnant samples.

To reduce the risk of order bias, all participants completed the measures in a randomised order.

Data analysis

Participants with missing data in the MAAS, MAIA, or BUMPs (i.e., they missed at least one full questionnaire) were removed from all analyses. All analyses were conducted in Rstudio (version 4.2.2; *interactions, stdmod, lm.beta* and *rstatix* packages). Normality of the data were examined using Shapiro Wilks tests. Only BUMPs was normally distributed so correlations used Kendall's Tau (τ) non-parametric analysis (Table 2). We conducted a hierarchical moderated multiple regression on the global score of the MAAS, with our hypothesised predictors (see Table 2) and the interaction between not-worrying (MAIA) and BUMPs. Significant interaction effects from the regression (moderation) were followed up with simple slopes analysis (Bonferroni corrected one samples *t*-tests, critical p= .016) at high (one standard deviation above the mean), moderate (mean) and low (one standard deviation below the mean) levels of the moderator (not-worrying). In accordance with recommendations for interpretation of moderation analysis, predictor variables were mean centred (Muller et al., 2005). To aid interpretation the not-worrying scale was reverse scored for the simple slopes analysis and plots (high scores = high levels of worry).

Results

Participant demographics

Please see table 1 for participant demographics. Gestation data were missing for two individuals ($N = 157$), pre-pregnancy weight information was missing for 12 individuals ($N = 147$), current weight information was missing for 14 individuals ($N = 145$) and weight gain was missing for 18 individuals ($N = 141$).

All measures, except for BUMPs, had significant Shapiro Wilks statistics, suggesting that the distribution of the data was statistically different from a normal distribution. BUMPs, Gestation, MAIA Trusting, MAIA Noticing and MAIA Not-worrying were all found to have significant correlations with antenatal attachment (MAAS; Table 2).

Predictors of antenatal attachment

Previously identified predictors of MAAS with significant zero-order correlations were entered in step 1 (BUMPs, and weeks gestation) using the entry method. Model 1 was significant, explaining 8 % of the variance. BUMPs and gestation were significant predictors. In step 2 we included predicted constructs of interoceptive sensibility with significant zero-order correlations (noticing, body trusting and not-worrying). Model 2 was significant, explaining 21 % of the variance. BUMPs, gestation, not-worrying and body trusting were significant predictors. The interaction between BUMPs and not-worrying was then entered in step 3. Model 3 was significant, explaining 24 % of the variance. BUMPs, gestation, not-worrying, body trusting and the interaction between BUMPs and not-worrying were significant predictors (Table 3). Current or pre-pregnancy BMI along with pregnancy weight gain and not-distracting (MAIA) did not correlate with MAAS so were not included in the regression models.

These results suggest that body trusting was the strongest predictor included in the model. The significant interaction also supports a moderation effect of not-worrying on the relationship between BUMPs and MAAS.

Simple slopes analysis

To follow-up the significant interaction found in the regression model, simple slopes for BUMPs and MAAS were computed at three levels of not-worrying (low, moderate and high). For high levels of worry, the slope did not differ from zero ($t(158) = -0.33$, $p = .74$), whereas for both moderate ($t(158) = -2.82$, $p = .01$) and low ($t(158) = -3.40$, $p < .001$) worry, the slope differed significantly from zero such that higher BUMPs scores were associated with lower MAAS scores (see Fig. 1). Participants who felt more negatively about their bodies during pregnancy were likely to feel less attached to their unborn baby, however the strength of this association was moderated by level of worry towards bodily signals.

Table 1
Sample Characteristics.

	Sample
N	159
Mean maternal age *(SD)*	31.50 *(4.05)*
Mean number of weeks pregnant *(SD)*	25.3 *(8.61)*
Expecting first baby (%)	70
First trimester (%)	8
Second Trimester (%)	45
Third Trimester (%)	47
Married or in a relationship (%)	98
Ethnicity White (%)	80
University Undergraduate Degree or higher (%)	84

Note. For brevity we have reported the percentages of respondents categorised within the majority group for marital status, ethnicity and education.

Discussion

The current results replicate the role of pregnancy body dissatisfaction in antenatal attachment (AA), such that dissatisfaction with the pregnant body is associated with weaker bonds. Furthermore, the current study also shows statistical support for our hypothesised moderation effect in which the relationship between body satisfaction and AA is moderated by individual differences in how much pregnant people worry about their internal bodily signals. High levels of worry about bodily signals reduce the strength of the relationship between pregnancy body dissatisfaction and AA, so that greater dissatisfaction with the pregnant body was not associated with weaker AA. For low and moderate worry however, there was a stronger relationship between these variables, such that greater dissatisfaction with the body was linked to weaker AA and less dissatisfaction with the body was associated with stronger AA. Of our other interoceptive sensibility constructs of interest, only body trusting was significantly related to AA and was the strongest of all included variables.

The moderation effect is consistent with the competition of cues hypothesis (Pennebaker and Pennebaker, 1982; Pennebaker, 2012), such that high attention to one aspect of bodily signals (worry about interoceptive signals) could reduce the importance of other bodily information (body dissatisfaction). This in turn could result in a reduced negative impact of body dissatisfaction on developing AA because body-related evaluations might be based more on how an individual's body feels rather than how it looks. This moderation could also explain previous mixed results in the literature. We found that high body dissatisfaction is associated with stronger AA when accompanied with high worry about interoceptive signals. This might suggest that more focus on internal signals (i.e., high levels of worry) can facilitate AA, even with very negative feelings about body appearance. On the other hand, our results also suggest that any positive effects of low body dissatisfaction on AA may be mitigated by high levels of worry, such that AA might be relatively weaker in those who feel very positive about their body if they are focused more on internal signals (see Fig. 1). Thus, without accounting for individual differences in subjective feelings (worry) about internal signals, this may lead to findings of no direct effect of body satisfaction on AA (Haedt and Keel, 2007) or even that high body dissatisfaction can relate to stronger AA (Małus et al., 2014). However, it should be noted that given the relatively low internal consistency of the not-worrying subscale the moderation effect should be taken with caution.

The interoceptive construct of body trusting was most strongly related to AA. Body trust seems to be an important construct for mental wellbeing, with links to body (dis)satisfaction (Crossland et al., 2022) , depression (Dunne et al., 2021) and now AA. This could also be related to the competition of cues hypothesis (Pennebaker and Pennebaker, 1982; Pennebaker, 2012). Pregnant bodies change dramatically, which is likely to increase the sensory information coming from the body, including that coming from within (interoception). This may mean that maintaining stable representations of the body might require greater mental capacity than when not pregnant. Because attentional resources are finite, this would leave fewer attentional resources available for bonding with the fetus. Therefore, trusting signals from the body might represent a freeing of mental resources, providing the mother with mental availability to focus more on thoughts and feelings about the baby (Condon and Corkindale, 1997).

Limitations

When considering the current findings, we need to do so in the context of the study limitations. First, the MAIA has not been validated for use in pregnant samples. Evidence suggests aspects of interoceptive sensibility change during pregnancy (Crossland et al., 2022; Noda et al., 2022; Singh Solorzano et al., 2022). Thus, interoceptive measures developed in non-pregnant samples may miss important factors relevant

Table 2
Zero Correlations, along with normality tests and descriptives, for Maternal Antenatal Attachment Scale (MAAS) in Relation to Measures of Pregnancy Body Satisfaction, Gestation, Pregnancy BMI measures and interoceptive sensibility.

	Descriptives *n*	Mean	SD	range	Normality Shapiro Wilks	Correlation MAAS Kendall's Tau (τ)
MAAS	159	61.90	8.22	37–78	.977**	-
BUMPs total	159	54.3	14.2	19 – 89	.994	−0.18**
Gestation	157	25.3	8.61	6–40	.97**	0.15*
Pre-pregnancy BMI	147	25.9	5.53	17.3–47	.909***	−0.067
Current BMI	145	28.1	5.64	18.6–47.8	.948***	−0.067
Pregnancy weight gain (Δ in BMI)	141	2.21	2.36	−2.99–10.5	.930***	0.025
MAIA Trusting	159	3.17	1.14	0–5	.955***	−0.25***
MAIA Not- Distracting	159	2.29	1.04	0–5	.978*	0.007
MAIA Noticing	159	3.22	0.93	0–5	.925***	0.120*
MAIA Not- Worrying	159	2.40	0.96	0–4.67	.983*	−0.12*

Note: BUMPs: Body Understanding Measure for Pregnancy scale; MAIA: Multidimensional Assessment of Interoceptive Awareness. * = <0.05, ** = <0.01, *** = <0.001.

Table 3
Summary of hierarchical regression analyses predicting antenatal attachment.

Outcome variable	Model	Predictor	b	R^2	Adjusted R^2	F	Δ R^2	ΔF
Global attachment	Step 1	BUMPs	−0.23**	.092	.08	7.76**		
		Gestation	.16*					
	Step 2	BUMPs	−0.18*	.24	.21	9.46***	.15	9.72***
		Gestation	.16*					
		Not worrying (MAIA)	−0.24**					
		Trusting (MAIA)	.40***					
		Noticing (MAIA)	−0.09					
	Step 3	BUMPs	−0.21**	.27	.24	9.04***	.027	5.50*
		Gestation	.15*					
		Not-worrying (MAIA)	−0.24***					
		Trusting (MAIA)	.38***					
		Noticing (MAIA)	−0.11					
		BUMPs*Not worrying (MAIA)	−0.17*					

Note: BUMPs: Body Understanding Measure for Pregnancy scale; MAIA: Multidimensional Assessment of Interoceptive Awareness.

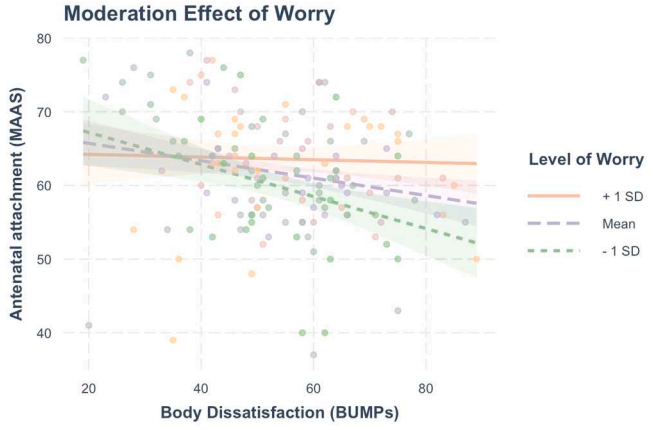

Fig. 1. Graph depicting the moderation effect of the interoceptive sensibility construct, not-worrying, on the relationship between pregnancy body dissatisfaction (BUMPs) and antenatal attachment (MAAS). Slopes represent high, moderate and low worry towards interoception. Scores on the not-worrying scale have been reversed to assist interpretation. Low worry (green dotted line) and moderate worry (purple dashed line) demonstrated significant slopes with high body dissatisfaction associated with weaker attachments and low body dissatisfaction associated with stronger attachments. High worry (orange solid line) reduced this relationship. Shaded sections represent 95 % confidence intervals.

to pregnancy. This concern about validation of the measure is highlighted by low internal consistency for some of the subscales, including not-worrying. Indeed, the not-worrying subscale, although intuitively linked to AA through concern for fetal well-being, focuses on pain and discomfort. Intuitively, the sort of pain and discomfort non-pregnant samples refer to when completing this measure might be different relative to pregnant people when considering the same items.

Second, only 8 % of the sample were in the first trimester of their pregnancy and most of the sample identified as white. The lack of participants in their first trimester is most likely because fewer people realise they are pregnant in their first trimester. The lack of ethnic diversity could be because of the local groups we recruited from. Both these factors could limit the generalizability of these results to a more diverse sample. This is because the ideal body (Winter et al., 2019) and interoceptive sensibility (Freedman et al., 2021) varies between cultures. Also, body dissatisfaction can differ depending on trimester (Crossland et al., 2022). Given that internal body sensations change throughout gestation (Chortatos et al., 2018), it might also be expected that interoceptive sensibility differs between trimesters.

Third, the proportion of variance explained was substantially lower here (8 % in Model 1) compared to previous findings (27 %; (Kirk and Preston, 2019). This discrepancy may have arisen because we did not include all significant variables from the previous study i.e., depression and relationship satisfaction (Kirk and Preston, 2019) Omission these variables might be important in the current study given the context of the global pandemic when the data were collected. COVID-19 put additional strain on the mental health of the populations, and particularly those in the perinatal period (Matvienko-Sikar et al., 2020) and restrictions that kept people at home put relationships under pressure (Schokkenbroek et al., 2021). These factors could have inflated the role of depressive symptoms and relationship satisfaction in AA at the time of data collection, reducing the variance our model could account for.

Fourth, given this was a cross-sectional study, the causality and

direction of this relationship is not certain. The relationship between interoception, body dissatisfaction and AA may be bi-directional. Having a strong AA might encourage mothers to take up health recommendations during pregnancy (e.g. Jussila et al., 2020), some of which could also help limit pregnancy related bodily changes. For example, maintaining a healthy diet and engaging in regular exercise can limit pregnancy weight gain. Such pregnancy weight gain can be a source of body dissatisfaction during pregnancy (Linde et al., 2022). Furthermore, higher BMI is also associated with interoceptive deficits (Robinson et al., 2021). Therefore, it could be that AA is indirectly acting upon body dissatisfaction and interoception through its potential influence on weight gain, rather than body dissatisfaction and interoception acting upon AA. Nevertheless, this study did not uncover a direct relationship between weight gain and AA, which we cautiously deduce as supporting our inferences on the direction of the relationship.

Fifth, although our hypothesised moderated effect was statistically supported, the effect size was small. However, small effect sizes can have important implications for vulnerable individuals (Götz et al., 2022). Moreover, what these results do show is that the relationship between bodily experience and AA is complex, potentially explaining seemingly mixed results in the literature. Our findings also make it clear that the pregnant bodily experience is important for AA. This could introduce vulnerability for individuals who may not be typically considered at-risk prior to pregnancy.

Strengths and implications

In terms of possible implications of these results, our findings suggest that high levels of worry about (or focus on) internal bodily signals could lessen the negative impact of high pregnancy body dissatisfaction on AA. Therefore, interventions that can enhance attentional focus towards internal bodily signals during pregnancy or increase body trust (e.g., mindfulness or yoga; (Koncz et al., 2023; Lima-Araujo et al., 2022)) could help enhance AA for mother's dissatisfied with their pregnant body.

This study may also have implications for pregnant people at risk of postnatal depression. Our research suggests focusing more on interoceptive signals could encourage increased AA, at least in people with high body dissatisfaction. Research indicates tight links between AA and postnatal depression (Rollè et al., 2020), so that ensuring a secure bond prior to birth might offer protection against it. However, previous research has shown that greater worrying scores on the MAIA early on in pregnancy are related to greater depression postnatally (Singh Solorzano et al., 2022). This seems to contradict the current suggestion that high levels of worry about interoceptive signals could be beneficial to AA, at least in mothers with high body dissatisfaction, which could in turn protect them from postnatal depression. However, our results also suggest that high worry about internal body signals is detrimental to bonding *when accompanied with low body dissatisfaction.* When considering the aforementioned link between AA and postnatal depression, this could in turn leave them vulnerable to postnatal depression. Moreover, in a similar way to has been suggested for postnatal bonding, although some worry might be essential to ensure infant/fetal well-being, too much worry could be pathological through hypervigilance (Kim et al., 2016). Therefore, there may be an optimal level of worry about internal bodily signals that could be protective against postnatal depression. In terms of clinical practice, these results advocate for an individual approach, asking pregnant women about body concerns and recommending interventions (e.g., yoga; (Koncz et al., 2023)) for those expressing negative feelings towards their pregnant body.

In conclusion, the current study replicated previous findings that pregnancy body dissatisfaction is important to AA, but suggests a more complex relationship that should also consider feelings about interoceptive sensations. Specifically, the relationship between body dissatisfaction and AA is moderated by worry about body signals, such that high levels of worry weaken the relationship between body dissatisfaction and AA. Additionally, trust in interoceptive signals might also play an important role in AA. Therefore, increased attention to (or worrying about) bodily signals during pregnancy, along with increased body trust, could be protective against the negative effects of body dissatisfaction on AA. These results have implications for maternal care by informing the development of future interventions aimed at strengthening maternal bonds.

CRediT authorship contribution statement

Lucy Stafford: Conceptualization, Data curation, Formal analysis, Funding acquisition, Writing – original draft. **Lydia Munns:** Validation, Writing – review & editing. **Anna E. Crossland:** Validation, Writing – review & editing, Funding acquisition. **Elizabeth Kirk:** Conceptualization, Methodology, Writing – review & editing. **Catherine E.J. Preston:** Conceptualization, Data curation, Formal analysis, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

No potential conflict of interest is reported by the authors.

Statement of significance

Problem: There is limited understanding about the role of the pregnant bodily experience in the strength of antenatal attachment (AA).

What we already know: During pregnancy the mother is connected to the fetus primarily through their bodily sensations. Research suggests that body appearance satisfaction contributes to AA without a consensus as to how. Internal bodily sensations (interoception) have not been considered.

What this paper adds: Interoception is moderates the relationship between body dissatisfaction and AA, suggesting implications for maternity care. Focusing on internal sensations may be a protective strategy against weaker AA in those with pregnancy body dissatisfaction.

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Author contributions

LS and CP conceived the study, analysed data and wrote the original draft. LM, AC, and EK contributed to interpretation of the data and revised and edited the manuscript. All authors read and agreed to the final version of the manuscript.

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