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Investigating the relationship between self-reported interoceptive experience and risk propensity

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ABSTRACT

Risky behaviour may be associated with visceral experiences, such as increased heart rate. Previous studies examining the relationship between perception of such signals (interoception) and risk-taking typically used behavioural tasks with potential for monetary reward. This approach may be less informative for understanding general risk propensity. In addition, such research does not usually consider the varied ways individuals engage with interoceptive signals. However, examining these different forms of engagement may help us understand how subjective experience of interoception influences risk-taking. As such, we performed two surveys (n = 471, primarily young adults) to examine the relationship between self-reported engagement with interoceptive signals (measured using the Multidimensional Assessment of Interoceptive Awareness) and a generalised measure of risk propensity (the General Risk Propensity Scale). Results indicated that different ways of interpreting or engaging with interoceptive signals were differentially associated with risk propensity. In particular, they provide preliminary evidence that those with the ability to ignore or not worry about visceral signals when they are uncomfortable display greater risk propensity (and these effects may possibly be gender-specific).

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Signals from the autonomic nervous system might guide decision-making under uncertainty, possibly by steering us away from potentially harmful outcomes (Bechara et al., 1996, 1997; Damasio et al., 1996; Forte et al., 2022; Lees et al., 2022; Simonovic et al., 2019; Xu & Huang, 2020; but see Dunn et al., 2006; FeldmanHall et al., 2016). Several studies have therefore investigated whether the perception of sensory signals from inside of the body (interoception) modulates risk-taking behaviour. Such research has often focussed on how accuracy in judging one's heart rate (typically referred to as a form of "interoceptive accuracy"; Forkmann et al., 2016; Garfinkel et al., 2015) predicts performance in lab-based and naturalistic monetary decision-making tasks. This has led authors to propose that one's behaviour in risky situations relies in part on effective perception of visceral signals (Kandasamy et al., 2016; Sokol-Hessner et al., 2015; but see Desmedt et al., 2018, 2020; Ring & Brener, 2018; Zamariola et al., 2018 for possible limitations of the heartbeat counting task used in these cases). However, whilst such experiments may outline the potential importance of interoceptive signals for modulating risky behaviour, research using heartbeat counting tasks considers just one very specific interoceptive dimension (i.e., "accuracy") and sub-modality (cardioception), and is less informative about the

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role of different visceral signals (e.g., that arise from the gut or skin) and how individuals may subjectively experience them. The self-reported tendency to focus on and detect interoceptive signals is commonly referred to as "interoceptive sensibility" (Forkmann et al., 2016; Garfinkel et al., 2015), and several questionnaires, which may address a range of interoceptive signals, are proposed to examine this phenomenon (e.g., Longarzo et al., 2015; Mehling et al., 2012, 2018; Porges, 1993; Shields et al., 1989). Interoceptive sensibility has been found to be dissociable from measures of interoceptive accuracy (Forkmann et al., 2016; Garfinkel et al., 2015) and has been proposed to be particularly important for subjective wellbeing (Ferentzi et al., 2019). As such, further study of this interoceptive dimension may provide a more complete picture of the role of interoception in risky behaviour, like those with negative outcomes such as gambling addiction or criminality (e.g., Salvato et al., 2020). It can also help us understand whether the role of interoception in risk-taking is primarily related to the detection of interoceptive signals, or if one's interpretation of these signals may also be important.

On this point, recent evidence for a role of subjective interoceptive experience in risk-taking has been mixed. Neither Herman et al. (2018) nor Herman et al. (2021) observed a statistically significant relationship between self-reported interoceptive experience (measured using the Body Perception Questionnaire, or BPQ, Porges, 1993) and behaviour in risk-taking tasks. However, Salvato et al. (2019) proposed that higher subjective awareness of interoceptive signals predicted more conservative behaviour in a monetary risk-taking task when the stimuli involved were body-related. Specifically, participants performed the Balloon Analogue Risk Task (BART, Lejuez et al., 2002), in which they were required to inflate a virtual balloon. Larger balloons could be redeemed for a greater reward, but if a balloon popped, then nothing was received. In the classic version of the task, Salvato et al. (2019) did not observe a statistically significant relationship between BPQ score and risk-taking (though a Bayesian analysis was uninformative in this regard). However, a negative relationship was observed when the balloons were replaced with a virtual body that could be inflated, suggesting that subjectively experienced interoception may influence risky decision-making in the presence of stimuli related to the body. Conversely, a later study observed that participant responses to the Self Awareness Questionnaire (SAQ, Longarzo et al., 2015) *positively* predicted risk-taking in the classic BART (Baiano et al., 2021), indicating greater risk-taking in those who reported greater engagement with interoceptive signals.

Such varied results are perhaps surprising: one might reasonably expect that the (often) salient, visceral experiences associated with risky behaviour could play a powerful and consistent role in shaping that behaviour. It is important to note though that the frequently used BPQ tends to focus on the subjective *awareness* of negative and neutral visceral sensations, whilst the SAQ focusses on the *frequency* of perceiving negative visceral sensations. Whilst total scores on these two questionnaires do moderately correlate ($r = .48$), they do not appear to align with a single factor in an exploratory factor-analysis containing items from multiple questionnaires designed to measure interoceptive sensibility (Desmedt et al., 2022). That the two questionnaires may be examining different constructs could provide one explanation for divergent results. It is also important to note that neither the BPQ or SAQ examine the more varied ways in which individuals may choose to engage with interoceptive signals (e.g., if they are believed to be useful, or if they can be ignored or downregulated). These broader facets of interoceptive experience may not neatly align with the typical formulation of "interoceptive sensibility" (Desmedt et al., 2022), and may be more informative for understanding how subjective experience of bodily signals influences risk-taking. For example, individuals are likely to have different valuations of the physiological changes associated with risk: whilst some people are attracted to the "rush" associated with risky activities, or might readily ignore or downregulate such sensations, others may find such experiences dominate their perception and are strongly aversive. With this in mind, studying varied ways of experiencing and interpreting interoceptive sensations may be informative regarding individual differences in risk-taking.

Another possible limitation of previous research on the influence of subjective interoceptive experience on risk-taking is that it has focussed on risk-taking in behavioural tasks with the potential for monetary reward. This may be less informative for understanding individual attraction to risky situations more generally (risk propensity). That is, by presenting a gambling context, participants are required to engage with a risky scenario even if, in daily life, they would not choose to engage in other forms of risky behaviour. In addition, lab-based studies investigating monetary risk-taking behaviour usually do not involve real money and/or the potential monetary loss is unremarkable, meaning that even participants who are typically risk averse could decide to take risks without the negative outcomes commonly associated with risky situations. This further makes the relevance for understanding "real life" risk propensity hard to evaluate. Indeed, several researchers have queried the effectiveness of behavioural tasks for assessing propensity to engage in risky behaviour. Although self-report measures can be prone to biases or error in self-perception, for evaluating risk propensity they may possibly exceed behavioural tasks in convergent and predictive validity (Arslan et al., 2020; Frey et al., 2017; Highhouse et al., 2022; Palminteri & Chevallier, 2018; Pedroni et al., 2017). As such, the aim of this study was to better understand how the subjective experience of interoception might relate to self-reported propensity for risk-taking.

To do this, we examined the relationship between self-reported engagement with interoceptive signals and a generalised measure of risk-taking propensity, the General Risk Propensity Scale (GRiPS, Zhang et al., 2019). This is a domain-general measure of risk propensity as a trait, that may capture attraction towards reckless or irresponsible behaviour, and it correlates with summated measures of self-reported domain-specific risk propensity (e.g., financial, health, recreation; Weber et al., 2002). The GRiPS is therefore particularly useful for capturing broad engagement with risky behaviour, rather than specific actions in a narrow context (the study of which may result in inconsistent results across domains). The questionnaire is designed with non-clinical samples in mind and for the assessment of risk propensity as a possible personality trait that varies between healthy adults. In line with the formulation of risk propensity outlined by Zhang et al. (2019) we consider risk propensity as a "cross-situational tendency to engage in behaviours with a prospect of negative consequences such as loss, harm, or failure" (p. 2; Zhang et al., 2019).

To assess subjective engagement with interoceptive signals in a broad manner, we used the Multidimensional Assessment of Interoceptive Awareness (MAIA, Mehling et al., 2012, 2018). The MAIA is perhaps the most popular self-report measure that aims to assess different ways in which individuals engage with interoceptive signals (Desmedt et al., 2022). The questionnaire is proposed to capture the subjective experience of interoception across eight factors: *Noticing* (awareness of uncomfortable, comfortable, and neutral body sensations), *Non-distracting* (tendency not to ignore or distract oneself from sensations of pain or discomfort), *Not-worrying* (tendency not to worry or experience emotional distress with sensations of pain or discomfort), *Attention regulation* (ability to sustain and control attention to body sensations), *Emotional awareness* (awareness of the connection between body sensations and emotional states), *Self-regulation* (ability to regulate distress by attention to body sensations), *Body listening* (active listening to the body for insight), and *Trusting* (experience of one's body as safe and trustworthy).

The second version of the MAIA (MAIA-2) introduced changes to the items included in the *Non-distracting* and *Not-worrying* factors (Mehling et al., 2018). In addition, recent re-evaluation of the MAIA, published around the time we were planning and performing this research, suggested that the original factors may not be as dissociable as originally proposed. It has been suggested that the *Non-distracting* and *Not-worrying* factors may be relatively independent, with the other items being well-explained with a single factor (Ferentzi et al., 2021; see also Calì et al., 2015; Da Costa Silva et al., 2022; Desmedt et al., 2022; Todd et al., 2020, 2022). Such a factor may reflect a more general measure of the extent to which individuals engage with interoceptive signals, perhaps in an adaptive fashion (Desmedt et al., 2022; Ferentzi et al., 2021). It has also been found to moderately correlate with the Body Awareness Questionnaire (Shields et al., 1989), which captures one's ability to notice or predict their body's reaction to internal (e.g., hunger, fatigue) and external (e.g., food, weather) factors (Desmedt et al., 2022; Ferentzi et al., 2021; Vig et al., 2022).

Our work was primarily exploratory, and we decided to examine whether there were relationships between GRiPS and the MAIA-2 factors both in their original and alternative factor structure (Desmedt et al., 2022; Ferentzi et al., 2021; Vig et al., 2022). Given the proposal that visceral sensations play a role in warning individuals away from potentially negative outcomes, we had originally, and tentatively, hypothesised that we might observe selective relationships between propensity for risk-taking and MAIA-2 factors with the original factor structure. Namely, we expected that those who are more aware of their bodily sensations (*Noticing*) and listen to their body for insight (*Body listening*) may be less likely to take risks due to increased salience of the physiological changes associated with risk. We also hypothesised that those who trust in their bodily sensations (*Trusting*) could be less likely to take risks since they perceive physiological responses (such as an increase in heart rate) as more reliable for guiding their behaviour. However, given that the MAIA factor structure has been questioned, we also decided to assess the relationship between a general MAIA factor ($MAIA_g$, containing six of the original factors) and GRiPS. We performed two surveys to evaluate these possible links between subjective interoceptive experience and risk propensity.

1. Survey 1

1.1. Method

1.1.1. Participants

We aimed to recruit at least 200 participants. Assuming a statistical power of 80%, this sample size is sensitive to detect population correlations of $\rho = .2$ (two-tailed). We recruited 301 undergraduate students from the University of Stirling, all of which had no self-reported mental health condition (e.g., anxiety, depression). These students received course tokens for taking part, which contributed to their completion of Psychology modules. Following exclusions (see below), we retained 255 participants (184 women, 67 men, 4 non-binary individuals) aged between 18 and 53, mean ± SD age = 20.5 ± 4.46 years. All participants provided informed consent, and ethical approval was provided by The University of Stirling NHS, Invasive & Clinical Research Ethics Committee (approval code: NICR 2021 0173 1541).

1.1.2. Materials and apparatus

Three questionnaires were presented within the University of Stirling Psychology participant recruitment system (Sona Systems, https://www.sona-systems.com). To assess risk propensity, we used the GRiPS questionnaire (Zhang et al., 2019). Participants were asked to indicate their level of agreement to eight statements (such as "Taking risks makes life more fun") on a scale from 1 ("Strongly disagree") to 5 ("Strongly agree"). The GRiPS has a 3-month test-retest reliability of r = 0.80.

Subjective engagement with interoception was assessed using the MAIA-2 (Mehling et al., 2018). The MAIA-2 includes 37 items to which participants reported how often each statement applies to them generally in daily life, using a 6-point scale from 0 ("Never") to 5 ("Always'). To ensure participants were not responding randomly, a foil statement was added alongside the MAIA-2 items ("If you are paying attention, please select number 5: Always').

Finally, since self-reported interoceptive experience might feasibly be confounded by trait anxiety (Garfinkel et al., 2016), we also used the Beck Anxiety Inventory-Trait (BAIT) questionnaire (Kohn et al., 2008). The BAIT includes 21 anxiety-related experiences (e.g., fear of losing control, hot/cold sweats) to which participants are asked to report how much they are bothered by each on a day-to-day basis. Responses are provided using a 4-point scale from 0 ("Rarely or never") to 3 ("Almost always'). The BAIT has been reported to have a test-retest reliability of r = 0.83. A foil statement was also added to the BAIT ("If you are paying attention, please select "Almost always"").

1.1.3. Procedure

Participants completed surveys on their personal computers at a time and place of their choosing, and took between 2 and 36 min to do so (mean ± SD = 7.65 ± 3.92 min for included participants). First, participants were informed about the requirements of the survey before providing consent. After reporting their age in years and gender, participants were presented with the three questionnaires (GRiPS, MAIA-2, BAIT) in a random order. Questionnaires were presented on separate pages, and the order of items within each questionnaire was randomised. Participants were then debriefed regarding the background and aims of the project and given guidance on how they might withdraw their data if desired.

1.1.4. Data analysis

Participants were excluded if they failed to fill in all survey items or if they failed any of the foil questions (leaving 255 participants). All analyses were performed in jamovi (The Jamovi Project, 2021). Reliability for GRiPS items, BAIT items, and MAIA-2 factors were assessed with Cronbach's alpha.

We generated a GRiPS score by calculating the mean of the eight GRiPS items. The eight MAIA-2 factors (*Noticing*, *Non-distracting*, *Not-worrying*, *Attention regulation*, *Emotional awareness*, *Self-regulation*, *Body listening*, *Trusting*) were calculated by taking the mean of the relevant items, reverse coding where necessary. $MAIA_g$ was calculated using the mean of the items for six MAIA-2 factors, excluding *Non-distracting* and *Not-worrying*. A BAIT score was generated for each participant by summing response values for all items.

Eight partial correlations were performed to examine the relationship between MAIA-2 factors and GRiPS score, whilst controlling for trait anxiety with the BAIT score. A further partial correlation was performed for the $MAIA_g$ factor. Since a Shapiro–Wilk test indicated that the distribution of GRiPS scores deviated from normality, Spearman's rank correlation was used. To account for an increased false-positive rate when performing nine correlations in an exploratory analysis, a Bonferroni-corrected alpha threshold of .00556 was used for assessing statistical significance.

1.2. Results

Acceptable reliability was observed for the GRiPS ($\alpha = .920$) and BAIT ($\alpha = .913$) questionnaires, as well as for $MAIA_g$ ($\alpha = .917$) and the MAIA-2 factors *Non-distracting* ($\alpha = .789$), *Attention regulation* ($\alpha = .820$), *Emotional awareness* ($\alpha = .738$), *Self-regulation* ($\alpha = .817$), and *Trusting* ($\alpha = .801$). The MAIA-2 factors *Noticing* ($\alpha = .618$), *Not-worrying* ($\alpha = .691$), and *Body listening* ($\alpha = .661$) had poorer reliability.

When controlling for BAIT scores, we observed a statistically significant negative partial correlation between GRiPS score and *Non-distracting* ($r_s = -.178$, $p = .00437$, Figure 1). We also observed a statistically significant positive partial correlation between GRiPS score and *Emotional awareness* ($r_s = .263$, $p < .001$, Figure 1). Statistically significant positive correlations at an uncorrected alpha threshold were observed for *Not-worrying* ($r_s = .163$, $p = .00941$), *Attention regulation* ($r_s = .141$, $p = .0245$), and *Self-regulation* ($r_s = .126$, $p = .0453$). There was no statistically significant partial correlation between GRiPS and *Noticing* ($r_s = .122$, $p = .0513$), *Body listening* ($r_s = .0939$, $p = .136$), or *Trusting* ($r_s = .0862$, $p = .171$). The partial correlation between $MAIA_g$ and GRiPS score was not statistically significant at a corrected alpha threshold ($r_s = .159$, $p = .0110$).

1.3. Discussion

We examined whether there is a relationship between subjective experience of interoception and self-reported risk-taking behaviour. In contrast to our hypotheses, we did not observe statistically significant negative associations between GRiPS score and *Noticing*, *Body listening*, and *Trusting*. Instead, all other partial correlations had a *p*-value less than .05, with two considered statistically significant at a corrected alpha level: a negative correlation between GRiPS score and *Non-distracting* and a positive correlation between GRiPS score and *Emotional awareness*. To verify these findings, we repeated the survey with the aim of trying to replicate the results.

2. Survey 2

2.1. Method

Unless otherwise stated, all materials and procedures were identical to Survey 1.

2.1.1. Participants

Prolific (https://www.prolific.co/) was used for recruitment of participants from the general public. We recruited 220 participants based in the UK, aged between 18 and 25 years (i.e., a similarly aged population to Survey 1), without an ongoing mental health condition. Participants received monetary compensation for their time, equivalent to £7.50 per hour. Following exclusions, we retained 216 participants (136 women, 79 men, 1 non-binary individual) aged between 18 and 25 years, mean ± SD age = 22.1 ± 1.99 years.

2.1.2. Materials and apparatus

In this survey the questionnaires were presented through Qualtrics (https://www.qualtrics.com/). Participants used their own smartphone, tablet, or computer to take part. They took between 2 and 20 min to complete the survey (mean ± SD = 5.53 ± 2.93 min for included participants).

2.2. Results

2.2.1. Reliability and partial correlation

Acceptable reliability was observed for the GRiPS ($\alpha = .933$) and BAIT ($\alpha = .914$) questionnaires, as well as for $MAIA_g$ ($\alpha = .929$) and the MAIA-2 factors *Non-distracting* ($\alpha = .782$), *Attention regulation* ($\alpha = .839$), *Emotional awareness* ($\alpha = .759$), *Self-regulation* ($\alpha = .804$), *Body listening* ($\alpha = .721$), and *Trusting* ($\alpha = .753$). The MAIA-2 factors *Noticing* ($\alpha = .608$) and *Not-worrying* ($\alpha = .657$) had poorer reliability.

When controlling for BAIT scores, statistically significant positive partial correlations were observed

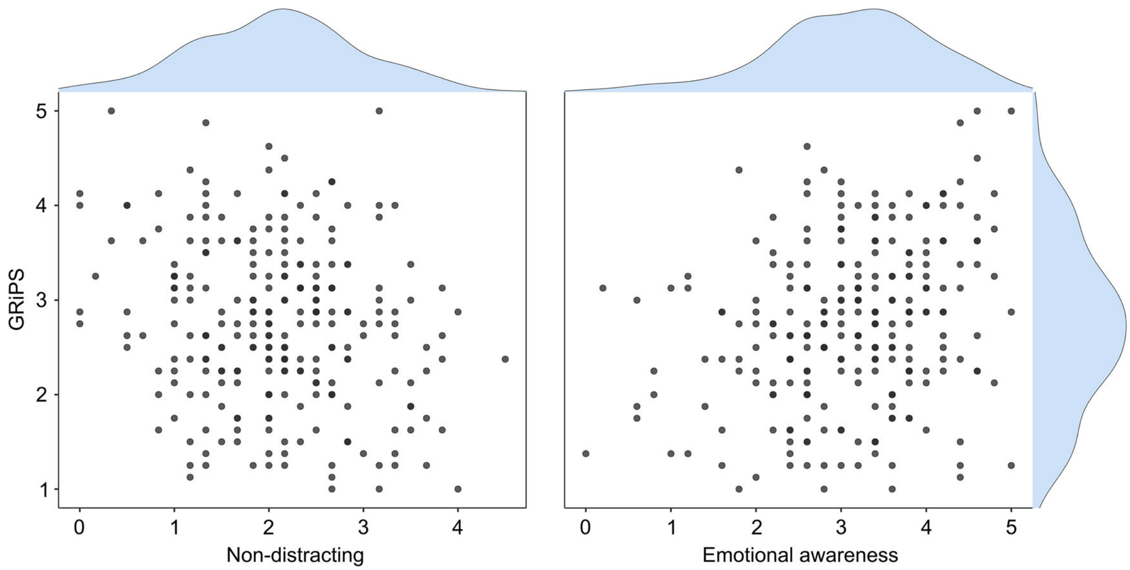

Figure 1. Scatterplots and distributions for GRiPS and *Non-distracting*, GRiPS and *Emotional awareness* (Survey 1). A lower GRiPS score indicates lower risk propensity. A lower score for *Non-distracting* suggests a greater tendency to ignore or distract oneself from sensations of pain or discomfort. A lower score for *Emotional awareness* suggests a lower awareness of the connection between body sensations and emotional states.

between GRiPS score and *Noticing* ($r_s = .230$, $p < .001$), *Attention regulation* ($r_s = .379$, $p < 001$), *Emotional awareness* ($r_s = .290$, $p < .001$), *Self-regulation* ($r_s = .273$, $p < .001$), *Body listening* ($r_s = .242$, $p < .001$), and *Trusting* ($r_s = .190$, $p = .00514$). A statistically significant negative partial correlation was observed between *Non-distracting* and GRiPS score ($r_s = -.265$, $p < .001$). There was no statistically significant correlation between GRiPS score and *Not-worrying* at the corrected alpha threshold ($r_s = .164$, $p = .0160$). There was a statistically significant positive partial correlation between $MAIA_g$ and GRiPS score ($r_s = .340$, $p < .001$).

2.2.2. Multiple regression with a combined dataset

Given the non-specificity of the correlation results in Survey 2, we decided post hoc to use multiple regression to see whether any MAIA-2 factors (particularly *Non-distracting* and *Emotional awareness*) could predict GRiPS score whilst other factors are held constant. To make the most of the data we collected and to minimise the influence of between-sample differences, we combined the datasets from both surveys and also included age and gender (dummy coded, man = 0, woman = 1) as predictors. For this analysis the sample consisted of 466 participants, with five

Table 1. Multiple linear regression using original MAIA-2 factors.

Predictor	Standardised estimate	Estimate	SE	t	*p*
Intercept		2.39	0.360	6.63	<.001
Age	−.0516	−0.0121	0.0102	−1.18	.238
Gender	−.179	−0.329	0.0851	−3.87	<.001
BAIT	.0460	0.00391	0.00449	0.870	.385
Noticing	−.0149	−0.0154	0.0614	−0.250	.803
Non-distracting	−0.157	−0.162	0.0468	−3.46	<.001
Not-worrying	.130	0.135	0.0529	2.55	.0112
Attention regulation	.123	0.124	0.0750	1.65	.0996
Emotional awareness	.261	0.240	0.0525	4.58	<.001
Self-regulation	−.0420	−0.0346	0.0540	−0.640	.522
Body listening	.0306	0.0268	0.0540	0.496	.620
Trusting	−.0860	−0.0685	0.0465	−1.47	.142

non-binary participants excluded due to the dummy coding of gender. As with our correlation analyses, we used the MAIA-2 in both the original and an alternative factor structure (Desmedt et al., 2022; Ferentzi et al., 2021). This required two regression analyses.

In the first regression, the independent variables were age, gender, BAIT score, and MAIA-2 factors. In the second regression, the independent variables were age, gender, BAIT score, *Non-distracting*, *Not-worrying*, and $MAIA_g$. Regression was performed using the "Enter" method, and the suitability of the analysis was confirmed by checking for the linearity of the relationship between independent and dependent variables, the absence of outliers (standardised residual > |3|), the independence of observations, homoscedasticity, normal distribution of residuals, and absence of multicollinearity. Participants with a standardised residual > |3| were excluded from analysis.

The first multiple linear regression suggested that age, gender, responses to the BAIT, and MAIA-2 could predict 15.5% of the variance in GRiPS score, $F(11,453) = 8.76$, $p < .001$, adj. $R^2 = .155$. Gender and *Non-distracting* were statistically significant negative predictors. *Not-worrying* and *Emotional awareness* were statistically significant positive predictors (Table 1).

The second multiple linear regression suggested that age, gender, BAIT, *Non-distracting*, *Not-worrying*, and $MAIA_g$ could predict 11.7% of the variance in GRiPS score, $F(6,459) = 11.3$, $p < .001$, adj. $R^2 = .117$. Gender and *Non-distracting* were statistically significant negative predictors (Figure 2). *Not-worrying* and $MAIA_g$ were statistically significant positive predictors (Table 2, Figure 2).

Given that gender had the strongest relationship with GRiPS score, interactions with gender were not evaluated, and that our sample was mainly composed of women, at the suggestion of a peer reviewer we repeated our regression analyses separately for men and women (Tables 3 and 4). We observed that for women including all MAIA-2 factors as predictors with BAIT and age predicted 14.5% of the variance in GRiPS score, $F(10,309) = 6.39$, $p < .001$, adj. $R^2 = .145$. *Non-distracting* and *Trusting* were statistically significant negative predictors, whilst *Emotional awareness* was a statistically significant positive predictor. The comparable analysis for men predicted 17.2% of the variance in GRiPS score, $F(10,134) = 3.98$, $p < .001$, adj. $R^2 = .172$. However, in this case *Not-worrying* and *Attention regulation* were statistically significant positive predictors.

The second multiple linear regression for women suggested that age, gender, BAIT, *Non-distracting*, *Not-worrying*, and $MAIA_g$ could predict 11.0% of the variance in GRiPS score, $F(5,313) = 8.89$, $p < .001$, adj. $R^2 = .110$. Age and *Non-distracting* were statistically significant negative predictors, whilst $MAIA_g$ was a statistically significant positive predictor. The comparable analysis for men predicted 14.1% of the variance in GRiPS score, $F(5,139) = 5.72$, $p < .001$, adj. $R^2 = .141$. *Not-worrying* and $MAIA_g$ were statistically significant positive predictors.

3. General discussion

In two surveys we examined the relationship between subjective interoceptive experience (assessed using the MAIA-2) and self-reported risk propensity (assessed using the GRiPS). We performed analyses using both the original (Mehling et al., 2018) and an alternative MAIA-2 factor structure (*Non-distracting*, *Not-worrying*, and $MAIA_g$). In Survey 1 we observed statistically significant (corrected) correlations between GRiPS score and the *Non-distracting* and *Emotional awareness* factors. However, the results of Survey 2 brought into question the specificity of these findings. In keeping with the fact that most MAIA-2 factors displayed uncorrected statistically significant correlations with GRiPS score in Survey 1, all MAIA-2 factors (except *Not-worrying*) and $MAIA_g$ were statistically significantly correlated with GRiPS score (when using a corrected alpha threshold). As such, we performed post hoc multiple regression analyses using our full sample to evaluate which variables might *predict* GRiPS score. Our first multiple regression analysis revealed that gender and *Non-distracting* were negative predictors whilst *Not-worrying* and *Emotional awareness* were positive predictors of GRiPS score. Our second multiple regression analysis revealed that gender and *Non-distracting* were negative predictors whilst *Not-worrying* and $MAIA_g$ were positive predictors of GRiPS score. However, analysing men and women separately revealed differences in the variables related to GRiPS score for the two groups. For women, the first analysis revealed that *Non-distracting* and *Trusting* were negative predictors, whilst *Emotional awareness* was a positive predictor. In the second analysis, Age and *Non-distracting* were negative predictors, whilst $MAIA_g$ was a positive predictor. For men, the first analysis indicated that *Not-*

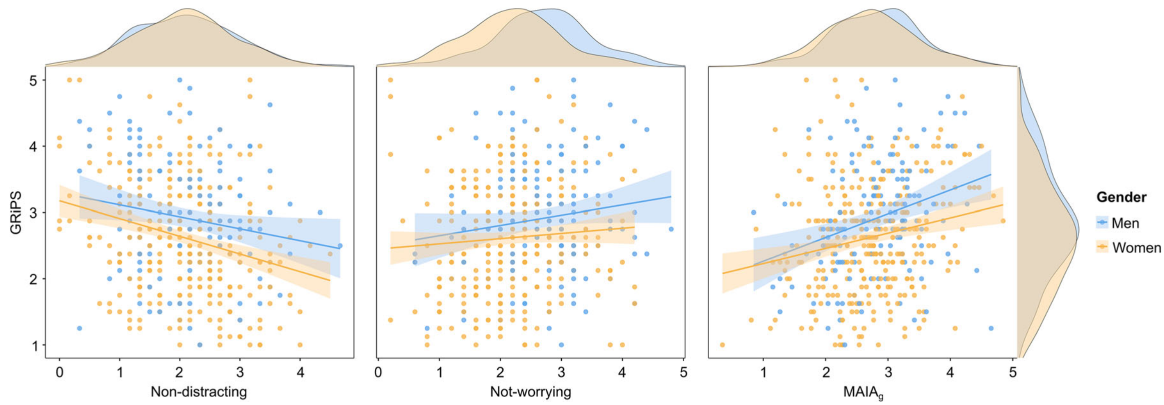

Figure 2. Scatter plots, distributions, and linear fit lines with standard error for GRiPS and *Non-distracting*, *Not-worrying*, $MAIA_g$ (combined sample). A lower GRiPS score indicates lower risk propensity. A lower score for *Non-distracting* suggests a greater tendency to ignore or distract oneself from sensations of pain or discomfort. A lower score for *Not-worrying* suggests a greater tendency to worry or experience emotional distress with sensations of pain or discomfort. All men and women from the combined sample are displayed, but note that some regression analyses had exclusions (never more than 1 participant in any single analysis, when standardised residual > |3|).

worrying and *Attention regulation* were positive predictors, whilst the second analysis revealed that *Not-worrying* and $MAIA_g$ were positive predictors.

3.1. Correlation

Before considering our results it is important to emphasise that this work was primarily exploratory, and that our key findings arise from post hoc analysis. Furthermore, there has recently been debate regarding the suitability of the original factor structure proposed for the MAIA, which may challenge our original goal of examining the link between risk propensity and different ways of engaging with interoceptive sensations (discussed in more detail below). As such, we first tentatively discuss findings aligned with the original structure, and then consider results attained using an alternative structure. Notably, our correlation results revealed relationships between all MAIA-2 factors and GRiPS score in at least one survey. This was not in keeping with our hypotheses for specific relationships with *Noticing*, *Body listening*, and *Trusting*, which were based on influential previous work proposing a role for interoceptive signals in steering individuals away from risky decisions (e.g., Bechara et al., 1996, 1997; Damasio et al., 1996). We theorised that such processes could feasibly be reflected in the subjective experience of interoception, such that those who notice these signals, listen to them for insight, and trust in them would be most likely to avoid risky behaviour.

Interestingly, such relationships were observed in the opposite direction. Whilst this may appear to be contrary to the proposal that visceral signals can play a role in guiding one away from risks (Bechara et al., 1996, 1997; Damasio et al., 1996; Forte et al., 2022; Lees et al., 2022; Simonovic et al., 2019; Xu & Huang, 2020), it is important to recognise that such research focused on objective physiological signals like perspiration (measured using skin conductance), rather than if and how these signals are perceived and interpreted. Indeed, that subjective engagement with bodily states might be related to behaviour in different ways to the bodily states themselves might be in keeping with distinctions that have been made between "interoceptive accuracy" and

Table 2. Multiple linear regression using alternative MAIA-2 factor structure.

Predictor	Standardised estimate	Estimate	SE	t	*p*
Intercept		2.52	0.354	7.13	<.001
Age	−.0554	−0.0130	0.0105	−1.24	.214
Gender	−.148	−0.274	0.0862	−3.18	.00160
BAIT	.0868	0.00739	0.00429	1.72	.0854
Non-distracting	−.170	−0.175	0.0474	−3.69	<.001
Not-worrying	.0964	0.101	0.0511	1.97	.0497
$MAIA_g$	.211	0.246	0.0531	4.63	<.001

Table 3. Multiple linear regression using original MAIA-2 factors, split by gender.

Gender	Predictor	Standardised estimate	Estimate	SE	t	*p*
Women	Intercept		2.53	0.404	6.27	<.001
	Age	−.103	−0.0222	0.0115	−1.93	.0551
	BAIT	−.0177	−0.00140	0.00497	−0.283	.778
	Noticing	.0228	0.0235	0.0731	0.321	.748
	Non-distracting	−.201	−0.203	0.0560	−3.62	<.001
	Not-worrying	.0977	0.105	0.0648	1.62	.107
	Attention regulation	.0226	0.0216	0.0848	0.254	.799
	Emotional awareness	.295	0.269	0.0607	4.44	<.001
	Self-regulation	.0307	0.0240	0.0635	0.378	.706
	Body listening	.0395	0.0335	0.0640	0.523	.601
	Trusting	−.154	−0.116	0.0533	−2.18	.0298
Men	Intercept		0.475	0.740	0.643	.521
	Age	.120	0.0342	0.0221	1.55	.124
	BAIT	.172	0.0212	0.0108	1.97	.0510
	Noticing	−.141	−0.139	0.114	−1.23	.222
	Non-distracting	−.0666	−0.0686	0.0857	−0.800	.425
	Not-worrying	.172	0.185	0.0930	1.99	.0487
	Attention regulation	.387	0.437	0.158	2.77	.00645
	Emotional awareness	.175	0.160	0.102	1.57	.119
	Self-regulation	−.193	−0.179	0.0997	−1.79	.0750
	Body listening	.0467	0.0421	0.0993	0.424	.672
	Trusting	.0952	0.0896	0.0966	0.928	.355

"interoceptive sensibility" (Forkmann et al., 2016; Garfinkel et al., 2015). Nevertheless, the fact that all MAIA-2 factors correlated with GRiPS score in at least one survey further cements the need for caution when interpreting specific findings arising from these analyses. To learn more from our data we combined responses from both surveys and performed multiple linear regression.

3.2. Regression and gender-related effects

Regression analyses revealed that *Non-distracting*, *Not-worrying*, and *Emotional awareness* were statistically significant predictors of GRiPS score when examining the entire sample (with *Non-distracting* and *Not-worrying* occurring in both the original and alternative MAIA-2 factor structure). The contribution of the *Non-distracting* factor in predicting GRiPS score could indicate that those who tend to ignore or distract themselves from sensations of pain or discomfort may have greater risk propensity. Similarly, the contribution of the *Not-worrying* factor could indicate that those who tend not to worry or experience emotional distress with sensations of pain or discomfort might be more attracted to risk. These results may feasibly align with the presence of *Emotional awareness* as a positive predictor in the first regression analysis, which could suggest that those with greater awareness of the connection between body sensations and emotional states are more attracted to risky behaviour. Furthermore, one could speculate that the presence of *Emotional awareness* is in line with previous work emphasising the importance of affective processes in decision making (Bechara et al., 1996, 1997; Damasio et al., 1996; Dunn et al., 2006; Lees et al., 2022; Simonovic et al., 2019; Xu & Huang, 2020), in this case extending the potential link beyond monetary decision-making or gambling tasks to general risk propensity. For example, whilst previous work proposed that visceral signals may warn one away from potentially harmful outcomes, an awareness of such signals occurring in response to a risk-related affective state, and the ability to more effectively manage one's responses, may make risk-taking less aversive.

However, it is important to note that some differences between men and women were observed when separate regression analyses were performed. *Non-distracting* and *Emotional awareness* were observed to predict GRiPS score for women, whilst *Not-worrying* was observed to predict GRiPS score for men. In addition, *Trusting* was found to negatively predict GRiPS score for women, whilst *Attention regulation* was found to positively predict GRiPS score for men. It is well-established that men display greater risk propensity than women (Byrnes et al., 1999; Figner & Weber, 2011; Nicholson et al., 2005), and this was also shown in our results. It also appears that ways of engaging with interoceptive sensations, as they relate to risk-taking, could vary between men

Table 4. Multiple linear regression using alternative MAIA-2 factor structure, split by gender.

Gender	Predictor	Standardised estimate	Estimate	SE	t	*p*
Women	Intercept		2.90	0.389	7.26	<.001
	Age	−.108	−0.0230	0.0116	−1.98	.0488
	BAIT	.0169	0.00134	0.00476	0.282	.778
	Non-distracting	−.251	−0.251	0.0566	−4.43	<.001
	Not-worrying	.0319	0.0338	0.0625	0.0540	.589
	$MAIA_g$	.207	0.230	0.0610	3.78	<.001
Men	Intercept		0.624	0.717	0.871	.385
	Age	.116	0.0330	0.0223	1.48	.142
	BAIT	.136	0.0168	0.0101	1.66	.0986
	Non-distracting	−.0759	−0.0782	0.0867	−0.901	.369
	Not-worrying	.175	0.189	0.0866	2.18	.0309
	$MAIA_g$	.310	0.383	0.103	3.71	<.001

and women. The aforementioned links between *Non-distracting*, *Not-worrying*, and *Emotional awareness* and GRiPS score may be more strongly associated with different genders. Furthermore, the presence of *Trusting* as a negative predictor might suggest that women who experience their body as safe and trustworthy are more risk averse (in line with one of our original hypotheses). This result was surprising given the *positive* correlation observed between GRiPS and *Trusting* in Survey 2. It is unclear what could have caused this discrepancy, but the larger sample size in the regression analysis suggests that it may be the more reliable result (at least for women). This finding could indicate that women who perceive physiological responses (e.g., increased heart rate) as more reliable for guiding their behaviour may be less likely to take risks. The presence of *Attention regulation* as a significant predictor could suggest that men who are better able to sustain and control attention towards bodily sensations may have greater risk propensity. This latter effect for men could feasibly align with the proposed effect of *Not-worrying*, in that regulating attention towards bodily sensations may help one to avoid worrying about such sensations.

As stated above, however, some have expressed concern regarding the structure and independence of MAIA factors. Ferentzi et al. (2021), examining the original MAIA, suggested that only *Non-distracting* and *Not-worrying* are independent, with other factors (which are unchanged in the MAIA-2) perhaps capturing a single phenomenon ($MAIA_g$). Whilst the original MAIA factor structure has been reported by several authors across varied samples and languages (e.g., Bornemann et al., 2015; Brown et al., 2017; Fekih-Romdhane et al., 2023; Fiskum et al., 2023; Jones et al., 2021; Valenzuela-Moguillansky & Reyes-Reyes, 2015), it has also been observed by some that there are strong correlations between all factors except for *Non-distracting* and *Not-worrying* (Calì et al., 2015; Da Costa Silva et al., 2022) and other alternatives to the original factor structure have been shown (Shoji et al., 2018; Teng et al., 2022; Todd et al., 2020). Although our survey was not designed to examine the factor structure of the MAIA-2, and our sample size was smaller than studies for which factor analysis was a specific goal (Ferentzi et al., 2021; Mehling et al., 2018), a three-factor structure including $MAIA_g$ (plus *Non-distracting* and *Not-worrying*) may be in keeping with the unspecific correlation results observed in our work. Even though we observed no problems with multicollinearity for our regression analyses (with VIF ≤ 3.04), it was nonetheless possible to observe large correlations between original MAIA-2 factors in our combined sample (the maximum being r = .722 between *Self-regulation* and *Attention regulation*, with mean r = .523 between all factors excluding *Non-distracting* and *Not-worrying*). It may therefore be worth treating the current findings related to *Emotional awareness*, *Attention regulation*, and *Trusting* with caution. The results concerning factors *Non-distracting* and *Not-worrying* are likely to be more convincing, given that these factors are likely to be most distinct from the other original MAIA factors, and their associated effects were replicated in analyses alongside $MAIA_g$. Notably, in Survey 2 we also observed that $MAIA_g$ correlated with GRiPS score (and this effect was statistically significant at an uncorrected alpha threshold in Survey 1). In all multiple regression analyses in which it occurred, $MAIA_g$ was also observed to positively predict GRiPS score.

3.3. Interpretation of $MAIA_g$

What might the relationship between $MAIA_g$ and GRiPS score indicate? Given that $MAIA_g$ is a summation of several of the original MAIA-2 factors, the exact aspects of interoception it captures have been the subject of discussion. Ferentzi et al. (2021) proposed that $MAIA_g$ could capture one's perception of body changes and rhythms, in line with its relatively strong correlation with the Body Awareness Questionnaire (see also Vig et al., 2022). Some have even suggested that this combination of the original factors could be considered "a suitable marker of the global interoceptive sensibility construct" (p. 18), based on an Item Pool Visualisation of multiple interoception questionnaires (Todd et al., 2022). In keeping with these claims, a simple interpretation of the current results is that a greater self-reported awareness of internal bodily states is associated with greater risk propensity. However, it is possible that $MAIA_g$ is reflective of other behaviour. For example, Desmedt et suggested that an overarching MAIA-2 factor may assess an "adaptive relationship with body sensations" (p. 5). In this view it may be that the ability to flexibly engage with interoceptive sensations is important for risk propensity, rather than the awareness of such states.

It is clear that further work will be necessary to verify the meaning of the $MAIA_g$ results. Given the variability in phenomena assessed by self-report questionnaires of interoception (Desmedt et al., 2022; Todd et al., 2022; Vig et al., 2022), assessing other subjective aspects of interoception may help to refine our understanding. For example, different questionnaires can support the measurement of an individual's awareness of varied and specific sources of interoceptive sensation (the Three-domain Interoceptive Sensations Questionnaire, Vlemincx et al., 2023), how accurate their perception of visceral signals is (the Interoceptive Accuracy Scale, Murphy et al., 2020), or awareness of the influence of internal and external factors on bodily sensations the Body Awareness Questionnaire, (Shields et al., 1989). Using a wider range of questionnaires in a single sample may ensure that varying aspects of "interoceptive sensibility" can be measured and confirm an appropriate interpretation of $MAIA_g$.

3.4. Non-distracting *and* Not-worrying

Given that the most convincing and readily interpretable results of this work are those observed for *Non-distracting* and *Not-worrying*, we provide further detail on what these results might reflect. We first emphasise that the GRiPS is not a direct measure of behaviour, but rather provides a concise way of evaluating one's general disposition towards risk-taking. Whilst this could mean that links between MAIA-2 factors and GRiPS are reflective of one's *beliefs* that they are risk takers, rather than actual engagement with risky behaviour, we think this is unlikely. Participants appear able to effectively reflect on their own experiences of risk-taking to generate their responses to self-report measures of risk propensity (Arslan et al., 2020; Steiner et al., 2021). Furthermore, self-report measures of risk propensity, including the GRiPS, tend to have good test-retest reliability and are found to be related to real-world behaviour and life outcomes (Frey et al., 2017; Zhang et al., 2019). As such, we believe that the current results are informative for understanding how subjective experience and engagement with interoceptive signals influences risk propensity.

As proposed above, our results therefore indicate that the ability to ignore or avoid becoming distressed by potentially negative visceral signals is associated with increased risk propensity. This could possibly be because one can then (re)interpret such sensations as positive (i.e., excitement) or prioritise the potentially positive outcome of the risky behaviour over any physiological "warning". In this way, distraction and avoidance of worry may play an important role in shaping responses to risk-related interoceptive signals, guiding eventual behaviour. Indeed, we can consider how such an effect might readily influence behaviour in daily life. For example, consider the experience of two individuals preparing to bungee jump – one who enjoys extreme sports and another member of the general population. The former may interpret the heart racing as excitement when they prepare to jump, the latter as a warning, possibly even inhibiting their ability to step over the edge. However, we should also note that effects may be gender-specific, with women displaying the effect linked to *Non-distracting* and the analysis of men highlighting *Not-worrying*. Given that we did not directly assess interaction effects, and our sample did not have an even gender split, it is worth following up on these gender-specific results in future studies to better understand individual differences in the relationship between risk propensity and the ability to ignore/not worry about visceral sensations.

3.5. Links to previous work, limitations, and future directions

Our results build on previous studies which used behavioural tasks to measure risk-taking (Baiano et al., 2021; Herman et al., 2018, 2021; Salvato et al., 2019). In contrast to this previous work, our conclusions are not limited to the relatively constrained behaviour captured in gambling tasks, and instead indicate that one's subjective experience of interoception may be associated with risk preference more broadly. However, it remains likely that interoceptive signals, and their interpretation, have different impacts on risk-taking in specific risk-related situations and for individual attraction to risk on a broader scale. For example, whilst early, pioneering work indicated that the magnitude of sympathetic nervous system response (i.e., skin conductance) to risky outcomes might guide one's actions within the confines of a behavioural risk-taking task (Bechara et al., 1996, 1997; Damasio et al., 1996), subjective interpretation of such interoceptive signals, as measured here, may be more important for driving attraction towards risky situations in daily life.

Relatedly, we must consider whether the links between *Non-distracting*, *Not-worrying*, and GRiPS score are relevant for all scenarios in which an individual may engage in risky behaviour. In the current work we treat risk propensity as a single trait by using the GRiPS (Zhang et al., 2019). When correlated with a domain-specific questionnaire of risk propensity (the Domain-Specific Risk Taking Scale, Weber et al., 2002), the GRiPS appears to have stronger associations with financial, health, and recreation dimensions than social and ethical dimensions, the latter of which may treat risk-taking more indirectly (e.g., by evaluating non-conformity or disregard for moral rules, Zhang et al., 2019). One can draw on different life experiences to evaluate their level of risk propensity, and some types of risky behaviour may be more prominent than others during this process (Arslan et al., 2020). Whilst our results may therefore suggest a role for *Non-distracting* and *Not-worrying* in global risk propensity, it still remains feasible that they could be more strongly related to risk propensity in specific domains.

More work will also be useful for verifying the predictive validity of our findings: our analyses were exploratory and we should emphasise that regression models were only predictive of a relatively small amount of change in GRiPS score. For example, an increase in a unit of $MAIA_g$ predicted only a change of 0.246 out of 5 in GRiPS. Whilst this suggests that responses to the MAIA-2 can only account for a small amount of divergence in individual differences, the addition of other questionnaires in future work (as mentioned above) will likely enable us to capture a greater amount of variance in risk propensity measurement. In addition, it is important to note that the GRiPS does not assess risk perception, which also plays a role in risky decision making: two individuals with similar risk propensity may differ in their engagement with a risky behaviour due to differences in the perceived risk associated with a particular scenario (Zhang et al., 2019). Evaluating the link between subjective interoceptive experience and both risk propensity and risk perception will be necessary to better understand how one's experience of interoceptive signals drives risky decision making in different contexts.

To consider other limitations, it may be that the observed differences between correlation results in Survey 1 and 2 are due to the two samples used (though when using an uncorrected alpha threshold, only *Noticing*, *Body listening*, and *Trusting* differed in the presence of effects across the surveys). Whilst there were only minor differences between the demographics of the samples in the two surveys (20.5 versus 22.1 years mean age, 26% versus 37% men), and our combined analysis addresses this, it is possible that different motivations for completing the survey (money or course credit) could have influenced the level of attention participants paid to their responses. Additionally, it is worth noting that our results are likely to be most reliable for women under the age of 25. Risk propensity is influenced by age, such that younger adults are less risk-averse than older adults (Duell et al., 2018). We only observed statistically significant predictions based on age when performing a regression analysis on women, but the range of ages in our sample was limited as was the proportion of men. Finally, we note that *Not-worrying* had relatively poor reliability, something that is consistent with the original reporting of the MAIA-2 in a larger sample (Mehling et al., 2018). Verification of results relating to this specific factor may be particularly useful.

4. Conclusion

In sum, our results provide further understanding of the possible links between ways of engagement with interoceptive signals and risk propensity. In particular, our findings most strongly suggest that those with the ability to ignore or not worry about visceral signals when they are uncomfortable display greater risk propensity, and that these effects may possibly be gender-specific. This work therefore provides deeper insight into the ways in which interoception might influence individual differences in risk propensity. Future work should aim to refine our understanding of these effects, using multiple interoception questionnaires to examine more varied aspects of subjective experience, as well as determining which of these may influence risk-taking in a causal manner. Expansion across different risk domains and in relation to applied outcomes is also likely to be informative.

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No potential conflict of interest was reported by the author(s).

Data availability statement

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