Exploring the Dimensional Structure of Subjective Interoception and the Differential Impact of Abuse and Neglect

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Author Note

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Abstract

Background: Subjective interoception plays a critical role in emotional well-being, but its constituents have rarely been examined. Additionally, little attention has been paid to how abuse and neglect, as two distinct yet often co-occurring dimensions of child maltreatment, may differentially impact subjective interoception.

Objective: The present study aimed to examine the dimensional structure of subjective interoception, and how its different dimensions are associated with internalizing psychopathology and are differentially influenced by abuse and neglect.

Participants and Setting: Participants (N = 391; M_{age} = 19.29 years; female: 67.5%; Hispanic: 57.3%) were recruited in 2021-2022 as part of a larger study.

Methods: Exploratory graph and confirmatory factor analyses were used to establish the dimensional structure of subjective interoception, and structural equation modeling was used to examine the relationships between different dimensions of subjective interoception, abuse and neglect, as well as internalizing psychopathology.

Results: The results suggested that subjective interoception was comprised of two dimensions: proactive and reactive interoception. Whereas abuse was positively associated with reactive interoception only, neglect was negatively associated with both proactive and reactive interoception. Proactive, but not reactive, interoception was negatively associated with internalizing psychopathology.

Conclusions: The findings provide compelling evidence for the differential impact of abuse and neglect on different facets of subjective interoception, highlighting the significance of considering abuse and neglect as two distinct experiential elements. The results also inspire the idea that emotion-body connection should be considered in future emotional development research.

Keywords: child maltreatment; subjective interoception; internalizing psychopathology

Exploring the Dimensional Structure of Subjective Interoception and the Differential Impact of Abuse and Neglect

Interoception, the processes by which signals originated from within the body are sensed, integrated, interpreted, and regulated, plays a central role in mental health and affective experiences and encompasses a wide range of features (Chen et al., 2021; Khalsa et al., 2018; Quigley et al., 2021). As interoceptive science begins to blossom, much attention has been devoted to *interoceptive accuracy* (or *ability*), the objective measure of one's capability to accurately detect bodily sensations, often measured by the heartbeat detection task (Whitehead et al., 1977) and heartbeat tracking task (Schandry, 1981). For example, there is increasing research on improving the assessment of interoceptive accuracy (e.g., considering different interoceptive domains, beyond just cardiac perception) and exploring the neural underpinnings and computations of such ability (Khalsa et al., 2018). This effort is important to advancing our theoretical understanding of interoceptive accuracy and aiding in translational research, but the psychological, subjective aspects of interoception should not be overlooked. Despite the easiness of collecting self-report data (relative to physiological and neural data), there remain critical issues in the study of subjective interoception, including its operationalization and psychometric properties, let alone the need to explore its antecedents and consequences. One particularly relevant antecedent is child maltreatment. Child maltreatment has profound effects on both the mind and body, yet little research has examined how abuse and neglect, as two distinct yet often co-occurring dimensions of child maltreatment, impact subjective interoception. The present study thus aimed to unravel the dimensional structure of subjective interoception, its association with internalizing psychopathology, and how it is impacted by child maltreatment.

Dimensions of Subjective Interoception

As noted, interoception can be measured objectively (i.e., interoceptive accuracy or ability) and subjectively. One of the subjective facets of interoception is *interoceptive sensibility*, the perceived tendency to notice and focus on one's bodily sensations. Another aspect of subjective interoception is *interoceptive belief*, the evaluative belief about the nature of bodily feelings (MacCormack et al., 2024). One key distinction between interoceptive sensibility and belief is that the former only involves the trait-like tendency to notice and monitor, but not the evaluation of, visceral sensations, while the latter involves evaluative judgment about bodily feelings. Some researchers used the term *interoceptive awareness* to indicate either sensibility or accuracy. To clarify the distinction between objective and subjective interoception, we used sensibility and accuracy instead of awareness.

Although interoceptive sensibility and belief are relatively easy to assess via self-report questionnaires, there are several issues involving the psychometrics of the extant measures. Vig and colleagues (2022) investigated the relationships between the three most commonly used interoceptive sensibility measures, namely the Body Awareness subscale of the Bodily Perception Questionnaire (BPQ-BA; Porges, 1993), the Body Awareness Questionnaire (BAQ; Shields et al., 1989), and the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012), and suggested that they were only weakly to moderately correlated, and that they showed inconsistent associations with negative and positive affect. This indicates that these questionnaires measure, to some degree, distinct constructs and do not solely measure interoceptive sensibility alone.

In terms of interoceptive belief, there are not as many widely-used measures as interoceptive sensibility, reflecting that this construct is under-researched. The Physical Concerns

subscale of the Agoraphobic Cognitions Questionnaire (ACQ), as well as the Body Sensations Questionnaire (BSQ) have been used as indices of interoceptive belief (Chambless et al., 1984; Yoris et al., 2015). The Physical Concerns subscale of the ACQ measures catastrophic thoughts when one is nervous (e.g., "I must have a brain tumor"), and the BSQ measures how frightened one is by specific bodily sensations (e.g., "frightened by heart palpitations"). The construct measured by the former measure reflects concerns about somatic symptoms only when being nervous, which deviates from the evaluative belief about bodily sensation. The latter only measures feelings of frightening, which could be one, but not all, aspect of interoceptive belief. More recently, Bonar, MacCormack, Lindquist, and colleagues have developed the Bodily Signal Beliefs Questionnaire, a 22-item questionnaire that measures 3 aspects of interoceptive beliefs: intensity, distress, and low efficacy beliefs (MacCormack et al., 2024). The multidimensional nature of this questionnaire allows to scrutinize the nuance of interoceptive belief, and an overall interoceptive belief score can also be calculated. Although it has been utilized in their research, the questionnaire itself has not been published as the current study was conducted.

Although the MAIA has been argued to not purely measure interoceptive sensibility (Vig et al., 2022), the multidimensional nature of this measure affords an invaluable opportunity to investigate different dimensions of subjective interoception. The MAIA consists of 8 dimensions that were assumed to be distinct aspects of "interoceptive sensibility": 1) *noticing*, the awareness of bodily feelings, regardless of how they feel; 2) *not-distracting*, the tendency not to distract oneself from discomfort bodily feelings; 3) *not-worrying*, the tendency not to worry about discomfort bodily feelings; 4) *attention regulation*, the ability to maintain attentive to bodily sensations; 5) *emotional awareness*, the awareness of the connection between emotion and bodily feelings; 6) *self-regulation*, the capability to regulate negative emotion by paying attention to

bodily feelings; 7) *body listening*, the tendency to actively listen to bodily sensations for insights; and 8) *trusting*, considering one's body as safe and trustworthy. As Vig and colleagues (2022) argued, MAIA does not seem to only measure interoceptive sensibility. While *noticing* does measure spontaneous tendency to detect bodily feelings, other dimensions involve higher-order cognitive processing (e.g., tendency to direct attention to bodily sensations) and the evaluation of interoceptive signals. Hence, we believe that the MAIA can be useful to identify subjective interoceptive dimensions, above and beyond what it was designed to measure (i.e., interoceptive sensibility).

Originally, the MAIA was developed such that the facets of "interoceptive sensibility" should be investigated separately, under the assumption that these different dimensions are to some degree distinct from each other, and that there isn't an "interoceptive sensibility" common factor. Ferentzi and colleagues (2021) challenged this assumption by testing the factor structure of the MAIA and showed that a bifactor model without *not-distracting* and *not-worrying* fitted the best. However, bifactor models tend to always have a better fit than traditional models regardless of whether the model reflects the true factor structure or not because of increased parameters (Markon, 2019). Additionally, the study did not examine whether there existed more than one higher-order or general factor, assuming that "interoceptive sensibility" is unidimensional in nature. As discussed above, the MAIA seems to measure more than just interoceptive sensibility, so it is reasonable to speculate that more than one higher-order factor exists. Based on the distinction of interoceptive sensibility and belief, we hypothesized that *noticing*, *not-distracting*, *attention regulation*, and *body listening* would form one dimension representing interoceptive sensibility, and *not-worrying*, *emotional awareness*, and *trusting* would emerge as another dimension resembling interoceptive belief. As the definitions of interoceptive sensibility and belief do not

involve regulatory processes, *self-regulation* was posited to be another distinct aspect of subjective interoception, which would extend our operationalization and understanding of subjective interoception.

Subjective Interoception and Internalizing Psychopathology

There is an abundance of research showing that interoceptive accuracy is associated with psychiatric conditions, including depression and anxiety (Brewer et al., 2021; Eggart et al., 2019; Khalsa et al., 2018; Paulus & Stein, 2010). At the same time, several studies have found that when objective and subjective measures of interoception were simultaneously used to predict depression and anxiety, subjective measures, like sensibility, often emerged as the only significant predictor. To illustrate, interoceptive sensibility (measured by BPQ) was positively associated with anxiety, independent of interoceptive accuracy, and there were no significant relationships between accuracy and anxiety (Palser et al., 2018a). Garfinkel and colleagues (2016) found that interoceptive sensibility (measured by BPQ), but not accuracy, was positively associated with state anxiety. They also found that interoceptive trait prediction error, the discrepancy between accuracy and sensibility (reflecting subjective overestimation of interoception), was associated with higher anxiety. It should be noted that the most BPQ items measure bodily sensations linked to stress, and thus may reflect interoceptive belief more than interoceptive sensibility (Vig et al., 2022).

When interoceptive sensibility has been examined alone, unsurprisingly, it has also been found to be associated with internalizing psychopathology. Some dimensions of the MAIA were negatively associated with depression and anxiety among primary care patients (Dunne et al., 2021). In another study, some dimensions of MAIA were positively associated with depression and anxiety, while the others exhibited negative associations (Suzuki et al., 2021). In addition, in

a Spanish sample, *not-worrying* and *emotional awareness* led to higher and lower emotion dysregulation, respectively, which further led to depression (Desdentado et al., 2023). Furthermore, a study demonstrated that a mindfulness-based intervention increased interoceptive sensibility, which in turn led to decreases in anxiety and stress (Shen et al., 2023). Using BPQ, Palser and colleagues (2018b) found that interoceptive sensibility was associated with higher trait anxiety.

Although interoceptive belief is less studied, it has been argued to be pivotal in interoceptive regulation (the ability to match one's current physiological state to the desired state) and subsequent behaviors, including emotion regulation (Joshi et al., 2021). One study suggested that the main effect of interoceptive belief, as well as its interactions with physiological reactivity, were consistently the most robust predictors of negative, high-arousal emotion during acute stress, compared to interoceptive accuracy and sensibility, showcasing its significant contribution to our affective response under stress (MacCormack et al., 2024). Another study discovered that patients with anxiety disorders, compared to healthy controls, did not differ in interoceptive accuracy, but rather, interoceptive belief (Yoris et al., 2015).

Taken together, prior research indicates that subjective interoception is heavily involved in our affective well-being, sometimes even above and beyond the effect of objective interoception. Hence, it is of great theoretical and clinical relevance to investigate what different dimensions of subjective interoception are, and how they are associated with internalizing psychopathology. This investigation could further our understanding of the nature of subjective interoception, potentially having it as an intervention and treatment target.

Subjective Interoception and Child Maltreatment

If identifying the correlates and consequences of subjective interoception (e.g.,

internalizing psychopathology) can help us discern whether it could serve as a modifiable factor to promote well-being and diminish negative outcomes, delineating the antecedents of subjective interoception can provide opportunities to examine the contexts where it is influenced, which can further illuminate the nature and function of subjective interoception and aid in prevention. As human behaviors are a complex, integrated system, solely studying its typical, healthy operations is less useful for understanding the functions of individual constituents of the system and their interrelations. Adverse childhood experiences afford the opportunity to look at the atypical functioning of different domains of behavior, which can further our theoretical understanding of these domains and allows us to observe the consequences associated with such abnormal functioning (Cicchetti, 2020). The impact of early adversity, thus, can be utilized to understand the functions of subjective interoception.

The dimensional model of early adversity has garnered increasing popularity in research, as it overcomes some of the limitations of the prior approaches. According to this model, some adverse childhood experiences share common features, so they lead to the same outcomes through the same mechanisms, and these experiences belong to the same dimension of adversity (Sheridan & McLaughlin, 2014). This approach accounts for the co-occurrence of individual types of early adversity, while maintaining high specificity regarding the mechanisms by which early adversity leads to later outcomes (McLaughlin et al., 2021). Two proposed dimensions of early adversity are threat, characterized by the actual or threatened harm to one's physical integrity, and deprivation, characterized by the lack of species-expected and age-typical environmental input (e.g., cognitive and social stimulation; Sheridan & McLaughlin, 2014). While threat is hypothesized to be associated with aberrant emotional functioning and salience detection, deprivation is hypothesized to be linked with altered higher-order cognitive functioning (e.g., language, executive functioning).

In terms of psychopathology, extant findings have been mixed. While some research suggested that threat is more robustly associated with mental health than deprivation (Miller et al., 2018; Schäfer et al., 2023), other research has found that deprivation, but not threat, was associated with psychopathology, especially in younger children (Carozza et al., 2022).

Child maltreatment, as a potent and immediate stressor to children, can also be studied from the dimensional perspective. Experiences of child maltreatment comprise physical abuse, emotional abuse, sexual abuse, physical neglect, and emotional neglect. These experiences can be divided into abuse (including physical, emotional, and sexual abuse) and neglect (including physical and emotional neglect). This compartmentalization is consistent with threat and deprivation but also embodies the distinction between acts of commission vs. omission, supported by data-driven research (Brieant et al., 2023). Although child maltreatment has a documented association with psychopathology (see Jaffee, 2017 for a review), much of prior research utilized a categorical approach (i.e., dichotomizing children into exposed vs. non-exposed groups), which prevented us from understanding the effects of the different features (or dimensions) of early-life stress and how they interact to influence later outcomes (Cohodes et al., 2021). The dimensional model highlights that adversity dimensions should be measured on a continuum and are not mutually exclusive. Recent work that took a dimensional approach to child maltreatment found that abuse and neglect were, as expected, differentially associated with biobehavioral outcomes, including brain development (Kim-Spoon et al., 2021), diurnal salivary cortisol patterns (Sun et al., 2023), overall hair cortisol output (Doom et al., 2022), inflammation (Lindenmuth et al., 2024), and psychopathology (Duprey et al., 2023; Lindenmuth et al., 2024).

Research on child maltreatment and subjective interoception is sparse. One study found that total child maltreatment was negatively associated with body awareness (i.e., attention to

bodily signals in everyday life; Schmitz et al., 2023). To our knowledge, no studies have investigated the link between child maltreatment (or early adversity, more broadly) and interoceptive belief.

The Present Study

Hence, the goals of the current study were to 1) establish the dimensional structure of subjective interoception; and 2) examine the associations between the derived dimensions of subjective interoception and abuse, neglect, and internalizing psychopathology. We posited that: 1) using the MAIA scale, subjective interoception would comprise interoceptive sensibility, belief, and regulation; 2) these dimensions would each be associated with internalizing psychopathology; and 3) abuse and neglect would have differential impact on the subjective interoception dimensions.

Methods

Participants and Procedures

Participants (N = 1444) were recruited from introductory-level psychology courses at a regional comprehensive university in 2021 to 2022. As part of a large study focusing on psychosocial adjustment in emerging adults, participants took two online surveys, at least one week apart, on Qualtrics, asking their early experiences and multidomain adjustment. Only a subset of participants who completed part 1 chose to complete part 2 (where the interoception measure was administered). Participants who completed part 1 but not part 2 were excluded, and one participant who completed part 2 but not the interoception measure was also excluded. Attention checking questions [e.g., “Please click on “4 (Agree)”] were embedded in the survey. Participants (N = 58) were removed if they failed to answer more than half of the attention

checking questions correctly. Data from participants who began but did not complete the entire survey were retained on a measure-by-measure basis. One additional participant did not complete the maltreatment measure and thus was removed. Hence, data from 391 participants (M_{age} = 19.29 years, *SD* = 2.07) were used in the present study. The current sample is diverse (female: 67.5%; Hispanic/Latinx: 57.3%; see Table 1). The informed consent form was required to be signed electronically at the start in order to begin the survey. Research credits, as compensation, were given to participants to fulfill their course requirements. The study was approved by the Institutional Review Board of the university.

Measures

Subjective Interoception. Subjective interoception was measured by the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012), a 32-item scale assessing one's perception of how well they can sense their bodily feelings and are aware of mind-body connections on a scale of 0 (never) to 5 (always). The subscales of the MAIA include: 1) *noticing* (e.g., "I notice where in my body I am comfortable;" Cronbach's α = .82); 2) *not-distracting* (e.g., reverse-scored item "I distract myself from sensations of discomfort;" α = .72); 3) *not-worrying* (e.g., reverse-scored item "I start to worry that something is wrong if I feel any discomfort;" α = .70); 4) *attention regulation* (e.g., "I can return awareness to my body if I am distracted;" α = .91); 5) *emotional awareness* (e.g., "I notice how my body changes when I am angry;" α = .86); 6) *self-regulation* (e.g., "When I am caught up in thoughts, I can calm my mind by focusing on my body/breathing;" α = .87); 7) *body listening* (e.g., "I listen for information from my body about my emotional state;" α = .87); and 8) *trusting* (e.g., "I trust my body sensations;" α = .92). Of note, item 10 ("I can notice an unpleasant body sensation without worrying about it") was deleted, as

part of the *not-worrying* sub-scale, because its removal improved the sub-scale's reliability from $\alpha = .08$ to $\alpha = .70$. Composite scores were calculated for the above sub-scales.

Child Maltreatment. Child maltreatment was measured retrospectively using the Childhood Trauma Questionnaire-Short Form (CTQ-SF; Bernstein et al., 2003). The 25 items were rated on a 0 (never true)-to-4 (very often true) scale. Composite scores were calculated for the following sub-scales: emotional abuse ($\alpha = .89$), physical abuse ($\alpha = .78$), sexual abuse ($\alpha = .94$), emotional neglect ($\alpha = .91$), and physical neglect ($\alpha = .67$).

Internalizing Psychopathology. Anxiety was assessed by the Generalized Anxiety Disorder 7-item Scale (GAD-7; Spitzer et al., 2006). Seven anxiety symptoms were assessed on a 4-point scale, ranging from 0 (not at all) to 3 (nearly every day). A composite score was calculated for anxiety ($\alpha = .90$). Depression was assessed using the Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001), consisting of 9 items rated on a 0 (not at all)-to-3 (nearly every day) scale. A composite score was calculated for depression ($\alpha = .90$).

Covariates include age, biological sex (male vs. female), and ethnicity. Ethnicity was dummy-coded as Hispanic vs. non-Hispanic in the structural equation model.

Data Preparation

Descriptive statistics and missing value analysis were conducted using SPSS Statistics (Version 27). No variables of interest had more than 0.5% missing data, and demographic variables had no more than 1.5% missing data. Little's MCAR test suggested that data were missing completely at random ($\chi^2 = 54.83$, $df = 73$, $p = .95$). All of the following procedures were conducted in R (R Core Team, 2022). After confirming that missing data were missing completely at random, missing data on the variables of interest were imputed using the *mice* R package (van Buuren &

Groothuis-Oudshoorn, 2011) with the predictive mean matching method. The imputed data generated by this method are the least biased, and this method is preferrable when less than 50% of data are missing and missingness is at random or completely at random (Kleinke, 2017; Marshall et al., 2010a; Marshall et al., 2010b).

Statistical Analyses

Dimension Reduction

Because we were interested in how the subjective interoception dimensions assessed by the MAIA clustered, composite scores of these dimensions were used rather than the item scores. Exploratory graph analysis (EGA; Golino et al., 2020; Golino & Epskamp, 2017), as an exploratory analysis, was conducted to examine the dimensional structure of subjective interoception using the *EGAnet* package (Golino & Christensen, 2023). EGA is a graph-based dimension reduction technique that utilizes community detection. A simulation study demonstrated that EGA performs better (i.e., more accurate and less biased) than traditional dimension reduction methods, such as exploratory factor analysis, and the implementation and decision-making process of this technique (e.g. determine the number of dimensions to retain) are easier for researchers (Golino et al., 2020).

In the present study, graphical gaussian model (GGM) was used as the basis of EGA, as the interoception variables are all continuous. The graphical least absolute shrinkage and selection operator (graphical LASSO) was used with the extended Bayesian Information Criterion (EBIC) model selection. We examined the multivariate normality assumption of the GGM using the *MVN* package (Korkmaz et al., 2014). The Mardia's multivariate skewness and kurtosis coefficients were calculated for the interoception variables, with $p < .05$ indicating a violation of multivariate

normality. The results suggested multivariate non-normality (both skewness and kurtosis had *p* values lower than .05). Hence, Spearman's correlation, as a nonparametric method, was used in the GGM.

For the EGA, the Louvain community detection algorithm was implemented. The structural consistency of the communities (i.e., derived dimensions) and item stability of the variables were calculated using a parametric bootstrap approach with 1000 iterations. Structural consistency indicates how strongly the variables in the dimension are connected and how homogenous they are in the context of the other emerged dimension(s). Item stability represents the proportion of times a variable emerged in each of the derived communities across the bootstrap samples (Christensen et al., 2023; Christensen & Golino, 2021). The structural consistency and item stability statistics range from 0 to 1 and should be above 0.7 to be considered sufficient in general, but recommended guidelines for interpreting structural consistency have not been developed (Christensen & Golino, 2021). No techniques currently exist to conduct a power analysis for the EGA.

After EGA, confirmatory factor analysis was conducted to validate the factor structure derived from EGA. Model fit was assessed using the comparative fit index (CFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA). A CFI greater than .95, SRMR lower than .08, and RMSEA lower than .06 were considered an ideal fit (Hu & Bentler, 1999). Modification indices were inspected to adjust the factor structure accordingly if the model fit was not ideal. The adjustment of the factor structure based on the modification indices was made very carefully, and only the modifications that made conceptual sense were considered.

Structural Equation Modeling

We next examined the differential impact of abuse and neglect on different dimensions of subjective interoception, as well as the relationships between the subjective interoception dimensions and internalizing psychopathology using structural equation modeling with the *lavaan* R package. Childhood physical abuse, emotional abuse, and sexual abuse were modeled as the indicators of the latent abuse factor, representing acts of commission in the context of child maltreatment. Childhood emotional neglect and physical neglect were modeled as the indicators of the latent neglect factor, representing acts of omission in child maltreatment. Latent factors of the higher-order subjective interoception dimensions were constructed according to the confirmatory factor analysis. Depression and anxiety were modeled as the indicators of the latent internalizing psychopathology factor.

The latent factors of abuse and neglect were modeled as correlated, accounting for the co-occurrence of these experiences. The latent factors of subjective interoception dimensions and internalizing psychopathology were also modeled as correlated, examining their correlational relationships. These latent factors were regressed on to the abuse and neglect latent factors to delineate the differential impact of abuse and neglect on the outcome variables.

Six participants had missing data on at least one of the exogeneous covariates (i.e., age, sex, ethnicity) and thus were removed, resulting in N = 385 for the final structural equation model. Maximum likelihood estimation was implemented. Model fit was assessed with the same criteria used in confirmatory factor analysis discussed above. Post-hoc power analysis was conducted for the structural equation model using the shinny app of the *semPower* R package (Moshagen & Bader, 2023; https://sempower.shinyapps.io/sempower/). The power of a study should be at least 0.8 (Serdar et al., 2021). To detect misspecifications of the model corresponding to RMSEA = .05,

with α = .05, *df* = 68, and 15 manifest variables, the sample (N = 385) achieved a power of .99, which was sufficient.

Results

Descriptive Statistics

See Table 1 for demographic information of the sample and Table 2 for the bivariate correlations and descriptive statistics among the main study variables.

Dimensional Structure of Subjective Interoception

The exploratory graph analysis suggested that subjective interoception consists of two factors (Fig. 1a). The median number of dimensions emerged across the 1000 bootstrap iterations was 2, which appeared 955 times. The structural consistency of the two interoception dimensions were .73 and .98. The item stability ranged from .76 to 1, indicating excellent stability (Fig. 1b). *Attention regulation* had the lowest item stability (.76), as it clustered with the other dimension in 24% of the bootstrap samples. One factor included *noticing*, *not distracting*, *not worrying*, *attention regulation*, and *emotional awareness*. These variables represent how aware someone is to their bodily sensations and how strongly they feel about, or react to, the sensations. Hence, this factor was termed *reactive interoception*. The other factor included *self-regulation*, *body listening*, and *trusting*. These variables represent the degree to which someone proactively seeks information from their bodily sensations and uses them to regulate emotion. As a result, this factor was termed *proactive interoception*.

However, confirmatory factor analysis suggested that the fit of the model was not adequate (CFI: .91, RMSEA: .13, SRMR: .07). Modification indices suggested that having *attention*

regulation cross-load on both dimensions would greatly improve model fit. As it made conceptual sense (see the discussion section for detail) and echoes the relatively lower stability of this variable in the EGA, we modeled *attention regulation* as loading on both dimensions and assessed the model fit. This new factor model had a better fit (CFI: .94, RMSEA: .11, SRMR: .06) but still not excellent. Modification indices of this new model suggested that *emotional awareness* and *not-distracting* should also cross-load on both dimensions. We tested whether having these two additional variables cross-load would improve the fit. The result suggested that it had the best fit among all the tested factor models (CFI: .97, RMSEA: .08, SRMR: .03). As the fit was considered sufficient, and any further modification indices suggested for this final model did not make conceptual sense, this factor structure was determined to be the final structure. See Table 3 for the comparison of the models' fit indices and the discussion section for the rationale regarding adjusting the factor structure based on the modification indices.

Structural Equation Modeling

Using the factor structure of subjective interoception suggested by the final confirmatory factor analysis, we proceeded to test the differential impact of abuse and neglect on these two dimensions of subjective interoception, as well as the associations between these two dimensions and internalizing psychopathology (Fig. 2). The fit of the structural equation model was good, CFI = .94, RMSEA = .06 (90% CI [.05, .07]), SRMR = .05. All indicators significantly loaded on to their designated latent variables (p's < .001). Of note, the factor loadings of *not-distracting* and *not-worrying* on the reactive interoception latent factor were negative, indicating that higher scores on this factor reflected *less* of these behaviors. Abuse and neglect were differentially associated with proactive and reactive interoception. Abuse was not associated with proactive interoception

(β = .34, p = .11) but positively associated with reactive interoception (β = .71, p = .003). Neglect was negatively associated with both proactive (β = -.67, p = .004) and reactive (β = -.65, p = .01) interoception. While abuse was positively associated with internalizing psychopathology (β = .67, p < .001), there was not an association between neglect and internalizing psychopathology (β = -.22, p = .24). In addition, whereas proactive interoception was negatively correlated with internalizing psychopathology (r = -.24, p < .001), reactive interoception was not correlated with internalizing psychopathology (r = .06, p = .51). Abuse and neglect were positively correlated (r = .82, p < .001) and so were proactive and reactive interoception (r = .57, p < .001).

Discussion

The present study found that 1) subjective interoception was comprised of proactive and reactive interoception; 2) proactive, not reactive, interoception was negatively associated with internalizing psychopathology; and 3) abuse and neglect were differentially associated with subjective interoception.

Contrary to our hypothesis, interoceptive sensibility, belief, and regulation did not emerge as the different dimensions of subjective interoception. The exploratory graph analysis first revealed that the MAIA subscales *noticing*, *not distracting*, *not worrying*, *attention regulation*, and *emotional awareness* clustered together. We termed this dimension *reactive interoception* because they measure the degree to which individuals attend to their visceral sensations and emotionally react to them. The other subscales, namely *self-regulation*, *body listening*, and *trusting* formed another dimension. We named this cluster *proactive interoception* as they measure how individuals proactively listen to their body for insights and use them to regulate emotions. Of note, confirmatory factor analysis suggested that the fit of this factor structure could be improved, and

modification indices suggested that *attention regulation*, *emotional awareness*, and *not-distracting* should cross-load on both dimensions.

Originally, *attention regulation* belonged to reactive interoception. The cross-loading on proactive interoception suggests that attention regulation is also critical to proactive interoception, as sustaining attention to one's own bodily sensations may be the prerequisite for the other proactive interoceptive processes (e.g., body listening and self-regulation). This principle applies to *emotional awareness* as well; being aware of the emotion-body connection may help us choose to use the body as a guide to regulate emotions. Similarly, not to distract oneself from uncomfortable bodily feelings should be important for proactive interoception because they may serve as an important conduit that helps initiate emotion regulation processes (e.g., helping individuals think about why they are experiencing discomfort). It also suggests that attending to bodily feelings and actively not distracting from the sensations, no matter whether they are uncomfortable or not, are intertwined processes that enable subsequent regulation.

Interestingly, *not-distracting* positively loaded on proactive interoception but negatively loaded on reactive interoception. *Not-worrying* also negatively loaded on reactive interoception. This implies that the reactive interoception construct may include the tendency to worry about and distract oneself from discomfort visceral sensations as part of their reaction to those feelings. Whether such tendency is adaptive or maladaptive in specific contexts should be investigated further in future research.

We speculate that the hypothesized higher-order dimensions of subjective interoception, namely interoceptive sensibility, belief, and regulation, did not emerge because these facets of subjective interoception may work in concert to support a behavior or form a reaction, instead of being isolated, independent components. To illustrate, reactive interoception encompasses facets

of subjective interoception that were hypothesized to be related to both interoceptive sensibility (e.g., *attention regulation*) and belief (e.g., *not-worrying*). Being emotionally reactive to bodily sensations requires both attending to the feelings and having a negative attitude (i.e., worrying) toward them. Hence, proactive and reactive interoception may be emergent properties that stem from the interaction between multiple facets of subjective interoception (e.g., sensibility, belief, regulation).

In the structural equation model, proactive interoception was significantly and negatively associated with internalizing psychopathology. As proactive interoception represents regulatory processes guided by bodily feelings, it is reasonable that proactive interoception had a negative association with internalizing psychopathology, similar to the association between emotion regulation and internalizing psychopathology (Cai et al., 2021; Cole & Diaz, 2024; Niu et al., 2023; Sheppes et al., 2015). This result also speaks to the possibility that, in certain contexts, understanding emotion-body connection and using visceral information as a guide underlie emotion regulation and should be incorporated into future emotion regulation research. On the other hand, while proactive and reactive interoception were positively associated with each other, reactive interoception was not significantly associated with internalizing psychopathology. This could be because reactive interoception may be adaptive for certain people but maladaptive for others, or the association is context-dependent. As these two higher-order dimensions of subjective interoception share some fundamental constituents of subjective interoception in common, their significant, positive relationship was expected. The fact that they had differential associations with internalizing psychopathology indicates that they represent distinct, albeit overlapping, aspects of subjective interoception. The implications and contexts of, as well as individual differences in, reactive interoception should be studied in detail in the future.

In terms of child maltreatment, abuse and neglect were positively and significantly associated with each other, indicating their co-occurrence. Abuse was not significantly associated with proactive interoception, but it was significantly and positively associated with reactive interoception and internalizing psychopathology. As the abuse latent factor measures experiences of physical (in addition to emotional) harm, being more reactive to one's own bodily sensations may reflect an adaptation to the traumatic experiences, as noticing, paying attention to, and worrying about uncomfortable bodily feelings could help detect abnormal bodily status and choose the right actions to correct and prevent it, thus promoting survival. In addition, the prolonged pairing between the experience of threat and visceral discomfort may strengthen fear conditioning, such that negative bodily sensations may signal the presence of threat, eliciting a strong emotional reaction, even with an absence of the actual threat from the environment (McLaughlin et al., 2019). The positive association between abuse and reactive interoception provides evidence for the dimensional model of early adversity, such that experiences of abuse (representing threat) are associated with altered emotional processing (i.e., more emotionally reactive to bodily feelings), which, again, may be an adaptation to early traumatic experiences. The null effect of abuse on proactive interoception reflects that these two dimensions of interoception are to some degree distinct from each other. It is possible that there are individual differences in the association between child abuse and proactive interoception that were not captured by the current study, which should be explored by future research.

Conversely, neglect was significantly associated with lower levels of both proactive and reactive interoception, and it was not associated with internalizing psychopathology. As proactive interoception involves regulatory process, it is not surprising that neglect was negatively associated with proactive interoception, as early psychosocial deprivation was found to be associated with

emotion regulation difficulties (Tottenham et al., 2010). This result brings up an interesting future research direction on the investigation of the objective and subjective use of visceral information to regulate emotion. It would be interesting to see how the use of bodily information maps onto existing models of emotion regulation. The negative association between neglect and reactive interoception may reflect less reactive stress physiology, echoing prior research showing that early deprivation is associated with (or even causes) blunted sympathetic nervous system and hypothalamic-pituitary-adrenal (HPA) responses (McLaughlin et al., 2015; Reilly & Gunnar, 2019). Extant research on neglect and emotion reactivity is sparse, with a meta-analysis identifying only two studies that could enable the comparison of abuse and neglect in terms of emotion reactivity (Lavi et al., 2019). Hence, it is difficult to posit that the negative relationship between neglect and reactive interoception is because of low emotion reactivity in general. However, in an early environment characterized by deprivation, there are limited opportunities to learn about emotions from caregivers, leading to deficits in emotion knowledge (Milojevich et al., 2021). We argue that this principle applies to interoceptive socialization as well; neglected parents may not provide healthy scaffolding for children's understanding of bodily feelings, especially their evaluative belief about the sensations. Not being aware the connection between visceral information and emotion may lead individuals less emotionally reactive to uncomfortable bodily feelings. This finding sparks the ideas that 1) the emotion-body connection may be part of emotion knowledge; and 2) parental interoceptive socialization, such as teaching children's the connection between the body and emotion and the positive value of bodily feelings (i.e., interoceptive belief), should be considered as a critical part of typical emotional development. Overall, these results provided evidence for the dimensional model of early adversity and our hypothesis that abuse and neglect indeed have differential associations with the outcomes.

Limitations

The results of the present study should be interpreted with the following limitations in mind. First, the factor structure of subjective interoception was derived using the MAIA measure, which may not contain all facets of subjective interoception. In other words, the existence of proactive and reactive interoception may be specific to the MAIA scale. Future research should investigate whether other aspects of subjective interoception exist, how they map onto the dimensional structure of subjective interoception, and their relationships with proactive and reactive interoception. In addition, our finding of the differential effects of abuse and neglect on subjective interoception should only be interpreted in the context of child maltreatment, not general threat and deprivation. Although this compartmentalization of child maltreatment experiences was inspired by the threat and deprivation model, these two dimensions of early adversity contain a broader range of adverse childhood experiences. Future research can extend our findings to formally test whether threat and deprivation have differential impact on subjective interoception. Moreover, only depression and anxiety were used as indices of internalizing psychopathology. Other types of internalizing psychopathology, such as post-traumatic stress disorder/symptoms, should be considered in future work. Lastly, the current sample, although diverse, only represent the college student population in the United States, and the data utilized are cross-sectional. Researchers should consider replicating and extending our findings in other populations and cultures, as well as leveraging longitudinal data to better delineate the temporal precedence of subjective interoception and internalizing psychopathology.

Conclusion

In conclusion, the present study examined the multidimensional nature of subjective interoception, how its different dimensions were differentially associated with internalizing psychopathology, and how child abuse and neglect differentially impacted subjective interoception. We discovered that subjective interoception is comprised of proactive and reactive interoception. The former represents the tendency to proactively utilize bodily feelings to guide emotion regulation, and the latter represents the degree to which an individual focuses on and emotionally reacts to visceral sensations, and these dimensions share overlapping components. We provided evidence for the differential associations between these two dimensions of subjective interoception and internalizing psychopathology and for the differential effects of abuse and neglect on them. We hope that these results will inspire future inquiries regarding subjective interoception, in terms of both what it is and how it is impacted by early experiences, among other developmental and contextual factors.

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Table 1
Demographic Statistics

	N	Percentage
Age	M = 19.29, *SD* = 2.07	
Biological sex		
Female	264	67.5%
Male	122	31.2%
Did not report	5	1.3%
Ethnicity		
Hispanic/Latino	224	57.3%
Asian/Asian American	47	12%
Multiethnic	39	10%
White/Caucasian of European Descent	22	5.6%
Black/African American	24	6.1%
White/Caucasian of Middle Eastern Descent	19	4.9%
Native Hawaiian, Pacific Islander	1	0.3%
Native American/Alaska Native	1	0.3%
Other	9	2.3%
Did not report	5	1.3%

Table 2

Correlation Matrix and Descriptive Statistics

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Mean	SD
1. CEA	1															10.3	5.38
2. CPA	.54**	1														6.92	3.09
3. CSA	.31	.29**	1													6.51	4.10
4. CEN	.58	.35**	.17**	1												9.89	4.78
5. CPN	.39**	.35**	.15**	.41**	1											6.78	2.74
6. Noticing	.12*	.05	.05	-.05	-.07	1										12.6	4.38
7. Not-Distracting	-.22**	-.18**	-.18**	-.11*	-.07	-.37**	1									7.04	3.37
8. Not-Worrying	-.08	-.04	-.09	.06	.06	-.43**	.36**	1								4.75	2.52
9. AttReg	-.03	-.02	-.08	-.17**	-.1*	.54**	-.27**	-.42**	1							18.4	7.40
10. EmoAwar	.07	-.01	-.03	-.09	-.08	.58**	-.29**	-.44**	.62**	1						16.6.	5.36
11. SelfReg	-.15**	-.07	-.03	-.2**	-.16**	.29**	-.13*	-.25**	.59**	.56**	1					11.4	4.50
12. BodyList	-.14**	-.07	-.02	-.22**	-.08	.36**	-.09	-.32**	.58**	.52**	.69**	1				7.44	3.91
13. Trusting	-.25**	-.15**	-.13*	-.38**	-.23**	.32**	.04	-.23**	.51**	.4**	.56**	.64**	1			9.08	4.13
14. Depression	.44**	.24**	.22**	.29**	.15**	.07	-.24**	-.13**	-.06	.06	-.19**	-.13**	-.24**	1		10.2	6.97
15. Anxiety	.38**	.19**	.21**	.18**	.11*	.06	-.25**	-.14**	-.06	.08	-.16**	-.14**	-.21**	.77**	1	9.55	5.79

Note. *<.05; **<.01. CEA: childhood emotional abuse; CPA: childhood physical abuse; CSA: childhood sexual abuse; CEN: childhood emotional abuse; CPN: childhood physical neglect. Interoception-related abbreviations: AttReg: attention regulation; EmoAwar: emotional awareness; SelfReg: self-regulation; BodyList: body listening.

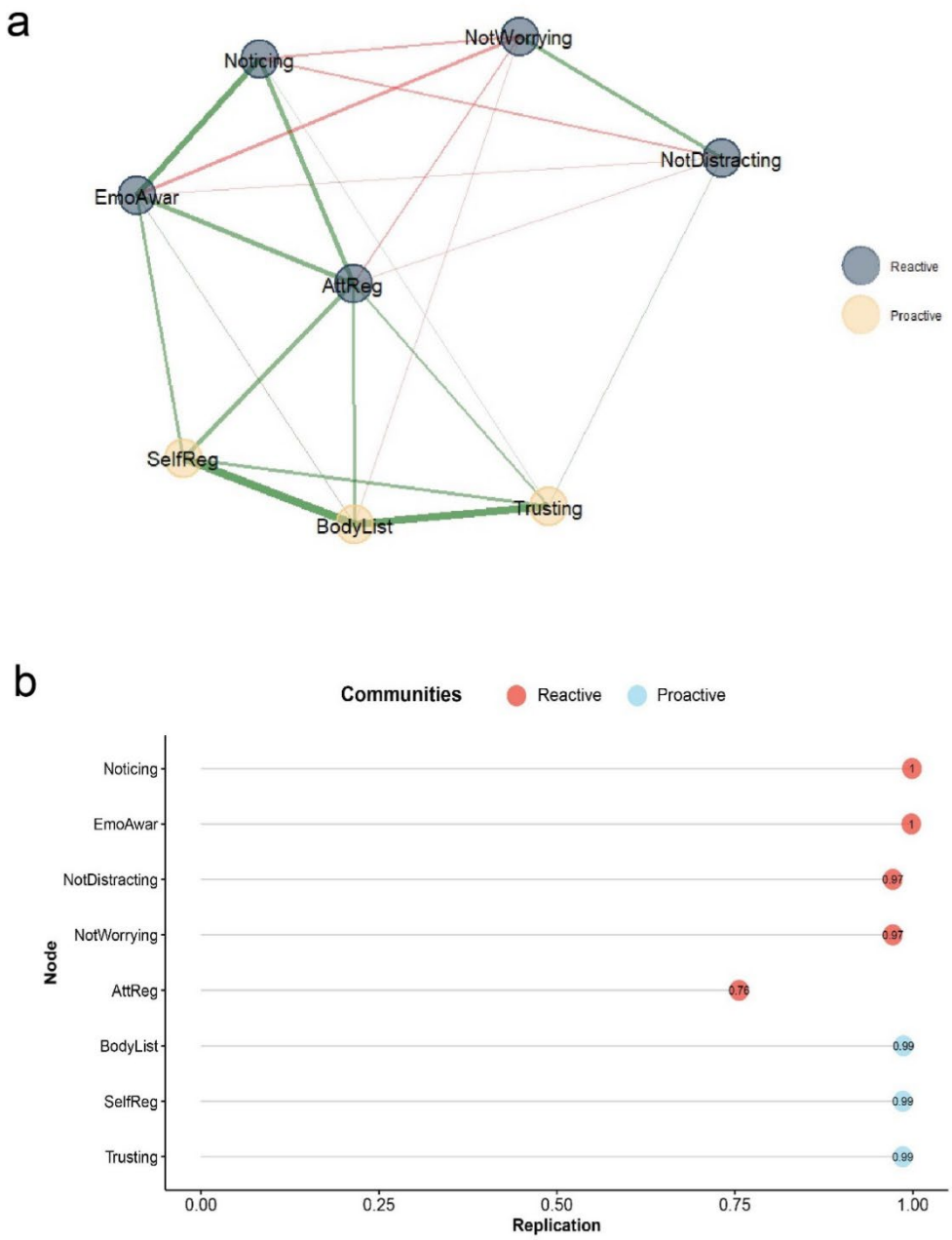
Table 3

Fit Comparison of the Confirmatory Factor Analyses

	CFI	**RMSEA** [90% CI]	**SRMR**
1. Two-factor model (EGA)	.91	.13 [.11, .15]	.07
2. Two-factor model with attention regulation cross-loaded	.94	.11 [.09, .13]	.06
3. Two-factor model with three items cross-loaded	**.97**	**.08 [.05, .10]**	**.03**

Figure 1

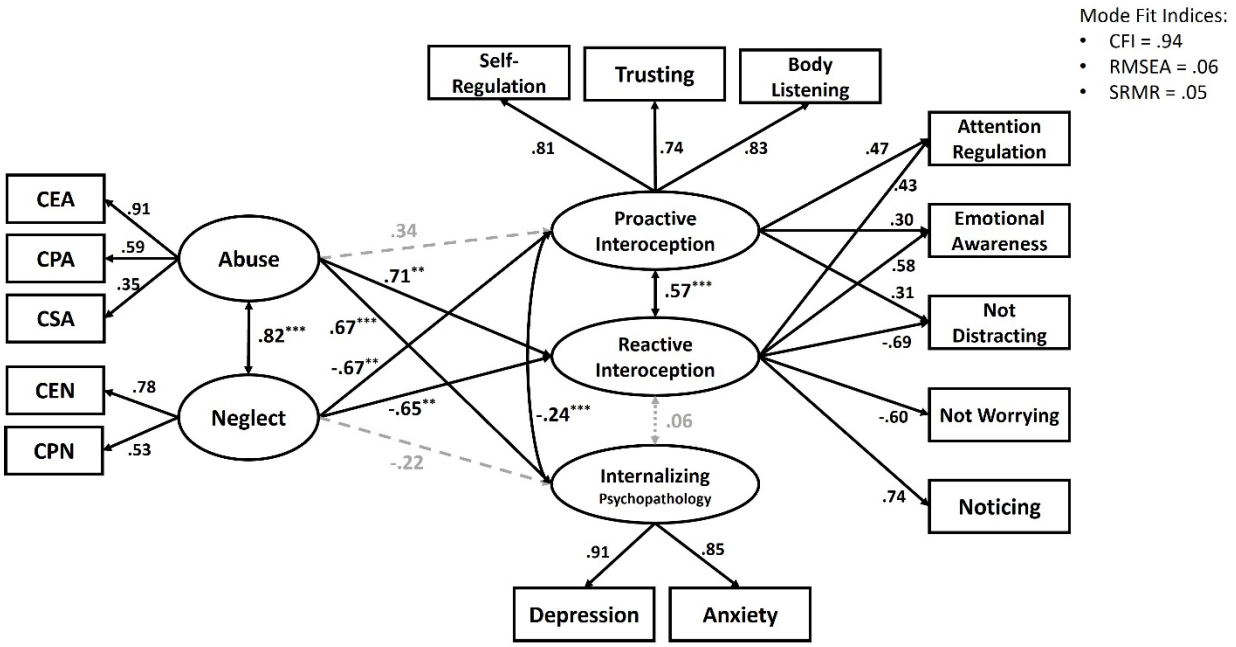
Exploratory Graph Analysis and Item Stability Plot



Note. a) Exploratory graph analysis of subjective interoception. The color of the edges indicates the direction of the relationship (green: positive; red: negative), and the thickness of the edges represent how strong the relationship is. b) Item stability plot. AttReg: attention regulation; EmoAwar: emotional awareness; SelfReg: self-regulation; BodyList: body listening.

Figure 2

Structural Equation Model



Note. **<.01; *** < .001. Dotted, light grey paths represent non-significant relationships. Standardized factor loadings and path coefficients were displayed. CEA: child emotional abuse; CPA: child physical abuse; CSA: child sexual abuse; CEN: child emotional abuse; CPN: child physical neglect.