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# Early maltreatment and interoceptive awareness in youth: Associations among age, sex and child sexual abuse

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ABSTRACT

*Background:* Early maltreatment negatively impacts interoceptive awareness (IA), the attention to internal states and bodily sensations in daily life. Body trust, the belief that one can rely on internal bodily sensations as safe and accurate cues for needs, emotions, and states of arousal, is especially compromised. Although this has significant implications for for emotional regulation, self-awareness, and treatment limited research has examined IA in clinical samples of maltreated youth.

*Objective:* The purpose of this study was to examine age and sex related differences in interoceptive awareness in a clinical sample of youth receiving treatment for complex trauma. A second aim was to examine the relationship between substantiated child sexual abuse (CSA) and body trust.

*Participants and setting:* Data are from a clinical sample of 131 maltreated youth (ages 7–17) receiving therapeutic services for abuse and neglect. Mean age of 12 years, with 54 % female and 80 % in adoptive or guardian care.

*Methods:* The study involved a secondary analysis of Multidimensional Assessment of Interoceptive Awareness-Youth (MAIA-Y) cross-sectional data. Two-way ANOVAs examined main and interaction effects for age and sex on five MAIA-Y scales. Linear regression analyzed the relationship between CSA and body trust.

*Results:* Attention Regulation ($p = .03$, $\eta^2p = .04$) was significantly higher in the older age group (11–17). Significant age by sex interactions emerged for Attention Regulation ($p = .025$, $\eta^2p = .04$), Self-Regulation ($p = .02$, $\eta^2p = .04$), and Trusting ($p < .001$, $\eta^2p = .11$). Adolescent females (11–17) scored significantly lower than males and younger females on all three measures. CSA uniquely explained a proportion of low body trust scores ($p = .005$, $R^2 = .07$).

*Conclusions:* Adolescent females with early maltreatment demonstrate unique vulnerabilities in self-regulatory aspects of interoceptive awareness. These findings underscore the need for developmentally sensitive, gender-specific interventions that prioritize restoration of body trust and self-regulatory aspects of interoceptive awareness in trauma treatment.

## 1. Introduction

In recent years the role of the body in trauma and mental health has gained considerable attention among researchers and clinicians. Of particular interest is the influence of interoception on self-awareness, emotional experience, self-regulation, and mental health (Khalsa et al., 2018; Khoury et al., 2018; Nayok et al., 2023). All of which are major concerns in youth with histories of early maltreatment for whom pervasive difficulties in emotional, behavioral, physiological, and cognitive regulation are commonplace (Van der Kolk, 2014).

Interoception is a sensory process in which internal body sensations are detected, processed, and regulated by the nervous system. It involves both functional awareness and unconscious monitoring of the internal state of the body which is essential to survival, body integrity and the maintenance of health (Craig, 2002). Interoception is a feature of a body-brain communication system designed to respond adaptively to changes in the internal state of the body (e.g. hunger, thirst, fatigue). It operates as a reciprocal feedback loop at both conscious and unconscious levels of processing (Joshi et al., 2021). Interoceptive *accuracy* involves the ability to correctly detect and track internal bodily sensations while interoceptive *sensibility*, also known as interoceptive awareness, is defined as the self-perceived tendency to focus on internal bodily sensations in daily life (Garfinkel et al., 2015; Khalsa et al., 2018).

Interoception plays a central role in emotion regulation, embodied cognition, social behavior, decision making, and subjective feeling states associated with motivation and emotion (Carvalho & Damasio, 2021;

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Pinna & Edwards, 2020; Shah et al., 2017). It is also pivotal in the development and expression of self-conscious emotions (i.e. shame, guilt and humiliation), the construction of body image and the experience of time (Craig, 2009; De Preester, 2019; Engelen et al., 2023; Köteles, 2021; Wittman & Meissner, 2019). Interoceptive awareness is a facet of self-awareness which is integral to sensing danger and safety, knowing one's needs and limitations, recognizing the early physical signs of escalating emotions, and distinguishing between different internal states (i.e. tired versus sad, excited versus scared). In the absence of body-based awareness youth struggle to develop a coherent sense of self because they lack reliable internal feedback about their own experiences (Fotopoulou & Tsakiris, 2017). When a child's internal signals of vulnerability, need, or distress are met with harm instead of care, they learn to disconnect from their body. This disconnection impairs both emotional regulation and self-awareness, as the child loses access to their internal compass for navigating emotional and relational experiences (Schaan et al., 2019; Schmitz et al., 2023; Schulz & Vögele, 2019).

### 1.1. Threat conditioning and predictive errors

Prolonged experiences of early abuse and neglect are associated with a lack of trust in one's bodily self. They violate basic assumptions of safety and persistently alter the way in which youth perceive body sensations and relate to their bodies (Rosenberg et al., 2025; Talmon & Ginzburg, 2018; Tsur et al., 2018). Maltreatment creates a predisposition to seeing threat even in the presence of safety. Rather than learning appropriate threat-safety distinctions, maltreated children develop overgeneralized threat responses that persist even when environmental cues indicate safety, contributing to chronic hypervigilance and difficulty with emotional regulation. These are negative by-products of threat conditioning and mental models arising from past abuse and neglect.

Mental models serve as the brain's internal representation of how the world works - they are the predictive models that generate expectations about sensory input, environmental patterns, and the consequences of actions (Friston, 2010). These models aren't passive storage systems but active prediction engines that continuously generate hypotheses about what will happen next based on current context and past experience**.** For example, a child's mental model of a caregiver might predict either comfort (in secure attachment) or harm (following abuse), creating specific expectations about what sensations and experiences are likely to occur. When actual experience doesn't match the prediction, errors arise. In healthy development, these prediction errors update mental models toward greater accuracy. However, in early maltreatment, mental models may become rigidly biased toward threat detection, resisting updating even when safe experiences contradict predictions (Kube et al., 2020). For these youth, a conditioned and unconscious state of threat shrouds the mental model through which life and relationships are perceived.

Two types of errors drive this process: prediction errors, which occur when expected and actual sensory observations don't match and subsequently lead to updated beliefs about the external world, and somatic errors, which occur when the body's actual internal state deviates from its preferred physiological state and trigger actions aimed at restoring homeostatic balance (Pezzulo et al., 2015; Seth & Friston, 2016). Unlike prediction errors about the external world, somatic errors concern the body's internal operating environment and directly motivate self-regulating behaviors. The brain resolves somatic errors through active inference - taking action to change the body's actual state to match interoceptive predictions rather than simply updating beliefs (Barrett & Simmons, 2015; Seth & Friston, 2016). For example, when the brain predicts a calm, regulated physiological state but detects actual acute stress markers - elevated heart rate, increased cortisol, and muscle tension - the resulting somatic error drives stress-reducing behaviors such as seeking safety, engaging in self-soothing activities, or avoiding the stressor to restore physiological equilibrium (Khalsa & Feinstein, 2019).

### 1.2. Traumatic stress, predictive errors and interoceptive dysfunction

Predictive error processing can become disrupted by maltreatment in multiple ways. The brain may develop chronically elevated set points for arousal and threat detection, creating persistent somatic errors as the body maintains states that deviate from what would be optimal for learning, growth, and social engagement. Additionally, traumatic stress can impair the accuracy of interoceptive predictions, leading to somatic errors that trigger challenging behavioral responses. For example, a maltreated child may misinterpret normal excitement or arousal from positive attention as danger signals, generating somatic errors that drive withdrawal or aggressive behaviors rather than recognizing the sensations as safe social engagement (Paulus et al., 2019). They might hoard food in attempts to correct perceived scarcity and metabolic uncertainty, or they may seek excessive physical contact with caregivers while simultaneously pushing them away - attempting to regulate attachment-related stress while managing conflicting needs for safety and autonomy.

When somatic errors become chronic - as occurs in anxiety, post-traumatic stress disorder (PTSD), and other trauma-related conditions - they create a persistently "noisy" internal environment that overwhelms interoceptive processing capacity. This background of physiological dysregulation makes it difficult to accurately detect and interpret subtle interoceptive cues, leading to a disconnection from the body's intelligence and impaired self-regulation (Kozlowska et al., 2015). Additionally, prediction and somatic error interactions create cascading effects that can impair emotional regulation and attachment formation. Chronic somatic errors (persistent physiological dysregulation) impair the brain's ability to accurately process prediction errors, while persistent prediction errors about external threats maintain somatic dysregulation.

A child can become trapped in a cycle where their body remains in defensive mode, their perceptual system continues to predict danger, and both systems reinforce each other's dysfunction. The child's inaccurate predictive models about internal bodily states create persistent prediction errors that interfere with clear interoceptive processing, leading to either hypersensitivity to bodily sensations (misinterpreting normal fluctuations as threats) or hyposensitivity (becoming disconnected from genuine bodily signals). In effect, creating a disconnection from a reliable internal guidance system.

They can lose the ability to accurately recognize when they are physically safe versus in danger, when they need comfort or soothing, or when they are experiencing basic physiological needs like hunger, thirst, or fatigue. This disconnection from internal bodily cues significantly impairs the child's capacity for emotional regulation (they cannot use bodily signals to identify and manage emotions), decision-making (they lack internal feedback to guide choices), and the formation of healthy attachments with caregivers (they cannot accurately communicate their needs or recognize when those needs are being met).

### 1.3. Traumatic stress and early development

Caregiver responsiveness plays a critical role in healthy interoceptive development during early childhood. When caregivers consistently respond to their infant's signals of hunger, fatigue, or discomfort, they facilitate the child's ability to recognize and interpret internal bodily cues and states through a process called "interoceptive scaffolding" (Fotopoulou & Tsakiris, 2017). This collaborative process helps infants make sense of their internal experiences within secure attachment relationships, leading to the development of interoceptive awareness, body signal recognition, and trust in bodily experiences over time (Tsur, 2020). Conversely, inconsistent or unresponsive caregiving can interfere with normal interoceptive development, potentially leading to difficulties in emotional regulation and self-awareness (Schore, 2001).

When external caregiver regulation is absent, children become trapped in unintegrated states of distress and emotional overwhelm, often leading to reliance on dissociation as the primary escape from unbearable internal states (Dutra et al., 2009; Perry et al., 1995; Schore, 2003). Dissociation functions as a neurobiological, hierarchical threat defense system that develops in response to overwhelming states of stress and fear (Lynn et al., 2022). During dissociative states, interoceptive awareness becomes severely blunted as children disconnect from bodily experience while fight/flight reactions are downregulated for self-preservation (Lanius et al., 2018). Traumatic events involving the body, such as physical or sexual abuse, commonly result in somatoform dissociation - a lack of integration among somatic elements of the traumatic experience (Nijenhuis, 2001). This creates persistent estrangement from bodily experiences, including phobia of body sensations, discomfort with movement, and chronic misinterpretations of internal body signals (Steele et al., 2017).

In maltreated youth, distorted internal working models of relationships often co-occur with chaotic internal working models of the body, creating compound prediction errors that maintain both interpersonal difficulties and physiological dysregulation (Putnam, 2016). Attachment-based predictions about relational safety directly influence somatic states and interoceptive processing, while bodily sensations and physiological arousal inform judgments about interpersonal trust and safety (Porges, 2011). Internal states become linked to negative self-appraisals and threat-related beliefs that distort interoceptive signals resulting in self-perpetuating prediction error loops that maintain dysregulation (Paulus et al., 2019; Paulus & Stein, 2010).

Persistent mismatches between predicted states and actual bodily experiences create an unreliable internal reference system, preventing youth from establishing stable baseline states needed to accurately interpret whether current sensations represent genuine safety, danger, hunger, or other important bodily information (Paulus & Stein, 2006). Consequently, youth are left in a state of constant disequilibrium where predicted body states and internal body states are perpetually misaligned. They may become locked in habitual state-driven patterns, leaving them overwhelmingly out of sync with their inner and outer worlds, and perpetuating cycles of behavior linked with physiological dysregulation and psychological deterioration (Khalsa & Feinstein, 2019; Paulus & Stein, 2010; Putnam et al., 2020).

In addition, childhood maltreatment is known to alter brain structure and function, including the processing of sensory information. Different types of maltreatment uniquely target specific sensory systems (Cassiers et al., 2018; Teicher & Samson, 2013, 2016). For example, severe parental verbal abuse affects the auditory system, while witnessing domestic violence impacts the visual system. These alterations reduce capacity to regulate impulses and emotions and diminish self-awareness and social awareness (Teicher & Samson, 2013, 2016). Maltreatment is also associated with structural changes to interoceptive brain regions such as the insula and anterior cingulate cortex (Teicher et al., 2014, 2016) both of which are involved in the emergence and integration of both interoceptive and emotional awareness (Craig, 2015).

### 1.4. Interoception, mental health, and early adversity

Early adverse experiences may disrupt interoceptive development, creating vulnerabilities that manifest across multiple mental health conditions that are strongly linked to traumatic stress exposure. Including but not limited to depression, anxiety, eating disorders and PTSD (Bremner & Wittbrodt, 2020; Khalsa et al., 2018). Depression is associated with altered activation patterns in key interoceptive regions. Individuals with major depressive disorders show hypoactivation of the right dorsal mid-insula during interoceptive recall tasks, suggesting impaired processing of bodily memories that may contribute to the somatic features of depression (Craske et al., 2017). This neural dysfunction may underpin the difficulty many depressed individuals experience in recognizing and responding appropriately to bodily signals of hunger, fatigue, or emotional arousal.

In contrast, anxiety disorders are characterized by heightened rather than diminished interoceptive sensitivity. Individuals with panic disorders demonstrate increased awareness of and reactivity to bodily sensations, especially cardiac signals (Domschke et al., 2010). This hypervigilance to internal cues can create a vicious cycle where normal physiological fluctuations are misinterpreted as threatening, leading to escalating anxiety and panic responses. The anterior insula, a critical region for interoceptive processing, shows altered connectivity patterns in anxiety disorders. These changes may reflect difficulties in distinguishing between adaptive and maladaptive bodily signals, contributing to the characteristic worry and physical symptoms characteristic of these conditions (Paulus & Stein, 2006).

Interoceptive dysfunction is well-established in eating disorders. Individuals with anorexia nervosa and bulimia nervosa show difficulties in recognizing hunger and satiety signals, leading to severely disrupted eating patterns (Khalsa et al., 2015). The relationship between interoception and eating disorders is thought to be bidirectional, with nutritional restriction potentially exacerbating interoceptive deficits while interoceptive dysfunction contributes to the maintenance of disordered eating behaviors (Klabunde et al., 2017; Smith et al., 2020).

PTSD involves significant alterations in interoceptive processing neural substrates, with individuals showing reduced activation in the right anterior insula during affective tasks and impaired parasympathetic modulation of autonomic arousal (Nicholson et al., 2016; Simmons et al., 2008). This dysfunction, directly traceable to trauma exposure, creates a dysregulated nervous system primed for rapid state switching between hyperarousal and hypoarousal, prioritizing self-protection over social engagement and learning, and perpetuating disconnection from accurate bodily awareness (Harricharan et al., 2021).

Interoceptive disturbances are transdiagnostic mental health markers that cut across traditional diagnostic boundaries, reflecting fundamental alterations in brain-body communication that contribute to psychological distress broadly rather than being specific to individual disorders (Khalsa et al., 2018). This underscores the importance of recognizing that many presenting symptoms may stem from the same underlying issue: disrupted brain-body communication. This means that a maltreated youth presenting with seemingly unrelated symptoms - sleep problems, emotional outbursts, attention difficulties, somatic complaints, and social withdrawal - may be experiencing manifestations of the same core interoceptive dysfunction (Khalsa et al., 2018).

### 1.5. Study purpose

The relationship between interoception and childhood maltreatment remains poorly understood. The primary purpose of this study was to examine age and sex related differences in interoceptive awareness in a clinical sample of children and adolescents receiving treatment for complex trauma. A second aim was to examine the relationship between substantiated child sexual abuse (CSA) and body trust, a dimension of interoceptive awareness known to be impacted by child maltreatment (Ditzer et al., 2025; Rosenberg et al., 2025).

## 2. Method

### 2.1. Study design and participants

The study involved secondary analysis of cross-sectional data collected at a developmental trauma center located in the Midwest region of the United States. The sample consisted of 131 English-speaking children ages 7 to 17, receiving therapeutic services for early abuse and neglect between September 2021 and October 2023. The center specializes in treating children up to the age of nineteen with histories of chronic early abuse or neglect, especially those who have not benefited from other therapies. The most common types of child maltreatment

treated at the location are child sexual abuse/assault, child physical abuse or neglect, and domestic violence.

### 2.2. Measures

#### 2.2.1. Interoceptive awareness

Interoceptive awareness was measured using the youth version of the Multidimensional Assessment of Interoceptive Awareness (MAIA-Y) questionnaire (Jones et al., 2021). The MAIA-Y is a 32-item self-report measure that captures eight separate dimensions of interoceptive awareness in children and youth, ages 7–17 years. The scales are meant to be scored separately, a practice supported by results of previous research (Mehling et al., 2012). The scales include Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body-Listening and Trusting. Items are rated using a 6-point Likert scale indicating how often each statement generally applies to them, ranging from never (0), to always (5). Higher scores indicate greater interoceptive awareness.

Three scales were excluded due to poor internal consistency reliability (α = .43 −.47), Noticing, Not-Distracting and Not-Worrying. Internal consistency for the remaining five scales (Attention Regulation, Emotional Awareness, Self-Regulation, Body-Listening and Trusting) containing 22 items is acceptable (α = .69 - .78). Attention Regulation assesses the ability to sustain and control attention to body sensations. Emotional Awareness assesses awareness of the connection between body sensations and emotional states. Self-Regulation assesses the ability to regulate distress by paying attention to body sensations. Body Listening assesses active listening to the body for insight. Trusting assesses the subjective experience of one's body as safe and trustworthy. Data were collected using an illustrated version of the MAIA-Y questionnaire (Petrenchik & Calvert, 2021) which includes a 5 x 7 card deck containing full-color illustrations of each response item. The illustrations show diverse groups of youth engaged in social participation and everyday activities. A 6-point visual rating scale is used to indicate how often each statement generally applies to them, ranging from never (0), to always (5).

#### 2.2.2. Child sexual abuse

Child sexual abuse was measured using Victims of Crime Act data (Department of Justice, 2023) collected as part of the standard intake process. It is a categorical measure (yes/no) of substantiated child sexual abuse or assault.

### 2.3. Data analysis

A series of two-way ANOVAs using general linear modeling with pairwise comparisons of estimated marginal means (EMM) and post hoc Tukey tests (α = .05) were performed separately for each scale with child sex and age as independent variables. A linear regression analysis was used to estimate the relationship between sexual assault/abuse and body trust (Trusting). Age group and sex were excluded based on the results of a correlation analysis. SPSS version 29 was used for statistical analysis with an alpha level of .05.

## 3. Results

Demographically, the sample consisted of 60 males and 71 females with a mean age of 12 years. There were 45 children in the 7–10 age group and 86 in the 11–17 age group, of whom eighty percent had current or prior foster care involvement. Three-quarters of the children were in adoptive or guardian care at the time of the study. Families self-identified as White (47 %), Black (28 %), multi-racial (16 %), Asian (5 %), and Hispanic/Latino (4 %).

### 3.1. Age and sex comparisons

MAIA-Y mean scores and estimated marginal means (EMM) are reported in Table 1. None of the scales showed a significant main effect for sex, one showed a main effect for age and three showed age by sex interactions (Table 2). For Attention Regulation there was significant main effect for age $F(1,127) = 4.98$, $p = .03$, $\eta^2p = .04$, with the 11–17 age group having higher mean scores (EMM = 2.82) compared to the 7–10 age group (EMM = 2.41). There was also a significant age by sex interaction, $F(1,127) = 5.18$, $p = .025$, $\eta^2p = .04$, with females in the older age group having significantly lower mean Attention Regulation scores (EMM = 2.58) than males (EMM = 3.07). For Self-Regulation there was a significant interaction between age and sex for the 11–17 age group $F(1,127) = 5.79$, $p = .02$, $\eta^2p = .04$ with females in the older age group having significantly lower mean Self-Regulation scores (EMM = 1.96) than males (EMM = 2.56). For Trusting there was a significant interaction between age and sex for the 11–17 age group $F(1,127) = 15.53$, $p < .001$, $\eta^2p = .11$ with females in the older age group having significantly lower mean Trusting scores (EMM = 2.87) compared to males (EMM = 3.94).

### 3.2. Child sexual abuse

In a linear regression analysis CSA was predictive of low body trust $F(1,103) = 8.14$, $p = .005$, $R^2 = .07$, accounting for 7 % of the variance in the Trusting scale.

## 4. Discussion

This study examined age and sex-related differences in interoceptive awareness among maltreated youth and investigated the relationship between child sexual abuse and body trust. We found no significant main effects for sex across the five dimensions of interoceptive awareness. For Attention Regulation, there was a significant main effect for age, with the 11–17 age group having higher mean scores compared to the 7–10 age group. This finding aligns with research showing that cognition undergoes significant development in mid-adolescence, with overall gains in attention and general cognitive control

**Table 1**
Means (*M*) and standard deviations (*SD*) with factorial estimated marginal means (*EMM*), standard errors (*SE*), and confidence intervals (CI) for the five MAIA-Y scales.

| Scale | Group | Descriptive statistics | | | Factorial analysis | | |
|---|---|---|---|---|---|---|---|
| | | *M* | *SD* | *n* | *EMM* | *SE* | 95 % CI |
| Attention Regulation | 7–10 | 2.42 | 1.03 | 45 | 2.41 | .15 | 2.11–2.71 |
| | 11–17 | 2.81 | 1.00 | 86 | 2.82 | .11 | 2.61–3.03 |
| | Male | 2.85 | 1.03 | 60 | 2.72 | .14 | 2.45–2.99 |
| | Female | 2.53 | .99 | 71 | 2.51 | .12 | 2.27–2.75 |
| Emotional Awareness | 7–10 | 3.27 | 1.18 | 45 | 3.24 | .16 | 2.92–3.57 |
| | 11–17 | 3.43 | 1.03 | 86 | 3.44 | .12 | 3.21–3.67 |
| | Male | 3.44 | 1.13 | 60 | 3.34 | .15 | 3.04–3.64 |
| | Female | 3.33 | 1.04 | 71 | 3.35 | .13 | 3.08–3.61 |
| Self-Regulation | 7–10 | 2.46 | 1.19 | 45 | 2.45 | .18 | 2.10–2.80 |
| | 11–17 | 2.24 | 1.18 | 86 | 2.26 | .13 | 2.01–2.51 |
| | Male | 2.51 | 1.20 | 60 | 2.48 | .16 | 2.16–2.81 |
| | Female | 2.15 | 1.15 | 71 | 2.22 | .14 | 1.94–2.51 |
| Body Listening | 7–10 | 2.49 | 1.34 | 45 | 2.48 | .18 | 2.13–2.83 |
| | 11–17 | 2.20 | 1.05 | 86 | 2.20 | .13 | 1.95–2.45 |
| | Male | 2.23 | 1.08 | 60 | 2.28 | .16 | 1.96–2.60 |
| | Female | 2.36 | 1.23 | 71 | 2.40 | .14 | 2.11–2.68 |
| Trusting | 7–10 | 3.66 | 1.11 | 45 | 3.64 | .19 | 3.27–4.01 |
| | 11–17 | 3.38 | 1.41 | 86 | 3.41 | .14 | 3.14–3.67 |
| | Male | 3.80 | 1.13 | 60 | 3.72 | .17 | 3.38–4.06 |
| | Female | 3.20 | 1.40 | 71 | 3.32 | .15 | 3.02–3.63 |

**Table 2**
F statistics and partial eta squares for main and interaction effects by age and sex on the five MAIA-Y scales.

| Scale | IV | *F* (1,127) | $\eta_p^2$ |
|---|---|---|---|
| Attention Regulation | Age | 4.98* | .04 |
| | Sex | 1.29 | .01 |
| | 7-10 age x sex | .05 | .00 |
| | 11-17 age x sex | 5.18* | .04 |
| Emotional Awareness | Age | 1.00 | .01 |
| | Sex | .00 | .00 |
| | 7-10 age x sex | 1.22 | .01 |
| | 11-17 age x sex | 2.18 | .02 |
| Self-Regulation | Age | .78 | .01 |
| | Sex | 1.46 | .01 |
| | 7-10 age x sex | .06 | .00 |
| | 11-17 age x sex | 5.79* | .04 |
| Body Listening | Age | 1.73 | .01 |
| | Sex | .28 | .00 |
| | 7-10 age x sex | .11 | .00 |
| | 11-17 age x sex | .20 | .00 |
| Trusting | Age | 1.03 | .01 |
| | Sex | 2.99 | .02 |
| | 7-10 age x sex | .48 | .00 |
| | 11-17 x sex | 15.53** | .11 |

Note: IV = independent variable; *p < .05; **p < .001.

(Tervo-Clemmens et al., 2023).

The most striking finding was a consistent pattern of diminished interoceptive awareness specifically among adolescent females (11–17 years) compared to both males in the same age group and females in the younger age group (7–10 years). All three affected domains - Attention Regulation, Self-Regulation, and Trusting - constitute foundational skills for emotional regulation and adaptive functioning. This pattern suggests that early maltreatment may erode self-regulatory advantages typically observed in females particularly those that depend on interoceptive-related abilities. Typically, females in early, middle, and late adolescence show developmental advantages in self-regulation, including higher levels of self-control and self-monitoring compared to males (Vanessa et al., 2019), higher levels of emotional regulation (Sanchis-Sanchis et al., 2020) and greater inhibitory control (Reardon et al., 2022). The reversal of this characteristic pattern in the present clinical sample suggests that abuse and neglect during critical developmental periods may disproportionately affect interoceptive related dimensions of self-regulatory capacities in adolescent females. Specifically, attention regulation, self-regulation, and body trust.

### 4.1. Child sexual abuse and body trust

CSA uniquely predicted low Trusting scores in both males and females. Although the effect accounted for only a modest portion of variance, it was consistent across genders which is consistent with previous research showing body trust is particularly vulnerable to maltreatment (Ditzer et al., 2025; Rosenberg et al., 2025). Most cases of CSA involve family members and attachment figures (Lim et al., 2021), making them profound betrayals of relational trust that undermine a child's sense of physical and psychological safety. CSA also commonly co-occurs with physical abuse, emotional abuse, and domestic violence (Putnam et al., 2020) making these additional factors likely contributors to low body trust in maltreated youth.

### 4.2. Age and sex comparisons

Presently, we lack comparative studies of interoceptive awareness in younger clinical populations, in particular studies involving maltreated youth. Comparisons with the limited research available show these study findings differ from studies involving non-clinical samples of youth and from retrospective adult studies of interoception and child maltreatment. Nearly all research on child maltreatment and interoception involves a mix of clinical and non-clinical samples of adults. In a meta-analytic review of child maltreatment and interoception in adults, maltreatment was not generally associated with changes in interoceptive awareness (Ditzer et al., 2025). The exception was body trust, which was negatively associated with child maltreatment. Notably, while Ditzer and colleagues (2025) found no significant relationships among age, gender, child maltreatment types and facets of interoception our study revealed substantial differences across multiple interoceptive domains, specifically among adolescent females. This suggests the adolescent period may represent a particularly vulnerable time for interoceptive awareness in females with histories of early maltreatment.

An earlier finding that Attention Regulation was stronger in males than females in a population-based sample of youth (Jones et al., 2021) fits with developmental research showing certain aspects of sustained attention in young males is often superior to young females, though the latter show better inhibitory control (Reardon et al., 2022). In contrast, maltreated youth in the present study did not differ in Attention Regulation based on sex alone. The negative and ubiquitous impact of maltreatment on attention across gender groups (Ford et al., 2022) may partially explain this finding. Additionally, chronological age and developmental stage are often out of sync in children with complex trauma, as evidenced by the high rates of pervasive developmental delay and neurodevelopmental conditions in this population (Putnam et al., 2020; Ross et al., 2021). The confluence of which must be considered in age and sex comparisons.

Lastly, the relationship between age, sex and interoception takes on additional complexity within LGBTQIA + populations. Notably, eighty percent of youth in the present study had prior involvement in the U.S. foster care system, in which LGBTQIA + youth are largely over-represented (Fish et al., 2019). Research in this area remains limited but emerging evidence suggests distinctive patterns of interoceptive processing may intersect with gender identity, sexual orientation, and the psychological impact of marginalization (Burke et al., 2017; Feusner et al., 2017; Tabaac et al., 2018). It is likely gender-related factors that were unaccounted for in this study influenced aspects of interoceptive awareness, particularly body trust.

### 4.3. Loss of trust in the body

The significantly lower Trusting scores among adolescent females in this study warrants particular attention. In non-maltreated youth, body trust has been shown to decline in both males and females during adolescence, although females appear to be more negatively impacted than males (Grabauskaite et al., 2017; Jones et al., 2021; Todd et al., 2019). The weakening of body trust during adolescence has been attributed to the rapid physical, neurobiological, and psychological changes associated with puberty (Jones et al., 2021; Marceau et al., 2011). Changes in body image accompany the onset of puberty, with adolescent girls experiencing more negative body image than boys (Calzo et al., 2012; Sabiston et al., 2022). For maltreated females, these normative challenges are compounded by trauma related factors.

Adolescent girls become the object of sexual interest and attention which can lead to objectification by self and others. This may partially explain declines in body trust among adolescent girls, in which body confidence is eroded through internalized experiences of objectification (Daniels et al., 2020). Maltreatment adds the corrosive effects of body shame (Talmon & Ginzburg, 2018) and a negative post-traumatic orientation to bodily signals among females (Tsur, 2020). Prolonged and early experiences of abuse and neglect are associated with a pervading lack of trust in one's bodily self and body sensations and persistently alter the way in which these youth relate to their bodies (Rosenberg et al., 2025; Talmon & Ginzburg, 2018; Tsur et al., 2018).

During adolescence, body image disturbances often intensify in

females, reflecting the combined influence of biological, psychological, and social factors. For maltreated youth, this convergence can further erode body trust. Research consistently demonstrates that adolescent females experience greater body dissatisfaction, appearance-related anxiety, and negative body evaluation compared to males (Calzo et al., 2012; Sabiston et al., 2022). These disturbances are associated with increased risk for eating disorders, depression, and reduced physical activity engagement (Sabiston et al., 2022). For females with maltreatment histories, abuse related disruptions in body trust may render them particularly vulnerable to these normative but complicated changes in body perception and evaluation during adolescence.

### 4.4. Clinical implications

These findings have implications for treatment and underscore the importance of considering sex, developmental stage, type of maltreatment and IA as core ingredients of trauma responsive interventions. The identification of adolescent females as uniquely vulnerable suggests that treatment protocols should include gender-specific and developmentally informed approaches.

Establishing a foundational sense of body-based trust and psychological safety emerges as a critical therapeutic priority. Without a basic sense of bodily safety and trustworthiness, higher-order therapeutic goals such as emotional regulation and interpersonal connection remain difficult to achieve. Because complex trauma leaves individuals feeling out of control and unsafe in their bodies, restoring a sense of power and control is essential. Restoration begins by focusing on control of the body and moves progressively outward towards managing challenging environments (Herman, 2015). Guided, corrective experiences that gradually update threat-biased predictions form the core of this work because developing an embodied sense of safety is achieved through direct experience, not through reasoning or explanations. This process requires time, consistency, and safe, supportive relational connection.

The unique pattern of interoceptive difficulties in adolescent females suggests the need for gender-specific intervention approaches that acknowledge both developmental vulnerabilities and maltreatment-related difficulties. Gradually rebuilding trust in bodily experiences while providing relational and external regulatory support during this vulnerable developmental period is essential. Promoting internal states supportive of self-care and post-traumatic growth is reliant on strengthening both embodied cognition and underlying interoceptive awareness. Ultimately, treatment approaches that integrate both cognitive work (updating beliefs) and experiential work (providing safe experiences that contradict maladaptive predictions) to reshape underlying mental models may be most effective. However, the therapeutic entry point is the establishment of body-based trust and psychological safety. Because embodiment is fundamental to recovery, experiential approaches based in structured movement, sensory-based activities, and somatic therapies are uniquely beneficial for scaffolding interoceptive awareness in maltreated youth.

### 4.5. Study limitations

Several limitations should be considered when interpreting these findings. The reliance on self-report measures introduces potential bias, and the MAIA-Y, while psychometrically sound, requires further validation in trauma-exposed populations. The cross-sectional design precludes causal inferences, and the single-site recruitment limits generalizability. Additionally, the binary classification of biological sex does not capture gender identity, and the absence of comorbidity data limits understanding of how mental health conditions influence interoceptive awareness. The measurement of child sexual abuse as a binary variable fails to capture important dimensions such as severity, duration, and perpetrator relationship, all of which matter in terms of their effects. Furthermore, CSA commonly co-occurs with physical abuse, emotional abuse, and domestic violence, the synergistic effects of which were not accounted for in the present study.

### 4.6. Future directions

Future studies are needed to examine the differential impact of specific types of abuse and neglect on interoceptive awareness and reveal the mechanisms by which interpersonal trauma affects youth's orientation towards the body. Longitudinal studies are needed for understanding ways in which facets of interoceptive awareness change or remain stable over time, particularly during the vulnerable adolescent period identified in this study. Mediation studies will be important for clarifying the relationship among child maltreatment, interoceptive awareness, symptom clusters and severity, and post-traumatic orientation to bodily signals. Additionally, intervention studies examining the effectiveness of gender-specific, body-focused therapies for strengthening interoceptive awareness would provide valuable guidance for clinical practice. Future research should also explore protective factors that may buffer against the interoceptive difficulties observed in adolescent females, as well as investigate whether the patterns identified represent temporary developmental disruptions or more enduring difficulties that persist into adulthood.

## 5. Conclusion

Adolescent females with histories of early maltreatment demonstrated a unique pattern of interoceptive difficulties, characterized by lower scores in Attention Regulation, Self-Regulation, and Trusting compared to both males and younger females. This constellation of impairments in self-regulatory competencies that rely on interoceptive abilities represents a concerning departure from typical developmental patterns, where females typically show advantages in these domains. The identification of body trust as particularly vulnerable to child sexual abuse, while accounting for only a small proportion of variance, underscores the complex nature of trauma's impact on the developing interoceptive system. These findings suggest that the intersection of gender, developmental stage, and distict patterns of maltreatment creates unique interoceptive vulnerabilities that require specifically targeted interventions.

Clinically, these results emphasize the critical importance of developmentally sensitive, gender-specific interventions that prioritize the restoration of body trust and self-regulatory aspects of somatic awareness in trauma treatment. Given that body trust serves as a foundation for emotional regulation, a internal sense of coherence, and higher-order executive functions, addressing its diminishment early may be vital for preventing associated mental health difficulties and promoting post-traumatic growth.

## Research data for this article

Due to the sensitive nature of the questions asked in this study, participants were assured that raw data would remain confidential and would not be shared.

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## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Data availability

The data that has been used is confidential.

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