

**Parental interoception: uncovering parents' capacity to read children's
bodily signals via subjective and psychophysiological methods**

by

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I, Carolina Villegas Martinez, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Interoception, the awareness and processing of internal bodily signals, is critical for homeostasis and emotional functioning. Its developmental mechanisms remain unknown, although theories suggest parent-child interactions play a key role. Direct evidence and appropriate instruments to investigate this are lacking. Therefore, this thesis developed and employed novel subjective and objective measures of **parental interoception** to investigate parents' ability to identify and respond to their children's interoceptive states, and how this relates to individual interoception, psychosocial traits, and child outcomes.

The Parental Interoception Questionnaire (PIQ) was created and validated in three phases (Chapter 2): item development, scale development, and scale evaluation. Across two samples (N1 = 601, 46% female; N2 = 511, 50% female) analyses yielded a 24-item questionnaire comprising five factors. PIQ scores correlated significantly with emotion regulation, parental mentalising, and child behaviours, supporting its construct validity.

Moreover, the Child Body Reading (CBR) task, was designed to assess adults' (N = 65, 69% female) and parents' (N = 57, 74% female) ability to discriminate children's cardiac signals (Chapters 3 and 4). Both groups performed above chance, indicating that adults can discriminate between the cardiac states of children. Overestimation of the heart rate, emotion regulation difficulties, stress, and anxiety related to better performance, suggesting that greater accuracy might not always be adaptive. Both subjective and objective measures of parental interoception were linked to child outcomes, including emotional lability and behavioural problems.

This thesis introduces the first tools to explicitly assess parents' ability to "read" their children's interoceptive signals and states, providing initial evidence for parental interoception as a multidimensional construct. The findings represent an important step toward understanding how parents read children's bodily states and support self-regulation development and also help identify individual differences in these processes.

Impact Statement

This thesis introduces the first conceptualization and measurement of parental interoception, parents' ability to notice and respond to their children's internal bodily signals and states. This involved the development, validation, and application of both subjective and objective tools: the Parental Interoception Questionnaire (PIQ) and the Child Body Reading (CBR) task. By providing the first dedicated instruments in this area, this research lays a foundation for a new line of investigation at the intersection of developmental psychology, psychophysiology, neuroscience, and mentalisation research.

Academic Impact

Theoretically, this work advances our understanding of interoception by extending it beyond the individual level to interpersonal and parental dynamics, introducing a novel multidimensional construct. Methodologically, it contributes robust, validated instruments that can be used across disciplines of developmental psychology, psychophysiology and neuroscience. The PIQ and the CBR task offer reliable tools for researchers to investigate how parents read or infer children's interoceptive signals and how these processes might relate to healthy development. These measures open research avenues for longitudinal and intergenerational research, supporting the exploration of developmental mechanisms and underlying factors linking parental interoception with emotion regulation and psychopathology. The thesis also informs methodological and theoretical debates by highlighting the complex, possibly non-linear relationship between parental interoception and psychosocial outcomes, encouraging nuanced and careful modelling of interoception and parental mentalising in future research.

Impact Beyond Academia

The findings in this thesis have potential to influence practices in healthcare, education, and community contexts. For clinicians, the PIQ and CBR tools provide opportunities to examine the role of parental interoceptive sensitivity in families with mental health difficulties, possibly informing the future development or adaptation of

interventions or preventive action to promote healthier parent-child relationships. For educators and caregivers in different contexts, this research, and future research informed by these findings and methodologies, can support the design of school, nursery, or community programs aimed at promoting healthy caregiving practices. Moreover, policymakers and service providers may also use these insights to inform their intervention strategies and incorporate bodily dimensions into child and family wellbeing initiatives.

More broadly, this work has the potential to enrich public knowledge on parenting by framing interoception as a key but sometimes overlooked dimension of caregiving. The findings could be communicated in lay terms through accessible media, community workshops, and collaborations with practitioners, to help parents and caregivers learn about how their attention and responses to children's bodily signals and states might affect development.

In sum, this thesis contributes a novel conceptual and methodological framework for studying parental interoception and provides practical tools with the potential to shape research, clinical practice, and caregiving approaches. Over time, these findings and future contributions may inform interventions that support healthier emotional development in children and enhance the quality of parent-child or caregiving relationships in different contexts.

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I am deeply grateful to my parents, whose unconditional love and support have allowed me to set big goals for myself and to pursue them; to try challenging things, not without fear, but with the certainty that, no matter the outcome, I would always have solid ground beneath my feet. These pages would not exist without you.

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Table of Contents

Abstract	3
Impact Statement.....	4
Acknowledgements	6
UCL Research Paper Declaration Form.....	7
Table of Contents.....	9
List of Figures	12
List of Tables.....	13
List of Appendices.....	14
Chapter 1: Introduction	15
1.1 Interoception and Homeostasis	15
1.1.1 Interoceptive Dimensions.....	17
1.2 Interoception and Emotional Processes	21
1.2.1 Interoception and Mental Health	25
1.3 Development of Interoception and the Parental Role	27
1.3.1 Parent-child Physiological Regulation and Synchrony.....	28
1.3.2 Parental Mentalising – “Reading” of Children’s Mental States.....	31
1.3.3 Parents’ Interoceptive Abilities and Children’s Outcomes.....	33
1.4 Parental Interoception.....	34
1.5 Thesis Outline	34
Chapter 2: Development and validation of the Parental Interoception	
Questionnaire (PIQ)	37
2.1 Introduction	37
2.2 General Methods	40
2.3 Phase 1– Item Development.....	41

2.3.1	Methods.....	42
2.3.2	Results	46
2.4	Phase 2 – Scale Development.....	49
2.4.1	Methods.....	49
2.4.2	Results	51
2.5	Phase 3 – Scale Evaluation	58
2.5.1	Methods.....	59
2.5.2	Results	65
2.6	Discussion.....	69

Chapter 3: Reading children’s interoceptive states: can adults discriminate children’s heart rates? 76

3.1	Introduction	76
3.2	Methods	80
3.2.1	Participants.....	80
3.2.2	Design	83
3.2.3	Procedures and Materials	84
3.2.4	Data Analysis	93
3.3	Results	98
3.3.1	Stimuli Check	98
3.3.2	CBR Task Performance	98
3.3.3	Relationships With Interoceptive Accuracy and Sensibility.....	102
3.3.4	Relationships With Psychosocial Traits	103
3.3.5	Summary of Results	104
3.4	Discussion.....	105

Chapter 4: Objective and Subjective Parental Interoception – Relationships with Individual Interoception, Psychosocial Traits and Child Outcomes 113

4.1	Introduction	113
4.2	Methods	119
4.2.1	Participants.....	119
4.2.2	Design	122

4.2.3	Procedures and Materials	123
4.2.4	Data Analysis	127
4.3	Results	133
4.3.1	CBR Task Performance	133
4.3.2	Relationships With Interoceptive Accuracy and Sensibility	137
4.3.3	Relationships With Psychosocial Traits	138
4.3.4	Effects of Parental Interoception on Child Outcomes	139
4.3.5	Summary of Results	140
4.4	Discussion.....	141
Chapter 5: Discussion		150
5.1	Measuring Objective and Subjective Ability to Infer Children's Interoceptive States – Parental Interoception	150
5.2	Relationships With Individual Interoception	159
5.3	Relationships With Psychosocial Factors	160
5.4	Effect on Child Outcomes	163
5.5	General Limitations	165
5.5.1	Validity of Measures	166
5.5.2	Sample Characteristics	167
5.5.3	Conceptual Scope	168
5.6	Directions for Future Research	170
5.7	Concluding Remarks.....	171
References		173
Appendices.....		206

List of Figures

Figure 1.1. Organs and sensations included in different definitions of interoception.	16
Figure 1.2. Dimensions of interoception.	18
Figure 2.1. Description of the stages in each phase of the study.	41
Figure 2.2. Guidelines for item wording.	44
Figure 2.3. Phase 2 – EFA model from Child group.	56
Figure 3.1. CBR task – trials and procedure.....	86
Figure 3.2. Children’s recording procedure.....	90
Figure 3.3. Predicted CBR task scores by participant gender and child sex.	100

List of Tables

Table 2.1. Phase 1 – Summary of changes after examining relevant measures.	44
Table 2.2. Phase 1 – Results from expert ratings.	46
Table 2.3. Phase 1 – Re-structuring of subscales after expert ratings.....	47
Table 2.4. Phase 2 – Demographic information for parent sample.	50
Table 2.5. Phase 2 – Item analysis for Baby and Child groups.....	52
Table 2.6. Phase 2 – EFA results for Baby and Child groups.	54
Table 2.7. Phase 2 – Factor loadings for CFA on Baby group.	56
Table 2.8. Phase 2 – Correlations between factors in CFA for Baby group.	57
Table 2.9. Phase 3 – Demographic information for parent sample.	60
Table 2.10. Phase 3 – Descriptive statistics for each PIQ factor.	66
Table 2.11. Phase 3 – Pearson correlations between PIQ factors.....	66
Table 2.12. Phase 3 – Factor loadings for CFA.	66
Table 2.13. Phase 3 – Pearson correlations between MAIA and PIQ subscales.....	68
Table 3.1. Demographic information for adult sample.....	81
Table 3.2. Demographic information for child sample.	83
Table 3.3. Operationalization of variables.	84
Table 3.4. Descriptive statistics for CBR task confidence ratings.	101
Table 3.5. Cues and strategies used by participants to complete CBR task.....	102
Table 3.6. Correlations between CBR task performance and MAIA-2 subscales. .	103
Table 4.1. Demographic information for parent sample.	120
Table 4.2. Operationalization of variables.	123
Table 4.3. Descriptive statistics for CBR task confidence ratings.	136
Table 4.4. Cues and strategies used by participants to complete CBR task.....	136
Table 4.5. CBR task performance and interoceptive variables correlations.....	137
Table 4.6. CBR task performance and DASS-21 subscales correlations.	138

List of Appendices

Appendix A. Chapter 2 – Phase 1 – Measures reviewed for item development. ...	206
Appendix B. Chapter 2 – Phase 1 – Final version of the PIQ in this phase.	215
Appendix C. Chapter 2 – Phase 2 – Descriptive statistics for all PIQ items.....	218
Appendix D. Chapter 2 – Phase 2 – Complete EFA results.	222
Appendix E. Chapter 2 – Final version of the PIQ and user instructions.	234
Appendix F. Chapter 3 – Analyses excluding outlier stimuli.....	239

Chapter 1: Introduction

“Only if a mother is sensitized in the way I am describing can she feel herself into her infant's place, and so meet the infant's needs. These are at first body- needs, and they gradually become ego-needs as a psychology emerges out of the imaginative elaboration of physical experience”
(Winnicott, 1956 p. 304)

1.1 Interoception and Homeostasis

Homeostasis is a key function in animal biology that refers to the continuous process through which different body functions, including physiological, immune, endocrine, and behavioural, work together to maintain the integrity and health of the body in an energy-efficient way (Craig, 2015). Interoceptive signals play a crucial role in homeostasis (Fotopoulou & Tsakiris, 2017; Khalsa et al., 2018) as they can inform the brain of the physiological conditions of the rest of the body (e.g., pH, insulin, oxygen, etc.) to guide regulation, decisions and actions (Craig, 2015; Fotopoulou & Tsakiris, 2017; Khalsa et al., 2018). As such, interoception is broadly defined as the processing, representation, and awareness of internal bodily signals serving homeostatic purposes (Craig, 2002; Khalsa et al., 2018).

Initially, the definition of interoception was limited to afferent information or sensations from the viscera (Cameron, 2001; Ceunen et al., 2016; Desmedt, Luminet, Maurage, et al., 2023). One of the earliest uses of the term by Sherrington (2023) referred to the “internal surface of the body” as interoceptive, distinguishing it from the external surface (i.e., exteroceptive) which is in direct contact with the environment. More recently though, the concept of interoception is commonly used as an umbrella term encompassing neurobiological and psychological facets that occur at different levels of the neurocognitive hierarchy, from afferent signaling, to central processing and neural representation of internal bodily signals, to mental representations, consciously accessible as felt sensations, percepts, and feelings (Brewer et al., 2021; Ceunen et al., 2016; Critchley & Garfinkel, 2017; Quadt et al., 2018). On some definitions, this broader view also includes signals and sensations originating both from within the body and its boundaries, i.e. the skin, such as affective touch, cutaneous pain, and

temperature sensations (Craig, 2002, 2010; Crucianelli & Ehrsson, 2023; Fotopoulou & Tsakiris, 2017).

Moreover, interoceptive signals can pertain to different “bodily axis” or interoceptive modalities, which refer to specific organ systems and their corresponding nervous system mechanisms (Suksasilp & Garfinkel, 2022). Some of the most studied modalities include the cardiovascular, gastric, and respiratory. However, according to the broader definition, interoceptive processing is involved in all biological systems that contribute to the homeostatic control of the body, including nociceptive, chemosensory, and thermoregulatory systems, among others (Crucianelli & Ehrsson, 2023; Greenwood & Garfinkel, 2025; Khalsa et al., 2018). See Figure 1.1 from Greenwood and Garfinkel (2025) for examples of body signals included in different definitions of interoception.

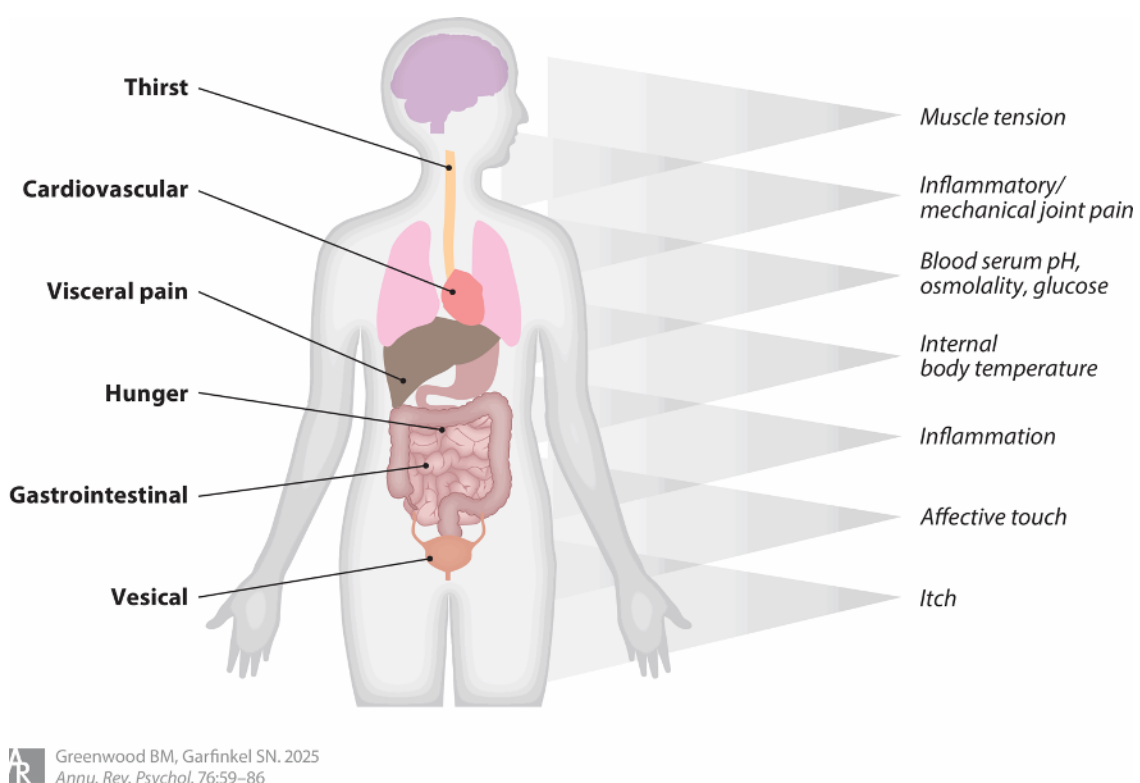


Figure 1.1. Organs and sensations included in different definitions of interoception. Body signals in bold are included in most definitions while body signals in italics are included only in some definitions (non-exhaustive list). Note: the figure is reproduced from Greenwood and Garfinkel (2025), an open access article distributed under the terms of the Creative Commons CC-BY license.

1.1.1 Interoceptive Dimensions

Apart from interoceptive modalities, the different facets of interoception have been classified into different dimensions. Garfinkel and Critchley (2013) proposed a well-known model differentiating between interoceptive sensibility, which refers to self-reported beliefs about one's internal bodily state and the tendency to be internally focused; interoceptive accuracy (also called sensitivity), which refers to objective accurate detection of internal bodily sensations; and interoceptive awareness, which is a metacognitive measure of knowledge and confidence in one's own interoceptive sensitivity.

Variations of this model have been proposed thereafter. For example, Khalsa et al. (2018) make a point to distinguish sensation from perception, and include interoceptive attention, detection, magnitude, discrimination, accuracy, insight, sensibility, and self-report as different interoceptive features. On their part, Murphy et al. (2019) propose a 2x2 factorial model that differentiates between what is being measured and how. The first factor refers to what is measured, accuracy or attention (the degree to which one pays attention to interoceptive signals), while the second factor refers to the type of measurement, objective vs. self-report. This model assumes therefore that both accuracy and attention can be measured both objectively and subjectively.

These models all focus on higher levels of processing (i.e., interoceptive processes of which one is consciously aware); however, the most recent model proposed by Suksasilp and Garfinkel (2022) includes lower levels as well, extending the model to include visceral, neural, and preconscious levels (see Figure 1.2). This thesis focuses mainly on the dimensions of interoceptive accuracy (i.e., objective) and interoceptive sensibility, also referred to as self-report or beliefs (i.e., subjective). These two dimensions and their assessment methods are described below.

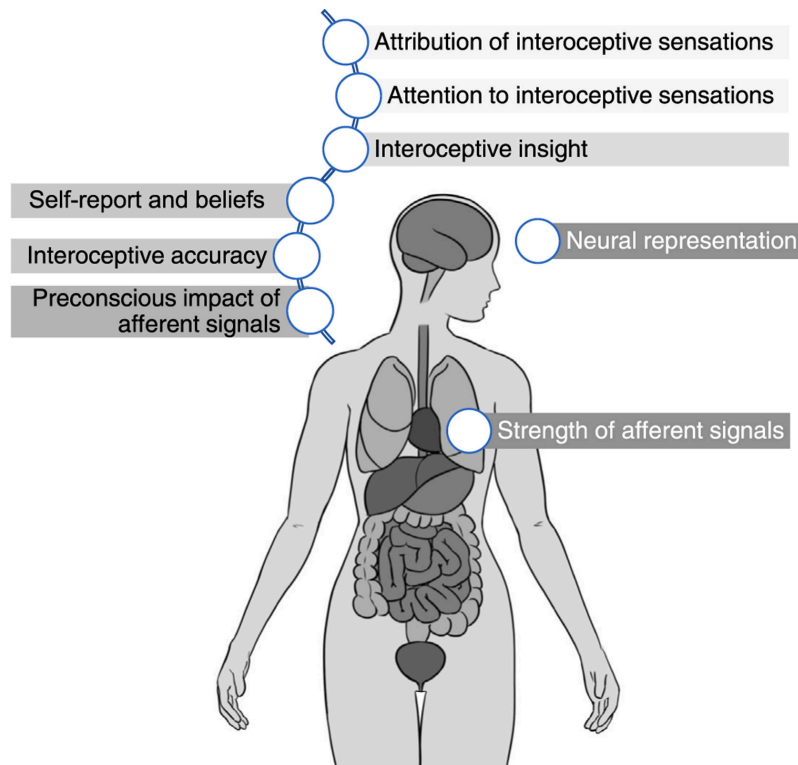


Figure 1.2. Dimensions of interoception. Note: the figure is reproduced from Suksasilp and Garfinkel (2022), an open access article distributed under the terms of the Creative Commons CC-BY license.

Interoceptive accuracy (IA). This dimension refers to the objective ability to accurately detect and monitor internal bodily sensations and events. Measuring IA poses a challenge because the strength of the interoceptive signal can vary both within and between individuals and is difficult to control (Brewer et al., 2021). Consequently, participants' performance on the same task may differ depending on signal strength. For example, cardiac perception accuracy has been found to increase when a stronger signal is induced through physical exercise (Jones & Hollandsworth, 1981; Schandry et al., 1993). Furthermore, controlling the stimuli (e.g., signal strength) in an interoceptive task is challenging; even when manipulated experimentally, only the stimulus intended to elicit an interoceptive change can be controlled, not the signal itself (Brewer et al., 2021).

Therefore, IA is typically assessed through behavioural tasks that involve objectively measuring physiological events – naturally occurring or sometimes experimentally manipulated – as accurately as possible, and quantifying the difference between these

events and participants' self-reports of the bodily sensations they experience (Garfinkel et al., 2015; Suksasilp & Garfinkel, 2022). A range of behavioural tasks has been developed to assess interoceptive accuracy across different modalities, mainly cardiac, respiratory, and gastric. These tasks require participants, for example, to detect their heartbeats or synchronise their heart rate with external stimuli (Critchley et al., 2004; Katkin et al., 1982; Schandry, 1981; Whitehead et al., 1977); estimate the volume of water in their stomach (Van Dyck et al., 2016); report hunger levels following glucose intake (Young et al., 2021); identify the vibration of an ingested capsule (Smith, Mayeli, et al., 2021); detect small differences in the duration of respiratory occlusions (i.e., interruptions in inspiration) (Van Den Houte et al., 2021); detect or discriminate respiratory resistive loads during breathing (Daubenmier et al., 2013; Garfinkel et al., 2016; Webster & Colrain, 2000); among other experimental procedures (for a systematic review see Desmedt, Luminet, Walentynowicz, et al., 2023).

Amongst these procedures, a large focus has been placed on the cardiac modality when assessing IA, in part due to the non-invasive nature of the methods and the ease in measuring cardiac signals compared to other interoceptive modalities. The most widely used paradigm is the heartbeat counting task (HCT; Dale & Anderson, 1978; Schandry, 1981), in which participants count the number of heartbeats they feel during a specified time interval without physically checking their pulse. Accuracy is calculated as the ratio of actual to reported heartbeats. However, the validity of the HCT has been questioned due to methodological issues, particularly the influence non-interoceptive processes such as prior beliefs and guessing strategies (e.g., estimating heart rate rather than reporting actual heartbeat sensations) (Brener & Ring, 2016; Desmedt et al., 2018; Desmedt, Luminet, Maurage, et al., 2023).

Variations of this task, such as heartbeat tracking or tapping (e.g., Flynn & Clemens, 1988), and alternative methodologies have been developed. One example is two-alternative forced choice (2AFC) paradigms based on signal detection theory (SDT). In these tasks a "cardiac feedback" stimulus (e.g., a flashing light or beeping sound) is presented either simultaneously with the participant's heartbeats or with a specific delay (e.g., Whitehead et al., 1977). Importantly, in some of these tasks, even the stimulus presented as "simultaneous" is delayed, based on the assumption that the

perception of a heartbeat occurs after the actual cardiac event. Participants must then decide whether the cardiac feedback is simultaneous with their heartbeat. This method has also faced criticism, as it assumes when participants are most likely to feel their heartbeat relative to the cardiac phase. This assumption has been challenged by studies using the method of constant stimuli (MCS), in which cardiac feedback is presented at various intervals after the R-wave to identify at which time participants most often judge the stimulus as simultaneous with their heartbeat (Brener et al., 1993). For a review of methods measuring cardiac IA, see Brener and Ring (2016).

More recently, Legrand et al. (2022) developed the Heart Rate Discrimination (HRD) task to address limitations of earlier approaches. In addition to the issues affecting heartbeat counting and tracking tasks (e.g., influence of prior beliefs and guessing), the authors argue that 2AFC and MCS procedures require high cognitive effort – they demand simultaneous attention to exteroceptive and interoceptive inputs – along with long testing times and specialised equipment capable of precise cardiac-stimulus synchrony. The HRD task instead uses a two-interval forced choice (2IFC) design in which participants attend to their cardiac sensations for five seconds and then decide whether a series of tones is faster or slower than their heart rate. Applying a psychophysical approach combined with Bayesian modelling, the task estimates each participant's threshold or bias: the difference between the true heart rate and the participant's estimated rate. The threshold, thus, corresponds to the point at which responses are equally likely to be “faster” or “slower”. A negative threshold indicates underestimation of the heart rate, while a positive threshold indicates overestimation.

As the authors note, the HRD task does not provide a straightforward measure of objective IA but rather captures the bias and precision of participants' beliefs about their heart rate. Despite its own limitations (e.g., a working-memory component, see Legrand et al., 2022 for details), the HRD task was selected for the experiments presented in later chapters of this thesis due to its robust methodology and improved validity compared to prior methods.

Interoceptive sensibility (IS). Referring to the subjective experience and beliefs about interoceptive sensations, IS relies on self-report questionnaires for assessment (Garfinkel & Critchley, 2013; Suksasilp & Garfinkel, 2022). These scales capture broad

trait-like features or general beliefs about bodily sensations. For example, the Interoceptive Accuracy Scale (IAS; Murphy et al., 2020) measures self-perceived accuracy in detecting bodily signals; the Body Awareness Questionnaire (BAQ; Shields et al., 1989) evaluates self-reported attentiveness to body processes, ability to detect subtle changes in bodily functioning, and ability to predict bodily reactions; and the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012) measures multiple aspects of IS, including noticing neutral, positive, and negative internal sensations, regulating distress through attention to bodily signals, and worrying about negative sensations.

Notably, Desmedt et al. (2022) found that the most commonly used questionnaires for measuring IS exhibit low intercorrelation scores and may, in fact, assess distinct constructs. Consequently, any comparisons or replication studies evaluating IS should consider the specific questionnaire or measurement tool employed, and results should be interpreted with caution, considering the different features of IS that each questionnaire evaluates.

Moreover, according to Suksasilp and Garfinkel (2022), participants' confidence ratings or judgements about how well they performed during behavioural measures of IA also fall within the dimension of interoceptive self-report. However, unlike questionnaire-based measures, these ratings reflect state-like beliefs, as they are obtained in real time on a trial-by-trial basis. The present thesis employs both self-report questionnaires and confidence ratings to assess IS, with further details provided in the subsequent chapters.

1.2 Interoception and Emotional Processes

Beyond serving homeostatic purposes, research has also found that interoception plays an important role in emotional processes, including experiencing, recognising, labelling, and regulating emotions (Brewer et al., 2021; Critchley & Garfinkel, 2017; Murphy et al., 2017; Quigley et al., 2021; Tsakiris & Critchley, 2016). Early theories of emotion were divided over whether the awareness of physiological arousal alone constitutes an emotion or whether the subjective experience of an emotion exists independently of such physiological responses (Bard, 1928; Cannon, 1931; James,

1948; Lange, 1885). Although some debates persist, current theories largely agree that emotions arise from a combination of physiological awareness and cognitive appraisal of contextual information (i.e., evaluating the significance of the environment for well-being; Moors et al., 2013). One of the main arguments for this consensus is that physiological changes are typically too broad to determine a specific emotion and therefore require cognitive appraisal to form the subjective emotion (Brewer et al., 2021; Greenwood & Garfinkel, 2025). For a comprehensive review of appraisal-based models, see Moors et al. (2013). The present thesis follows the most recent consensus and definitions (American Psychological Association; Damasio & Carvalho, 2013; Pace-Schott et al., 2019), using the term *emotion* to refer to complex phenomena involving experiential, behavioural, and physiological components that serve adaptive functions (i.e., motivating neural activity and particular behaviours), and that can be either evoked by or give rise to specific feelings (i.e., conscious experiences of the emotion) or cognitions.

As research on interoception has expanded, neurobiological evidence supporting its impact on emotional processes has also grown, deriving mainly from two general findings. First, there is an overlap between the neuroanatomical substrates that underlie interoceptive function and body regulation and those that underlie emotional experiences (Barrett & Simmons, 2015; Craig, 2008; Critchley, 2005; Kleckner et al., 2017; Lindquist et al., 2016). For example, the same brain regions are activated when participants evaluate their current emotional state and when they evaluate their body signals in a non-emotion focused context (Terasawa et al., 2013). Second, there is a temporal covariation of physiological changes (e.g., heart rate, skin conductance) and changes in emotional experience when individuals are exposed to emotionally evocative stimuli (Asutay et al., 2021-see Study 4). Sometimes, specific sets of physiological reactions have even been found to discriminate between different emotions (Ekman et al., 1983; Harrison et al., 2010; Jang et al., 2015; Schwartz et al., 1981).

In the context of emotion regulation research, physiological measures are commonly used in two primary ways: 1) as outcome measures of regulation success, and 2) to examine the physiological mechanisms underlying the emotion regulation process (McRae & Shiota, 2017). In the first case, sympathetic nervous system (SNS)

activation, often referred to as the “fight-flight” response, is considered. This can include increased heart rate, blood pressure, respiration rate, skin electrical conductivity, etc. (Cacioppo et al., 2008; Kreibig, 2010; McRae & Shiota, 2017). Because strong negative emotions typically activate the SNS (Cacioppo et al., 2008; Kreibig, 2010), effective emotion regulation strategies should attenuate this response. Indeed, cognitive reappraisal, an emotion regulation strategy that involves changing the way you think about negative situations to reduce their negative affect, has been shown to reduce SNS reactivity (Gross, 1998; Ray et al., 2010).

In the second case, vagal tone, reflecting parasympathetic nervous system (PNS) influence on the heart at rest, is associated with emotion regulation capacity (McRae & Shiota, 2017). Vagal tone is commonly measured through respiratory sinus arrhythmia (RSA) and heart rate variability (HRV). Research suggests that RSA increases during negative emotion tasks indicate that effortful emotion regulation is taking place. For instance, women using reappraisal strategies while discussing an upsetting film exhibit greater RSA increases than controls (Butler et al., 2006).

Additionally, RSA levels during negative emotion tasks correlate with trait-level emotion regulation deficits (McRae & Shiota, 2017). For example, one study found that healthy controls’ RSA increased while watching emotion-eliciting films but decreased in patients with borderline personality disorder (Di Simplicio et al., 2012). Similarly, Cui et al. (2015) found that adolescents with better self-reported anger and sadness regulation, along with higher pro-social behaviour, displayed a pattern of initial RSA decrease followed by RSA increase after recalling an anger-inducing event. Nonetheless, it is important to note that RSA and HRV primarily reflect effortful control, which extends beyond emotion regulation. Consequently, these measures might also indicate broader cognitive and executive control not specific to emotion regulation and they may not fully capture emotion regulation processes that do not require effortful control (McRae & Shiota, 2017).

Furthermore, evidence linking emotion regulation to direct measures of interoception suggests that better IA and IS are associated with more effective use of various emotion regulation strategies (Bornemann & Singer, 2017; Füstös et al., 2013; Kever et al., 2015; Pollatos et al., 2015; Schuette et al., 2021; Zamariola et al., 2019). For

example, Füstös et al. (2012) show that IA predicts the effectiveness of cognitive reappraisal in reducing physiological arousal and subjective experience when responding to negative stimuli. Additionally, using self-report measures of emotion regulation, Weiss et al. (2014) found that higher IA relates to better “frustration tolerance” and “affect differentiation and affect tolerance”, and Schuette et al. (2021) found that IS predicted emotion regulation and the use of adaptive coping strategies.

Of particular relevance to this thesis, behavioural and neurobiological studies indicate that interoceptive signals and abilities are important not only for self-focussed emotional processes but also for responsiveness to others’ emotions. For example, Terasawa et al. (2014) found that participants with higher IA (measured via the HCT) were more sensitive to others’ emotions of happiness and sadness in a morphed facial expressions task. Similarly, Chick et al. (2020) reported that higher IA (measured via a heartbeat tracking task) was associated with greater sensitivity to facial expressions of disgust and fear in a go/no-go task (detecting when a target emotional expression appeared). Dirupo et al. (2020), in turn, observed that higher IA (assessed with the HCT) was unrelated to accuracy in distinguishing emotional expressions of disgust and pain, but significantly correlated with higher ratings of emotion intensity. Similar to Grynberg and Pollatos (2015), who found that greater IA enhances cognitive and emotional empathy (i.e., estimations of degree of pain and feelings of compassion).

Additionally, Ernst et al. (2013) provided neuroimaging evidence that neural activity during an empathy task increased after a period of interoceptive attentiveness (task similar to the HCT) but not after exteroceptive attentiveness (counting auditory tones). Furthermore, Critchley et al. (2005) found that heart rate increases in response to sad and angry facial expressions and decreases when exposed to happy and disgusted facial expressions. Hübner et al. (2021) showed that IS also relates to emotion recognition in others. In their study, participants with higher scores on the self-report MAIA exhibited faster reaction times for high intensity expressions in a behavioural task in which they indicated whether a neutral face morphed into a happy or fearful expression. Collectively, these findings suggest that interoceptive signals, IA, and IS are linked to the processing of others’ emotions (see Brewer et al., 2021, section 3.1, for additional evidence). However, the studies do not address whether individual interoceptive abilities relate to identifying and responding to others’ internal bodily

states, a form of “interpersonal interoception”, which this thesis aims to investigate in the context of the parent-child relationship.

1.2.1 *Interoception and Mental Health*

Building on the evidence of interoception’s importance for typical functioning of emotional processes, research has linked impaired or atypical interoception to a wide variety of mental health conditions that affect self-focused emotional control (e.g., mood and anxiety disorders, alexithymia). This has led to the consideration that impaired interoception may represent a general risk factor for the development of psychopathology (Brewer et al., 2021; Critchley & Garfinkel, 2017; Khalsa et al., 2018; Paulus & Stein, 2010; Quadt et al., 2018). While some research has examined specific mental health disorders in relation to interoception, the present thesis will focus on the general population, where symptoms of anxiety, depression, and stress occur at varying intensities. These symptoms may represent a diagnosis in themselves (e.g., generalised anxiety disorder), may occur across multiple disorders, or may appear in subclinical forms, making them especially relevant for understanding the relationship between interoception and mental health outside strictly clinical contexts. Accordingly, evidence linking interoception with anxiety and depression is presented below.

Mood and anxiety disorders have been associated with difficulties in anticipating changes in interoceptive states (Paulus & Stein, 2010) and with reduced flexibility in interoceptive processing, particularly during states of physiological perturbation (Smith, Feinstein, et al., 2021). Specifically, using heartbeat tapping tasks, Smith, Feinstein, et al. (2021) found that healthy individuals exhibited increased cardiac IA during a breath-hold condition compared to a resting state condition. In contrast, patients with depression and anxiety, examined within a transdiagnostic approach, showed minimal improvement in performance under the same perturbation.

Nevertheless, the relationship between psychopathology and interoception remains complex and inconsistent across studies (Brewer et al., 2021; Jenkinson et al., 2024; Schoeller et al., 2025). In anxiety disorders, most studies report heightened cardiac IA (see Domschke et al., 2010 for a review; Van der Does et al., 2000); however, others have found reduced accuracy in both cardiac and respiratory modalities (Bogaerts et

al., 2006; De Pascalis et al., 1984; Ewing et al., 2017; Van Den Bergh et al., 2004). In depression, many studies report decreased IA (see Eggart et al., 2019 for a systematic review; Pollatos et al., 2009), but the findings are nuanced. For example, Dunn et al. (2007) observed significant IA impairments (measured via the HCT) only in participants with moderate depression, while those with severe depression had accuracy scores similar to controls. The authors suggested that medication status might have influenced these results, as patients with severe depression were more likely to be receiving pharmacological treatment, whereas those with moderate depression were less likely to be medicated.

A recent review on cardiac IA in anxiety and depression concluded that heartbeat perception is not systematically impaired in either condition (Jenkinson et al., 2024). Considering the multimodality and multidimensionality of interoception, as well as the methodological challenges in its assessment, such variability in findings is unsurprising. Interoceptive impairments may vary in multiple aspects: the modality affected (e.g., cardiac, gastric), the dimension involved (e.g., strength of signal, accuracy, attention), and the direction of change or pattern in which it is presented (i.e., heightened or reduced) (Brewer et al., 2021; Jenkinson et al., 2024). Consequently, expanding the scope of research beyond accuracy to other dimensions of interoception, such as IS, and to a wider variety of interoceptive modalities, may help clarify these mixed results.

Indeed, an increasing number of studies are examining IS in relation to mental health. Greater IS, as measured by self-report questionnaires, has been associated with higher trait anxiety (Olatunji et al., 2007; Palser et al., 2018; Slotta et al., 2021). Findings for depression are mixed, with some studies reporting greater IS (Wiebking et al., 2010) and others reporting lower IS (Dunne et al., 2021; Eggart & Valdes-Stauber, 2021). These inconsistencies likely reflect several moderating factors, such as the specific interoceptive feature assessed by the measure used, the severity of symptoms, and the possible influence of other psychosocial traits. For example, Wiebking et al. (2010) used the Body Perception Questionnaire (BPQ) as a measure for IS and found that higher scores were associated with depression only for subscales probing awareness of bodily changes during stress and awareness of autonomic nervous system reactivity, but not for general awareness of bodily processes. Also,

Palser et al. (2018) reported that the positive association between IS and anxiety was mediated by alexithymia (i.e., difficulty identifying and describing one's own emotions), such that the combination of elevated IS and alexithymia presented a greater risk for anxiety than altered IS alone.

Overall, existing research supports an association between interoceptive processes and mental health; however, it also highlights the complexity of this relationship. The multimodality and multidimensionality of interoception, combined with heterogeneity in participant samples (e.g., varying symptom severity) and divergence in measurement methods, contribute to inconsistent findings across studies. These complexities underscore the need for careful interpretation of results, though they do not negate the observed connection between interoception and psychopathology.

Considering the evidence presented, interoception is assumed to be associated with self-focused emotion regulation, responsiveness to others' emotions, and mental health symptoms; however, it remains unclear how interoceptive abilities develop and whether they are shaped by the same factors that are known to influence emotion regulation development, such as parental sensitivity and mentalisation (reviewed below). This thesis aims to investigate how parents understand and respond to the interoceptive signals of their children. Accordingly, the developmental perspective of interoception and related theories of parental influence are considered in the subsequent section.

1.3 Development of Interoception and the Parental Role

A handful of studies have started to implement neurobehavioral experiments to look for evidence of interoceptive abilities early in life. During sequential looking paradigms using eye tracking, infants watch an animated figure that moves either in sync or out of sync (faster or slower) with their own heartbeat or breathing. Infants as young as three months old display a looking preference for either synchronous or asynchronous stimuli, which has been interpreted to mean that they have some sensitivity to cardiac and respiratory interoceptive signals (Imafuku et al., 2023; Maister et al., 2017; Tünte et al., 2024). Nevertheless, Weijs et al. (2023) did not find any differences in 5- to 7-month-old infants' looking preferences between synchronous and asynchronous

stimuli in a similar task. While this contrasting result might be due to differences in the experimental paradigm (e.g., looking time manually coded, stimulus flashing instead of moving), more empirical research is needed to reach clear conclusions.

That said, the evidence of interoceptive sensitivity during infancy does not yet explain the mechanisms underlying its development. Infants are dependent on their parents to maintain homeostasis (e.g., regulating their hunger, sleep, and body temperature), thus, it has been theorised that the development of interoception is largely impacted by the interactions with the parent (Atzil & Barrett, 2017; Ciaunica & Crucianelli, 2019; Filippetti, 2021; Fotopoulou & Tsakiris, 2017). Unfortunately, direct empirical evidence supporting this theory is currently lacking and to my knowledge there are no related instruments to measure how parents “read” and react to their children’s interoceptive signals and states. Nevertheless, existing evidence from related areas of child-parent interaction research provide indirect support. Namely, we know from existing studies that 1) parents influence children’s physiological regulation, 2) parental “reading” of children’s mental states (i.e., mentalisation) is important for cognitive and socio-emotional development, and 3) parental interoceptive abilities are related to children’s developmental outcomes. These perspectives, along with corresponding evidence, will be reviewed below and considered in the context of this thesis.

1.3.1 Parent-child Physiological Regulation and Synchrony

Parents can impact their children’s physiological regulation, through behavioural, physiological, and neurological channels (Armstrong-Carter et al., 2021; Fairhurst et al., 2014; Graziano et al., 2012; Manzotti et al., 2019; Nguyen et al., 2021; Shih et al., 2018; Shih et al., 2019; Van Puyvelde et al., 2019; Waters et al., 2017; Winberg, 2005). While a comprehensive review of this topic is out of the scope of this introduction, it is relevant to briefly consider the evidence to elucidate how parents impact their children’s physiological states and regulation.

Looking at parental behaviour, close interactions involving touch, including affective touch, breastfeeding, and rocking, as well as other non-proximal behaviours like praising and imitating, affect the child’s physiological state (Fairhurst et al., 2014; Feldman et al., 2010; Fotopoulou et al., 2022; Manzotti et al., 2019; Van Puyvelde et

al., 2019). For example, parental affective touch can decrease infants' SNS activity (e.g., slow down heart rate, increase blood oxygenation levels), and increase their RSA (Fairhurst et al., 2014; Manzotti et al., 2019; Van Puyvelde et al., 2019). Close body contact can also regulate newborns' temperature, energy conservation, acid-base balance, and respiration (Winberg, 2005). Furthermore, training parents in child-directed behaviours like praising, reflecting the child's statements, imitating their play, and using enthusiasm has been shown to improve children's RSA suppression levels, for example, during a clean-up task (Graziano et al., 2012).

Studies have also demonstrated how parents' physiological state influences their child's physiological reactions during interactions. Different terms have been used to describe this, such as parent-child physiological synchrony (Feldman, 2007b) or co-regulation, which refer to patterns of convergence or divergence of physiological activity over time. Synchrony is a dynamic process that involves adapting to each other's rhythms, which, in the context of parent-child interactions, means that the infant can also influence the parent (see Birk et al., 2022; Davis et al., 2018; Leclère et al., 2014 for systematic reviews on parent-child synchrony). Another term used to describe this phenomenon is contagion, which refers specifically to the influence of one's physiological activity over another's subsequent activity, also called "time-lagged" synchrony (Armstrong-Carter et al., 2021; Shih et al., 2018). Investigating synchrony, Waters et al. (2017) found that mother-infant dyads whose mothers had been exposed to a low-arousal/relaxing condition had greater PNS covariation, while dyads whose mothers were previously exposed to a high-arousal/stress condition had greater SNS covariation. Similarly, other studies find that parents' RSA reactivity during a challenging task influences their child's subsequent RSA reactivity and PNS activation during a recovery phase (Shih et al., 2018; Shih et al., 2019), which indicates contagion or time-lagged synchrony.

Moreover, several studies on synchrony have found that parent-child dyads display physiological and neurological synchrony in different contexts. For example, using dual-fNIRS for neuroimaging, Nguyen et al. (2021) found that mothers' affective touch during a free play face-to-face interaction with their infant (4-6 months old) positively relates to neural synchrony (simultaneous activation in the same brain regions). Also, physiological synchrony (as measured by RSA) was found to be highest during the

face-to-face interaction compared to joint video-watching conditions. On their part, Armstrong-Carter et al. (2021) also found RSA synchrony in parent-child dyads during a puzzle task where the parent is asked to teach and support the child, and time-lagged RSA synchrony during a problem-solving task where the dyad tries to resolve a salient issue.

As seen, synchrony can serve to regulate responses to stressful events, but also more generally, it has been shown to be crucial for emotional development over time. In fact, a lack of synchrony, or dysregulation, in caregiver-child interactions has been linked to negative outcomes, such as school maladjustment (Harrist et al., 1994) and lack of empathy (Feldman, 2007a).

A related concept that has been increasingly studied is parental sensory predictability, which refers to the degree of consistency in the moment-to-moment sequence of sensory signals that the parent provides to the child (Davis et al., 2017). Sensory signals can be auditory (e.g., speech, laughter), visual (e.g., showing a toy to the child), or tactile (e.g., stroking, holding). These sensory signals are considered predictable when they follow a consistent pattern, for example, a parent who usually talks when they show their child a new toy, whereas they would be unpredictable if they are random or disorganised (see Davis et al., 2017 for details on how "unpredictability" is operationalised). Davis et al. (2017) argue that predictability in parental sensory input is a key mechanism by which caregiving influences brain development. Some studies have demonstrated that unpredictable maternal sensory signals relate to impairments in child cognitive functions, effortful control, and physiological responses to stress (Davis et al., 2019; Davis et al., 2017; Noroña-Zhou et al., 2020). Thus, the pattern or organisation of sensory input itself, apart from physiological synchrony, appears to influence child emotional and cognitive development as well.

The evidence presented in this section indirectly suggests that parents influence children's interoception, through physiological measures. However, to my knowledge there are no measures to directly assess such effects. The studies presented in this thesis aim to examine explicit parental responses to children's interoceptive states, which in combination with other parental and child measures can provide supplementary evidence of the parental role in interoception development.

1.3.2 Parental Mentalising – “Reading” of Children’s Mental States

Not only do parents influence their children’s physiological states, but their contingent responses – which involve accurately perceiving the child’s cues and reacting appropriately – to children’s mental and emotional states also play a crucial role in their cognitive and socio-emotional development. This has been widely studied and demonstrated through concepts such as, parental reflective functioning, maternal sensitivity, maternal mind-mindedness, and parental insightfulness. For more detailed literature reviews of these concepts, see Sharp and Fonagy (2008) and Medrea and Benga (2021), which discuss the parent’s capacity to treat their child as a psychological agent.

Parental reflective functioning (PRF) is considered a relationship-specific manifestation of the more general reflective functioning ability, or mentalisation; it refers to the parents capacity to reflect upon their own and their child’s mental states and experiences (e.g., wishes, feelings) and how they motivate behaviour (Sharp & Fonagy, 2008; Slade, 2005). PRF also involves the parent’s ability to reflect on how the interactions with their child can shape their own mental states and their thoughts, feelings and behaviours towards their child (Sharp & Fonagy, 2008; Slade, 2005). It has been found that PRF is crucial for the child’s development of a secure attachment (Sharp & Fonagy, 2008; Slade et al., 2005), and emotion regulation and social skills (Borelli et al., 2021; Ghanbari et al., 2023; Heron-Delaney et al., 2016). For a review of the origins of this concept and recent empirical developments see Luyten, Nijssens, et al. (2017).

In turn, maternal sensitivity refers to the parent’s ability to notice and accurately interpret their child’s signals and what they communicate with their behaviour, as well as the ability to respond to these signals and communications appropriately and promptly (Ainsworth, 1969). Maternal sensitivity has been widely studied in relation to children’s outcomes and associations have been found between this construct and children’s cognitive and socio-emotional development, including language acquisition, behavioural problems, emotional reactivity and regulation, among others (e.g., Kok et al., 2013; Leerkes et al., 2009). For a systematic review see Deans (2020) and for meta-analyses see Cooke et al. (2022) and Madigan et al. (2019).

A more recent term is maternal mind-mindedness (MMM), which refers to the parent's tendency to think of their child as a separate human with their own mind (very similar to how reflective functioning is described), and was developed through a rethinking of the concept of maternal sensitivity (Meins & Fernyhough, 2015). MMM has also been found to contribute, together with other parental variables like sensitivity, to the development of the child's secure attachment (Laranjo et al., 2008), and theory of mind (Laranjo et al., 2014; Meins et al., 2002). Similarly, the term parental insightfulness was developed through a revision of the sensitivity construct and refers to the parent's capacity to "see things from the child's point of view", that is to take the child's perspective, which was argued had only been inferred from parents' behaviour but not directly assessed (Oppenheim & Koren-Karie, 2013). Children's attachment (Koren-Karie et al., 2002; Oppenheim et al., 2001), behavioural problems and social skills (Oppenheim et al., 2004) have also been associated with parental insightfulness.

Although all of these constructs refer to specific parental capacities and the precise relationship between them is still debated, what underlies is the capacity to see and treat their child as an independent psychological agent, with their own thoughts, beliefs, intentions, feelings, and desires (Sharp & Fonagy, 2008). The constructs discussed largely emphasise semantic and verbal dimensions of mentalising and are often operationalised through linguistic methods; however, they overlook bodily or non-verbal aspects of parent-child interaction, leaving out mentalising states that are not symbolised by language (Shai & Belsky, 2017). To address this gap, Shai and Belsky (2011) introduced the concept of parental embodied mentalising (PEM), which takes an embodied relational perspective to evaluate parental mentalising (see also Fotopoulou & Tsakiris, 2017). PEM is the parent's capacity to understand (even implicitly) their child's mental states from their whole-body movements, and to adjust their own kinaesthetic patterns accordingly. This approach to assess parental mentalising assumes that observable kinaesthetic behaviour can reflect mental processes, and it considers different qualities of the movements, such as directionality and tempo (Shai & Belsky, 2011).

Parental embodied mentalising is also related to children's socioemotional functioning, attachment, and cognitive development (Shai & Belsky, 2017; Shai et al., 2022; Shai & Meins, 2018). Although there have been no experimental studies, longitudinal

findings show that PEM (assessed by observational coding) in infancy can predict: 1) children's language development 12 months later, assessed using the Bayley Scales of Infant Development (Shai et al., 2022), 2) their attachment security 9 and 30 months later, measured through the Strange Situation Procedure, and 3) their language abilities, academic skills, behaviour problems, and social competence 48 months later (evaluated using different measures such as teacher reports, and cognitive batteries) (Shai & Belsky, 2017; Shai et al., 2022). Nevertheless, parental embodied mentalising still refers to the “reading” or understanding of the child's *mental* state through body movements but does not consider the actual reading of the child's *interoceptive* states, that is, their bodily sensations and states, and the potential specific effects of the latter on mental states.

1.3.3 Parents' Interoceptive Abilities and Children's Outcomes

Some of the evidence reviewed thus far suggests that: a) interoception influences general responsiveness to others' emotions (Section 1.2); within the specific parent-child context, b) parents influence children's physiological regulation (Section 1.3.1), and c) parents' ability to read and respond to their children's mental states impacts socio-emotional development (Section 1.3.2). Nevertheless, while the findings presented highlight an important relational or social component of interoception, especially for parent-child interactions, they do not directly examine interoceptive abilities in either parents or children in the context of parental influence on development.

Recently, a handful of studies have attempted to correlate parents' interoceptive abilities to children's developmental outcomes in other domains. MacCormack et al. (2020) studied the effects of mothers' own interoceptive knowledge, which they describe as the mother's understanding about how the body feels during different subjective states (e.g., “my heart races when I'm excited”) on several child emotional and cognitive abilities. Results found that mother's interoceptive knowledge predicts children's emotion regulation and social skills, as rated by their teachers.

Additionally, a longitudinal neurobehavioral study showed that parents' interoceptive sensitivity in the brain (measured by activation of the anterior insula) modulates

children's somatic symptoms six years later (Abraham et al., 2019). While these findings suggest that parents' individual interoception capabilities are relevant to their children's development, the ability of parents to understand and respond specifically to their child's interoceptive states has not been directly studied, which is the main aim of the present thesis.

1.4 Parental Interoception

As reviewed above, despite a wealth of concepts and findings on the role of parent-child interactions in the development of emotional regulation, there has been less attention in how such interactions relate to interoception. Consequently, the term **parental interoception** is introduced here. Similar to parental reflective functioning being a relationship-specific manifestation of mentalisation, parental interoception refers to an interoceptive ability that is socially oriented and specific to the parent-child relationship. Explicitly, in this thesis I call parental interoception the parent's ability to notice and respond to their child's internal bodily signals and states. This is proposed as a multidimensional term, including unconscious processing levels as well as conscious, objective perception (e.g., accurately noticing the child's heart racing), and other active, cognitive processes such as attention to, regulation, and reflection of the child's interoceptive signals and states.

As a novel concept, new measures are needed to adequately investigate *parental interoception* and provide empirical evidence, first for the existence of this construct, and then to explore the role of *parental interoception* in the parent-child relationship and begin to generate empirical evidence that supports our understanding of the mechanisms underlying children's development of interoceptive processes. The subsequent chapters attempt to provide initial evidence of a parental interoception ability, both subjective and objective, and its relation to individual interoception, psychosocial traits, and children's socioemotional outcomes.

1.5 Thesis Outline

Considering the literature reviewed, understanding how interoception is developed has become a key aim for researchers in developmental, psychological and neuroscientific fields. Theoretical propositions point to parent-child interactions as

crucial in this process, considering infants' dependency on parents for their homeostatic control (Atzil & Barrett, 2017; Ciaunica & Crucianelli, 2019; Filippetti, 2021; Fotopoulou & Tsakiris, 2017). However, can parents read their children's interoceptive signals? Is this ability related to how they perceive and regulate their own bodily signals? What factors might strengthen or hinder this ability, and does it influence children's developmental outcomes? Although research on related parental behaviours and capacities (e.g., affective touch, synchrony, mentalisation) provides indirect support for the parental role in interoceptive development (see Section 1.3), direct empirical evidence and suitable measures are lacking.

Therefore, this thesis aimed to investigate **parental interoception** – defined as parents' ability to identify and respond to their children's interoceptive signals and states – and to examine how this ability relates to a) parent's individual interoception (about their own body), b) relevant psychosocial factors such as emotion regulation, attachment, and mental health symptoms, and c) children's socioemotional functioning. To achieve this, novel measures were developed and employed in physiological and behavioural experiments presented in the subsequent chapters.

First, **Chapter 2** presents the development and initial validation of the Parental Interoception Questionnaire (PIQ), a novel self-report measure to assess the more conscious aspects of interoception (i.e., interoceptive sensibility or self-report dimensions) relevant in a parental context: subjective parental interoception. This study is organised into three phases: item development, scale development, and scale evaluation. In **Chapter 3**, an adapted behavioural experiment, the Child Body Reading (CBR) task, is introduced and used to evaluate adults' objective ability to identify cardiac interoceptive signals in children solely through visual stimuli. The chapter assesses the validity of the task and provides initial evidence of potential links with individual interoception (participant's interoceptive accuracy and sensibility regarding their own bodily signals) and relevant psychosocial factors.

Next, **Chapter 4** builds on results from the previous chapters by applying the PIQ and the CBR task in a parental sample to investigate subjective and objective parental interoception. This chapter offers initial evidence of both objective and subjective parental interoception and their associations with parents' individual interoceptive

abilities, psychosocial factors, and child outcomes. Finally, **Chapter 5** presents a collective discussion of the findings, integrating them with the wider literature and considering limitations and directions for future research.

Chapter 2: Development and validation of the Parental Interoception

Questionnaire (PIQ)

2.1 Introduction

A growing body of research has investigated *interoception* (i.e., the processing of internal bodily signals) and its role in emotional regulation and mental health (see Chapter 1, Section 1.2). Parallel to this, there is extensive scientific work on parent-child relationships, particularly on how parents influence children's physiology and socioemotional development by "reading" and responding to their mental states (see Chapter 1, Section 1.3). Nevertheless, no studies to date have directly investigated parents' ability to read and respond to their children's *bodily* signals and states, referred to here as *parental interoception*, and how this ability might contribute to the development of healthy or impaired interoception and emotion regulation in children. As defined in Chapter 1 (Section 1.4), parental interoception is multidimensional, encompassing unconscious processing, conscious perception, and higher-order cognitive processes such as attention to, regulation, and reflection of the child's interoceptive signals and states. For this reason, assessment of parental interoception should capture the different interoceptive dimensions. The present chapter focuses on interoceptive sensibility or self-report, while later studies in this thesis incorporate objective measures suited to assessing the interoceptive accuracy dimension.

Some studies suggests that interoceptive sensitivity begins to develop early in life, with evidence observed in infants as young as three months (Imafuku et al., 2023; Maister et al., 2017; Tünte et al., 2024); however, the mechanisms underlying this developmental process remain unknown. Some theoretical frameworks propose that parent-child interactions play a crucial role, given the infants' reliance on caregivers to regulate and maintain homeostasis (Atzil & Barrett, 2017; Ciaunica & Crucianelli, 2019; Filippetti, 2021; Fotopoulou & Tsakiris, 2017). Indirect support for these ideas can be found in research on related parental behaviours and abilities, reviewed in more detail in Chapter 1 Section 1.3. Briefly, one well-established finding is that parental responsiveness to children's mental states influences socioemotional development, as evidenced by studies on constructs such as parental mentalising and sensitivity (e.g., Borelli et al., 2021; Kok et al., 2013). Furthermore, a smaller number

of recent studies suggest that parents' individual interoceptive features, for instance, interoceptive knowledge, can impact developmental outcomes such as emotion regulation and somatic symptoms (Abraham et al., 2019; MacCormack et al., 2020).

Constructs related to parental mentalising abilities, or parents' ability to read children's mental states, can be assessed using a variety of methodological approaches, most commonly semi-structured interviews and naturalistic observations. For a broader overview of concepts and measures used to assess parental mentalisation see Sharp and Fonagy (2008). In terms of self-report instruments, the Parental Reflective Functioning Questionnaire (Luyten, Mayes, et al., 2017b) is, to date, the only instrument specifically designed to capture this construct. The PRFQ is a multidimensional measure comprising three subscales: certainty about mental states, interest and curiosity, and pre-mentalising (e.g., malevolent attribution). It was designed as an easily administered instrument suitable for parents from diverse backgrounds, with the specific purpose of serving as a brief screening tool in large-scale studies rather than as a replacement for more in-depth methods.

Initial validation studies for the PRFQ demonstrated good construct validity, evidenced by significant associations with relevant demographic factors (e.g., education level and employment status) and psychosocial traits such as insecure attachment (Luyten, Mayes, et al., 2017b). The questionnaire was originally validated for use with parents of children aged 0-5, and a version adapted for parents of adolescents has also been validated (Luyten, Mayes, et al., 2017a). The PRFQ has since been translated into multiple languages and applied in numerous studies, with findings consistently confirming the three-factor structure and demonstrating associations between parental reflective functioning and a range of parental characteristics (e.g., attachment style, sense of competence, stress, emotion regulation). These results provide further support for the questionnaire's validity across cultures (e.g., De Roo et al., 2019; Moreira & Fonseca, 2023; Pazzagli et al., 2018; Ye et al., 2022).

Regarding interoceptive sensibility (IS), self-report measures assess trait-like interoceptive features or general beliefs about bodily sensations. Many validated questionnaires have been used as measures of IS and they cover many interoceptive features. For example, the Interoceptive Accuracy Scale (IAS; Murphy et al., 2020)

measures self-perceived accuracy in detecting bodily signals; the Body Awareness Questionnaire (BAQ; Shields et al., 1989) evaluates self-reported attentiveness to body processes, ability to detect subtle changes in bodily functioning, and ability to predict bodily reactions; and the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012) measures multiple aspects of IS, including noticing neutral, positive, and negative internal sensations, regulating distress through attention to bodily signals, and worrying about negative sensations.

Desmedt et al. (2022) conducted a systematic review and identified the two most frequently used self-report scales to measure IS: the Body Perceptions Questionnaire (BPQ; Porges, 1993) and the MAIA. Both questionnaires have been widely used and validated in multiple languages and settings. The BPQ is primarily a unidimensional measure, assessing the frequency of specific autonomic nervous system reactions, whereas the MAIA is multidimensional, comprising subscales related to attention, regulation, and worry about body signals. Research using the BPQ has shown that higher levels of autonomic symptoms reported on this scale are associated with a history of adversity and maltreatment, as well as symptoms of post-traumatic stress disorder (PTSD) (Dale et al., 2022; Kolacz et al., 2020). Moreover, the MAIA has several validated adaptations, including the MAIA-2 (Mehling, Acree, et al., 2018), the Youth Version (MAIA-Y; Jones et al., 2021), and a version for pregnant individuals (MAIA-Preg; Crossland et al., 2025). The MAIA has been linked to enhanced psychological well-being, and has demonstrated utility in clinical studies with populations experiencing eating disorders, depression, stress, anxiety, autism spectrum disorder, chronic pain, suicide ideation, and PTSD symptoms (Brown et al., 2017; Hanley et al., 2017; Klocek & Řiháček, 2023; Mehling, Chesney, et al., 2018; Solano Durán et al., 2024).

Importantly, following their systematic review, Desmedt et al. (2022) examined the five most used questionnaires for IS and found very low intercorrelations, suggesting that they measure distinct constructs. To explore their underlying dimensions, the authors conducted an item-level exploratory factor analysis, which yielded five factors. All BPQ items loaded onto a single factor, termed *Neutral and negative body sensations awareness*. Most MAIA items loaded onto a second factor, termed *Adaptive interoception*. The remaining factors were *Negative feelings propensity*, *Extero-*

interoceptive awareness, and *Interoceptive Not-Distracting* (the latter including three additional MAIA items). For additional details on specific item loadings, complementary measures, and results from a parallel network analysis see Desmedt et al. (2022).

Taken together, this evidence suggests that self-report measures of IS are generally valid and reliable. Nonetheless, comparisons or replication studies must carefully account for the specific questionnaire or measurement tool employed. Results should be interpreted with caution, considering the different features of IS that each questionnaire captures.

The Present Study

Despite the availability of numerous questionnaires for assessing both interoception and parental mentalising or “reading” abilities, no validated self-report measure currently exists for *parental interoception*, that is, parents’ capacity to read and respond to their children’s bodily signals and states. Therefore, the aim of this study was to develop and validate a questionnaire that evaluates the more conscious aspects of interoception (i.e., interoceptive sensibility or self-report dimensions) relevant in a parental context: the Parental Interoception Questionnaire (PIQ). As a self-report measure, the questionnaire is intended to reflect parents’ perspective on their ability, rather than an objective/behavioural measure of this capacity.

In combination with other parental and child measures, the PIQ can facilitate empirical investigations into the mechanisms by which children develop interoceptive abilities and the role parents play in this process. Furthermore, such a questionnaire can offer a tool for exploring broader hypotheses regarding parents own understanding of their children’s bodily needs and their role in supporting physiological regulation.

2.2 General Methods

The study was conducted online, using UCL Qualtrics for survey generation and distribution. Participants were recruited through Prolific and compensated according to the rate stipulated by the Division of Psychology and Language Sciences at UCL.

Ethics Approval was obtained from the UCL Research Ethics Committee (Project number CEHP/2019/577).

The study was divided in three phases (see Figure 2.1), following established procedures for scale development and validation (Boateng et al., 2018; Kyriazos & Stalikas, 2018a). Phase 1, Item Development, used a mixed-methods approach to generate questionnaire items and evaluate their content validity. Phase 2, Scale Development, used a quantitative approach, recruiting a large sample to perform item analysis, prune items, and determine the questionnaire's factor structure. Phase 3, Scale Evaluation, also adopted a quantitative approach, recruiting a second sample to confirm the factor structure and evaluate construct validity and reliability of the questionnaire. Specific aims, methods, and results for each phase are presented in the subsequent sections.

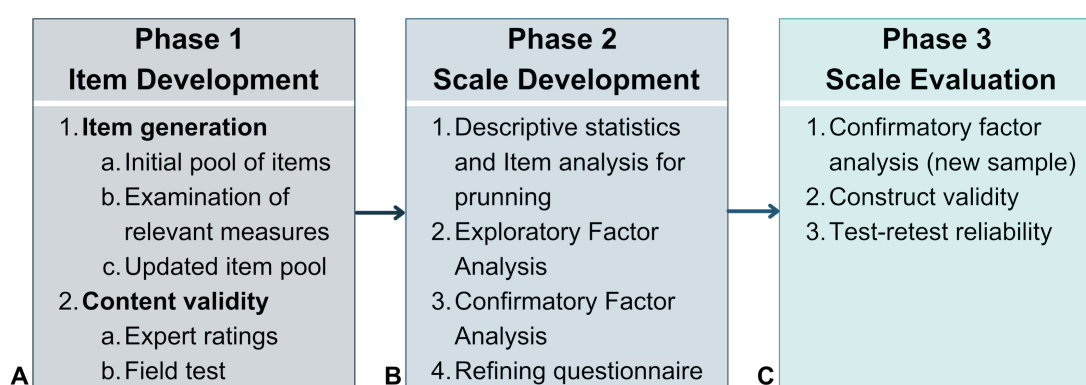


Figure 2.1. Description of the stages in each phase of the study. Phase 1, Item Development, included item generation and evaluation of content validity. Phase 2, Scale Development, included item analysis, exploratory factor analysis, confirmatory factor analysis, and refinement of questionnaire. Phase 3, Scale Evaluation, included confirmatory factor analysis and evaluation of construct validity and reliability.

2.3 Phase 1– Item Development

The aims of this phase were to generate the questionnaire items and evaluate their content validity (i.e., if the items adequately measure the domain of interest). Initially, two versions of the questionnaire were developed, one for parents of 0- to 3-year-olds (baby version) and another for parents of 3- to 10-year-olds (child version). The 0–3-

year-olds range covers the infancy and toddlerhood period, when communication is mainly nonverbal or very simple, after age 3 children gain more agency in terms of language and motor skills (Department for Education, 2023; Staples & Bates, 2018). The 3–10-year-olds range covers the childhood period just before puberty starts, when there are significant body changes (Kirby & Hodges, 2018; Ralph, 2018).

Several steps were followed (see Figure 2.1A): 1) item generation, which involved a) creating an initial pool of items, b) examining relevant measures, and c) updating the item pool, and 2) content validity, which included a) analysing expert ratings (evaluation by a panel of experts in relevant fields) and b) conducting a field test (evaluation by the target population). These steps were followed for both the baby and child versions of the questionnaire in parallel.

2.3.1 Methods

1a) Item generation - Creating initial pool of items. The initial structure of the PIQ was primarily based on the already validated Multidimensional Assessment of Interoceptive Awareness (MAIA-2; Mehling, Acree, et al., 2018). Unlike questionnaires such as the Body Awareness Questionnaire (BAQ; Shields et al., 1989) or the Interoceptive Accuracy Scale (IAS; Murphy et al., 2020), which focus mainly on the perception of bodily signals and states, the MAIA-2 includes perception, attention, and metacognitive aspects, such as regulation, trust, and linking bodily and emotional states, which were considered relevant for the new parental measure. For a more comprehensive discussion on interoceptive self-report measures see Desmedt et al. (2022).

Consequently, the initial pool of items consisted of 37 items divided into eight subscales: noticing, not-distracting, not-worrying, attention regulation, emotional awareness, self-regulation, body listening, and trusting. Subscale definitions and items were modified from the MAIA-2 to be baby/child-oriented and capture the *parental interoception* aspect of each question. In this way, instead of asking parents about their own interoceptive states, the items ask about their beliefs on their ability to “notice” their baby’s/child’s interoceptive state. For instance, the definition for *Noticing* was changed from “awareness of uncomfortable, comfortable, and neutral body

sensations” to “awareness of uncomfortable, comfortable, and neutral body sensations in baby/child”; and the item “I notice when I am uncomfortable in my body” was changed to “I notice when my baby/child is uncomfortable in their body”.

1b) Item generation – Examining relevant measures. Subsequently, other measures for interoception were examined, including the Interoception Sensory Questionnaire (ISQ; Fiene et al., 2018) and BAQ, cross-checking the dimensions and modalities of interoception included with those of the MAIA-2. Questionnaires and measures for other relevant constructs related to parental mentalising and parent-child relationships were also examined, such as the PRFQ and the Insightfulness Assessment (Oppenheim & Koren-Karie, 2013). A comprehensive table (see Appendix A) of all the measures and their corresponding subscales was created for use in the subsequent step.

1c) Item generation – Updating item pool. This step involved a deductive process in which 1) subscales were revised by comparing them with the table created during the previous step (Appendix A). Adjustments to the subscales were made if 1) the examined measures contained relevant items aligned with the subscale, in which case they were adapted and incorporated, or 2) if relevant themes were identified in the examined measures but the corresponding items were not suitable, in which case new items were developed. Moreover, subscales from the examined measures that were deemed relevant but were not initially included in the questionnaire were incorporated, using both adapted and newly created items. The guidelines (Boateng et al., 2018; Kyriazos & Stalikas, 2018b) in Figure 2.2 were followed to create new items and during each revision thereafter.

Items should:

Be clear, simple, and short

Include a single thought or idea

Avoid double-negatives

Avoid absolute words (e.g., always, none)

Avoid having multiple interpretations

Use the same tense

Figure 2.2. Guidelines for item wording. Items were created and adapted according to the following guidelines: clarity, simplicity, and brevity; inclusion of a single thought or idea; avoidance of double negatives and absolute terms; allowance for only one interpretation; and consistency of tense (Boateng et al., 2018; Kyriazos & Stalikas, 2018b).

After this process, the item pool grew to a total of 72 divided in 10 subscales. A summary of changes made can be seen in Table 2.1. Subscales added were: *Homeostatic (Emotional) Awareness*, *Awareness of Homeostatic Cycles*, and *Interpretation of Bodily Signals*.

Table 2.1. Phase 1 – Summary of changes after examining relevant measures.

Subscale	Action Taken	Number of items	
		Before	After
Noticing	Added 4 items adapted from the ISQ (x2), RFQ and PRFQ, and 1 new item.	4	9
Not-Distracting	Subscale discarded.	5	0
Not-Worrying	Added 1 item adapted from the CERQ.	6	7
Attention Regulation	None	7	7
Emotional Awareness	Added 1 new item (to cover all basic emotions).	5	6
Self-Regulation	Added 6 items adapted from the IERQ (x2), PACER (x2), DERS, CTNES, and 6 new items.	4	16
Body Listening	Added 1 item adapted from the PRFQ and 2 new items.	3	6
Trusting	Added 1 item adapted from the BRQ.	3	4

New	Added subscale: Homeostatic (Emotional) Awareness (7 new items).	-	7
New	Added subscale: Awareness of Homeostatic Cycles (6 items adapted from BAQ).	-	6
New	Added subscale: Interpretation of Body Signals (4 items adapted from the ISQ).	-	4

2a) Content validity – Expert ratings. After item generation, the next step was to assess content validity, first through the evaluation by experts. Ratings from eleven experts in the fields of neuroscience, developmental psychology, and clinical psychology were used to assess the items’ relevance for their corresponding subscale and their clarity. Experts were asked to rate the items on a 4-point Likert scale according to their relevance for each subscale (from “Highly relevant” to “Not relevant”) and their clarity (from “Very clear” to “Not clear”). They were also given the opportunity to provide qualitative feedback with comments and suggestions. Experts evaluated both the baby and child versions of the questionnaire simultaneously. Modifications were made according to the scores and feedback obtained (see *Data Analysis* section for cut-off points).

2b) Content validity – Field test. Finally, a field test was conducted to assess the questionnaire’s face validity and comprehensibility for the target population. The latest version of the questionnaire was used (after expert ratings). A total of nine parents participated, four of which were first time parents. Seven of them completed the baby version and two the child version of the questionnaire.

Parents were asked to complete the questionnaire and then provide ratings for each subscale on a 10-point Likert scale, assessing two dimensions: relatedness, indicating how much they could relate the questions to their parenting experiences (from “Not at all” to “Very much”); and relevance, indicating how important they considered the questions to be for their parenting experience or their relationship with their baby/child (from “Not at all important” to “Very important”). They were also asked to evaluate the clarity of the items and were given the opportunity to provide both specific feedback on individual items and general feedback on the subscales.

Data analysis. For expert ratings, Content Validity Ratio (CVR) was calculated for their relevance and clarity scores. The formula $CVR = (n_e - N/2)/(N/2)$ was used, where n_e is the number of raters with a rating of 1 or 2 (highly relevant-quite relevant/very clear-clear) and N is the total number of raters. This results in scores ranging from -1 to 1, with the cut off score of 0.62 considered low for 10 or more raters (Kyriazos & Stalikas, 2018b; Lawshe, 1975). Low scores indicate that the expert panel considers the item not sufficiently clear or relevant for its corresponding subscale and thus would need to be revised.

For the field test, mean scores were obtained for the relatedness and relevance ratings, which could range from 0 to 10, with scores below 8 considered low. Low scores would indicate that the parents found the items and/or subscales don't sufficiently relate to their parenting experiences or are not sufficiently relevant for them, in which case they would need to be revised. Finally, recurring themes were identified from the qualitative comments and feedback of both experts and parents, and modifications to the items and subscales were made to address these.

2.3.2 Results

1) Content validity - Expert ratings. Low relevance and clarity CVR scores (< 0.62) from the experts identified items that needed revision. Table 2.2 summarises the number of items with low CVR scores for relevance and clarity for each subscale. A total of 21 items had low clarity scores and seven had low relevance scores. The subscale with the lowest scores was *Trusting*, with all but one of its items scoring low on both relevance and clarity.

Table 2.2. Phase 1 – Results from expert ratings.

Subscale	Total # of items	# of items with low relevance CVR (< 0.62)	# of items with low clarity CVR (< 0.62)
Noticing	9	2	4
Not-Worrying	7	-	2
Attention Regulation	7	1	4
Emotional Awareness	6	-	-
Homeostatic (Emotional) Awareness	7	-	1
Awareness of Homeostatic Cycles	6	1	-

Self-Regulation	16	-	3
Body Listening	6	-	4
Trusting	4	3	3
Interpretation of Body Signals	4	-	-
Total	72	7	21

Moreover, one overarching recurring theme was identified from the expert's qualitative feedback: a need for clearer and simpler language. From this, the following sub-themes emerged: need for clearer definitions ("Seems very abstract"), avoiding the use of jargon ("Can this be rephrased to something more accessible for the lay person?"), and adding examples for difficult terms ("It might be helpful to add different body parts, so parents can think of specific situations").

All 28 items with low CVR scores were modified or completely changed, and all items and subscales were reviewed considering the qualitative feedback. This resulted in a new structure for the questionnaire, including six overarching categories with nine re-defined subscales (see Table 2.3).

Table 2.3. Phase 1 – Re-structuring of subscales after expert ratings.

Category	Subscale	Definition
Perception	Noticing Bodily Sensations	Ability to detect or discriminate uncomfortable, comfortable, and neutral body sensations in baby/child.
	Noticing Bodily Cycles	Ability to detect baby's/child's biological rhythms or biological clock syncing their body's functions and activities.
Attention Regulation	Holding Attention to Bodily Sensations	Ability to sustain and control attention to baby's/child's body sensations.
Regulation	Regulation of Bodily States	Ability to actively regulate baby's/child's body needs and states.
Contagion	Merger Between Parental and Child States	Automatic sharing and non-distinction between parental and baby's/child's physiological and emotional states.
Epistemic Attitudes Towards Bodily Signals	Epistemic Attitudes Towards Bodily Signals	Tendency to consider that baby's/child's body signals have communicative, practical value.
	Trust and Self-Efficacy	Tendency to consider that baby's/child's body signals convey trustworthy information and can be explored.

Mentalisation About Emotional and Physiological States	Linking Bodily Sensations to Emotions	Ability to detect changes in baby's/child's body sensations in relation to their feelings (such as fear, happiness, anger, joy).
	Linking Bodily Sensations to Physiological States	Ability to detect changes in baby's/child's body sensations in relation to their homeostatic emotions (i.e., feelings that demand attention and are evoked by an internal body state, such as hunger, pain, fatigue).

2) Content validity - Field test. Parent ratings were analysed to identify subscales that needed revision due to low relevance or relatedness scores (< 8). The overall mean score (across all subscales) for relatedness was $M = 8.32$ (range = 7.56–9) and for relevance it was $M = 8.62$ (range = 8.11–9.11). All subscales obtained a score above 8 for both relatedness and relevance except for *Noticing Bodily Sensations*, which had a marginally low score ($M = 7.56$) for relatedness.

Moreover, four recurring themes were identified from parents' qualitative feedback: 1) a need for clarification on what "bodily sensations/signals" mean ("...a little vague... maybe you should define what do you mean by bodily sensations"; "Needs a bit more clarity/context on what the exact meaning of 'bodily sensations' is in this questionnaire"), 2) questions too general or vague ("Need more context and clarification"; "...a bit abstract"), 3) repetitive questions, and 4) questions that could have multiple interpretations.

All items from the *Noticing Bodily Sensations* subscale were revised, due to its marginally low relatedness score, and the following actions were taken: a) two items were deleted due to repetition and unclear wording, and b) examples were added to another two items, to provide more context for parents to relate the questions to their experiences. Furthermore, all items were revised considering the qualitative feedback. In total, 22 items were deleted due to either a) repetition, b) multiple interpretations possible, or c) lack of clarity or specificity. From the remaining 49 items, examples were added to three and the wording was modified for another nine, to improve their clarity. Additionally, a brief description with examples of the key terms "bodily

sensations” and “bodily signals” was included at the beginning of the questionnaire (see Appendix B for the final version of the questionnaire in Phase 1).

2.4 Phase 2 – Scale Development

This phase explored the questionnaire’s psychometric properties with the aims of pruning its items and obtaining a reliable factor structure. To achieve this, a large sample of parents was recruited and their responses to the questionnaire were analysed following these steps (see Figure 2.1B): a) descriptive statistics and item analysis, during which psychometric properties of the items were evaluated and items were pruned, b) exploratory factor analyses, c) confirmatory factor analysis, and finally d) refining questionnaire, during which the final factor structure obtained was revised. The baby and child versions of the questionnaire were analysed separately and will be referred to as the “Baby group” and the “Child group”.

2.4.1 Methods

Participants and procedures. Parents were recruited online using the crowd-sourcing site Prolific. The inclusion criteria included being 18 years old or older, being a parent of a child 0-10 years old, and being literate in English. After reading the information sheet and providing informed consent, participants were asked to answer a sociodemographic survey and the questionnaire developed in Phase 1 (see Appendix B). Parents were asked to answer keeping their *youngest* child in mind.

The sample consisted of 601 parents with children between 0 and 10 years of age ($M = 3.62$, $SD = 3.01$), of which 45.59% were girls and 54.25% boys (one case undisclosed). Parents’ mean age was 36.54 years ($SD = 6.20$, range = 24–58), 50.58% identified as women and 49.42% men, 37.94% of them were first time parents. Most parents (81.86%) self-identified as White English, Welsh, Scottish, Northern Irish, or British. The highest level of education completed for almost half of the parents (47.92%) was an undergraduate degree or equivalent, and more than half (62.56%) were employed full-time. Regarding family and relationships, almost all parents (92.85%) were in a relationship, of which the duration was at least one year for most (98.75%). The Baby group had a total of 264 parents with a mean child age of 16.08

months ($SD = 8.39$), while the Child group had a total of 337 parents with a mean child age of 5.74 years ($SD = 2.32$). Demographic information is summarised in Table 2.4.

Table 2.4. Phase 2 – Demographic information for parent sample.

Parameter	Parents (N = 601)
Age ^a	36.54 (6.2)
Gender (%)	
Women	50.58
Men	49.42
Ethnicity (%)	
White English, Welsh, Scottish, Northern Irish, or British	81.86
Other White	5.66
Asian	5.78
Black, African, or Caribbean	3.49
Mixed	3.17
Education level (%)	
Secondary education	30.17
Undergraduate degree or equivalent	47.92
Postgraduate degree	18.47
Other	3.50
Employment (%)	
Employed full-time	62.56
Employed part-time	19.30
Self-employed	4.82
Not working/Parental leave	10.81
Annual household income (%)	
<£20,000	8.81
£20,000 - £39,999	26.95
£40,000 - £59,999	31.28
£60,000 - £99,999	24.96
>£100,000	5.83
Relationship status (%)	
In a relationship	92.85
Single	6.16
Relationship duration (%)	
More than a year	98.75
Relationship satisfaction (0-10) ^a	9.18 (1.95)
Family structure (%)	
Two-parent different sex	87.69
Two-parent same sex	3.66
Single parent	7.99
Child age (years) ^a	3.62 (3.01)
Child sex (%)	
Female	45.59
Male	54.25

Undisclosed	0.16
Number of children (%)	
One	37.94
Two	43.76
Three or more	18.30

^a Mean (SD)

Data analysis. R 3.6.3 for Mac OS X was used for data analysis, the package *psychometric* was used for item analysis, while the *psych* and *lavaan* packages were used for exploratory and confirmatory factor analyses respectively. To identify items for pruning, first, descriptive statistics were examined, including each item's mean, standard deviation, minimum and maximum values, skewness, and kurtosis. At this stage, items with skewness or kurtosis values $> |2|$ were eliminated. Then, item analysis was performed, calculating each item's, total correlation score (correlation of item with total test score) and reliability index. Also, "reliability if an item is dropped" was calculated for each item using the Cronbach's alpha (α) value. At this stage, items with total correlation scores or reliability indices $< |.3|$ were eliminated, as well as items whose α if dropped was higher than the overall α .

Following this, to investigate the factor structure of the questionnaire, exploratory factor analyses (EFA) were carried out with polychoric correlations (for ordinal variables) and oblique rotation (allowing correlations between factors). To determine the ideal number of factors eigenvalues above 1 and the point of inflection from the scree plot were considered; however, Horn's Parallel Analysis was used to define this, as it considers the adjusted eigenvalues. Items with low factor loadings (< 0.4), cross-loadings, or low item communality (< 0.3) were deleted and the EFA was repeated until a clear and coherent structure with good factor loadings appeared. Given that the factor structure for the Child group was clearer, this was tested with a confirmatory factor analysis (CFA) on the Baby group. The fit indices Comparative Fit Index ($CFI \geq 0.95$), Tucker Lewis Index ($TLI \geq 0.95$), and Root Mean Square Error of Approximation ($RMSEA \leq 0.06$) were used to determine model fit.

2.4.2 Results

In alignment with the item-pruning criteria, 12 items from the Baby group and 2 items from the Child group, each with a kurtosis score greater than 2, were removed. All

remaining items had skewness and kurtosis values lower than |2|. Complete descriptive statistics for the items in both the Child and Baby groups are provided in Appendix C, including mean, standard deviation, minimum and maximum values, skewness, and kurtosis.

1) Item analysis. Cronbach's alpha (α) for the Baby group was 0.90 and for the Child group it was 0.91. Only one item (from the Child group) had a higher alpha value if removed, item 10 from the *Merger Between Parental and Child States* subscale. This subscale was also the most problematic, as all its other items (7, 8, 9, 11 and 12) had low total correlation and reliability index scores for both groups. *Regulation of Bodily States* had low total correlation and reliability index scores in two out of six items for both groups. For the Child group, 11 items were removed due to low scores (< 0.3), and for the Baby group, 10 items were removed. Item analysis scores for all items are shown in Table 2.5.

Table 2.5. Phase 2 – Item analysis for Baby and Child groups.

Item	<u>Baby group</u>			<u>Child group</u>		
	total correlation	reliability index	α if item removed	total correlation	reliability index	α if item removed
Noticing Bodily Sensations						
1	.45	0.35	0.89	.46	0.31	0.91
2	.47	0.43	0.89	.55	0.52	0.91
3	-.19 ^a	-0.23 ^a	0.90	-.14 ^a	-0.17 ^a	0.91
4	.40	0.32	0.89	.50	0.43	0.91
5	.33	0.30	0.89	.46	0.42	0.91
6	.56	0.33	0.89	.52	0.38	0.91
Holding Attention to Bodily Sensations						
13	.54	0.35	0.89	.50	0.39	0.91
14	.45	0.27 ^a	0.89	.57	0.46	0.91
15	.50	0.34	0.89	.59	0.45	0.91
16	.64	0.45	0.89	.55	0.40	0.91
17	.59	0.47	0.89	.61	0.47	0.91
Noticing Bodily Cycles						
30	.50	0.40	0.89	.51	0.40	0.91
31	.56	0.47	0.89	.44	0.38	0.91

32	.61	0.46	0.89	.49	0.42	0.91
33	.29 ^a	0.34	0.90	.31	0.35	0.91

Merger between parental and child states

7	-.03 ^a	-0.04 ^a	0.90	-.05 ^a	-0.06 ^a	0.91
8	.05 ^a	0.06 ^a	0.90	.10 ^a	0.12 ^a	0.91
9	-.03 ^a	-0.04 ^a	0.90	.07 ^a	0.09 ^a	0.91
10	-.42	-0.37	0.90	-.39	-0.35	0.92 ^b
11	.19 ^a	0.22 ^a	0.90	.22 ^a	0.24 ^a	0.91
12	.28 ^a	0.30	0.90	.22 ^a	0.25 ^a	0.91

Linking Bodily Sensations to Emotions

18	.51	0.33	0.89	.56	0.40	0.91
19	.63	0.42	0.89	.66	0.49	0.90
20	.49	0.36	0.89	.44	0.29 ^a	0.91
21	.44	0.41	0.89	.52	0.49	0.91

Linking Bodily Sensations to Physiological States

22	.53	0.34	0.89	.48	0.30 ^a	0.91
23	.53	0.43	0.89	.61	0.53	0.91
24	.51	0.43	0.89	.51	0.45	0.91
25	.42	0.44	0.89	.42	0.41	0.91
26	.48	0.48	0.89	.45	0.42	0.91
27	.56	0.54	0.89	.54	0.53	0.91
28	.43	0.38	0.89	.47	0.45	0.91
29	.40	0.38	0.89	.41	0.42	0.91

Regulation of Bodily States

34	.53	0.42	0.89	.49	0.45	0.91
35	.35	0.38	0.89	.31	0.33	0.91
36	.21 ^a	0.24 ^a	0.90	.32	0.31	0.91
37	.38	0.47	0.89	.25 ^a	0.30 ^a	0.91
38	.48	0.47	0.89	.52	0.52	0.91
39	.21 ^a	0.23 ^a	0.90	.27 ^a	0.25 ^a	0.91
40	.43	0.38	0.89	.41	0.32	0.91
41	.42	0.34	0.89	.32	0.29 ^a	0.91

Epistemic Attitudes towards Bodily Signals

42	.49	0.44	0.89	.58	0.59	0.91
43	.62	0.49	0.89	.62	0.58	0.90
44	.57	0.41	0.89	.62	0.50	0.91
45	.50	0.45	0.89	.59	0.56	0.91
46	.34	0.32	0.89	.51	0.47	0.91

Trust and Self-efficacy

47	.57	0.43	0.89	.58	0.45	0.91
48	.52	0.38	0.89	.55	0.44	0.91
49	.45	0.37	0.89	.46	0.38	0.91

^a score is lower than 0.3.

^b Cronbach's alpha value is higher when item is removed.

2) Exploratory factor analyses. Subsequently, an EFA was carried out in each group. Items with low factor loadings (< 0.4), cross-loadings, or low item communality (< 0.3) were removed, with the purpose of eliminating psychometrically weak items and creating a more robust factor structure. This was repeated until the results from the EFA showed good factor loadings for all or most items, which occurred in the third round of EFA. Results from the first two rounds can be seen in Appendix D, and results from the last round are presented below.

Parallel analysis retained five factors for both groups; Table 2.6 shows the factor loadings and communality for this solution in both groups. In the Baby group, most items had a factor loading equal or greater than 0.4 for their corresponding factor (apart from items 17 and 22), five items had cross-loadings, but all of these were lower than 0.4. In the Child group, all items had a factor loading equal or greater than 0.4 for their corresponding factor, eight items had cross-loadings, but all of these were lower than 0.4.

Table 2.6. Phase 2 – EFA results for Baby and Child groups.

Item #	F1	F2	F3	F4	F5	Communality
Baby group						
21	.84					.68
29	.72					.52
28	.71					.56
27	.68					.62
10	-.60	-.25				.56
4	.56					.41
37	.55					.35
5	.51				-.24	.44
43		.86				.78
43		.79				.57
44		.67				.60
46		.49				.30

6			.99			.99
19		.23	.41			.64
22			.39			.51
32				.90		.96
17		.24	.30	.35		.55
49					.65	.55
48	.22		.27		.51	.56
34					.50	.45
Child group						
15	.75					.63
16	.72					.62
17	.71					.68
6	.62					.51
13	.51	.22				.54
14	.48	.34		.23		.65
4	.45				.30	.52
43		.82				.74
45		.77				.61
42		.66				.58
38		.53			.20	.36
44		.53	.25			.60
49			.73			.52
48			.65			.57
47			.60			.55
36				.81		.69
35				.71		.56
21	.23				.56	.67
27		.21		.35	.51	.75
28			.24	.26	.45	.54

Note: factor loadings below .20 are not shown.

Results for both groups were similar, however, the final factor structure for the Child group was more psychometrically robust (all the items had factor loadings greater than 0.4) and it was also more theoretically interpretable than that of the Baby group. For this reason, the factor structure for the Child group was tested with a CFA on the Baby group, to determine if a unified model could be established (results below).

Factors obtained in the Child group could be interpreted as: 1) Attention, which included seven items from the *Noticing Bodily Sensations* and *Holding Attention to*

Bodily Sensations subscales, 2) Epistemic Attitudes (EA), which included five items and remained almost equal to the original *Epistemic Attitudes Towards Bodily Signals* subscale, 3) Trust and Self-Efficacy (Trust), which included three items and remained the same as the original, 4) Regulation, which included only two items from the *Regulation of Bodily States* subscale, and 5) Linking, which included three items from the *Linking Bodily Sensations to Physiological States* and *Linking Bodily Sensations to Emotions* subscales. Figure 2.3 shows a summary of the model including the factor loadings for all items and correlation coefficients between factors.

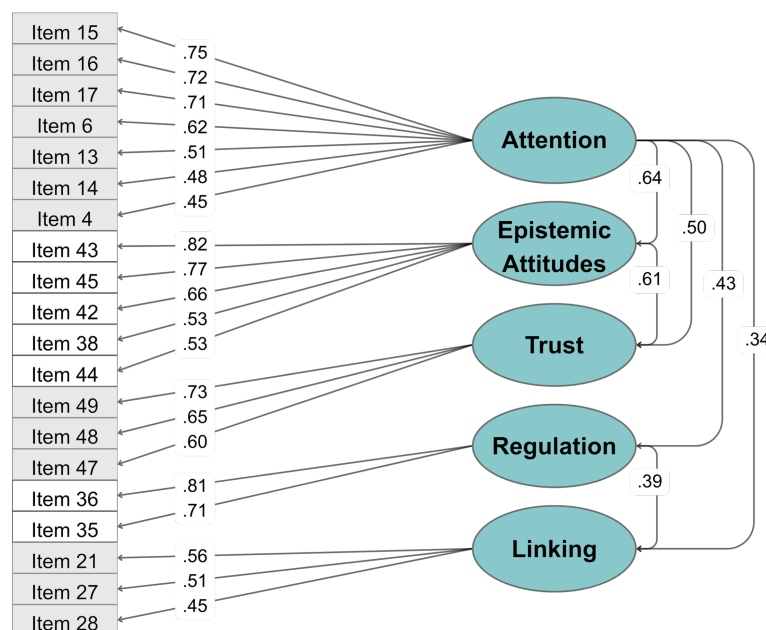


Figure 2.3. Phase 2 – EFA model from Child group. The figure shows factor loadings for each item and correlations between the factors, indicated by the double-headed arrows (only correlation coefficients $\geq .30$ are shown).

3) Confirmatory Factor Analysis. Using the model found in the Child group with EFA, a CFA was run with the Baby group sample. The model had good fit indices, CFI = 0.92, TLI = 0.91, RMSEA = 0.055 (95% confidence interval CI [.045, .065]). All items had high loadings (> 0.4) on their respective factor (see Table 2.7), and all factors were correlated with each other (see Table 2.8). The Cronbach's alpha estimates for the subscales were: *Attention* ($\alpha = 0.80$), *EA* ($\alpha = 0.75$), *Trust* ($\alpha = 0.69$), *Regulation* ($\alpha = 0.61$), and *Linking* ($\alpha = 0.76$).

Table 2.7. Phase 2 – Factor loadings for CFA on Baby group.

Item	Loading
Attention	
15	.63
16	.76
17	.69
6	.65
13	.69
14	.50
4	.40
Epistemic Attitudes	
43	.77
45	.56
42	.67
38	.43
44	.68
Trust and Self-Efficacy	
49	.55
48	.68
47	.73
Regulation	
36	.62
35	.72
Linking	
21	.75
27	.81
28	.62

Table 2.8. Phase 2 – Correlations between factors in CFA for Baby group.

	Attention	EA	Trust	Regulation	Linking
Attention	1	.61*	.54*	.23*	.47*
EA		1	.50*	.23*	.44*
Trust			1	.22*	.36*
Regulation				1	.45*
Linking					1

* p -value < .001

4) Refining questionnaire. As a final step in this phase, the resulting questionnaire was reviewed and a few modifications were made: 1) three items were added to the *Regulation* subscale given that it retained only two items, which could negatively impact the scale's internal reliability; and 2) two positively worded items

were added to the *Linking* subscale, which had only negatively worded items. The new items were created following the same guidelines as in Phase 1 of the study (see Figure 2.2), and their factor loadings and the internal reliability of their corresponding subscales were evaluated in the next phase of the study. This resulted in a total of 24 items.

2.5 Phase 3 – Scale Evaluation

This phase had three main aims (see Figure 2.1C). First, to confirm the factor structure of the questionnaire on a new sample and evaluate the new items created at the end of Phase 2. Second, to examine the relationship between the PIQ and a) parents' own interoceptive sensibility, b) other psychosocial variables of interest (emotion regulation, attachment style, mental health and somatic symptoms), c) parental abilities (parental reflective functioning), and d) children's socioemotional functioning. Third, to assess test-retest reliability. Given that this is the first measure developed to assess parental interoception, hypotheses for the second aim of this phase stem from theoretical propositions and research on similar or relevant constructs and should be considered as tentative.

- a) It was expected that parents own interoceptive sensibility (IS) would be positively associated with the PIQ, considering that i) the ability to detect bodily signals in others is theorised to be influenced by the sensibility to one's own bodily signals (Fotopoulou & Tsakiris, 2017; Steele et al., 2017), ii) IS has been associated with emotion recognition in others (Hübner et al., 2021), and iii) associations found between interoception and social variables, such as empathy and social connection (Arnold et al., 2019; Ernst et al., 2013; Ferri et al., 2013).
- b) Regarding other psychosocial traits, both interoception and parental reflective abilities (i.e., PEM and PRF) have been linked to higher emotion regulation abilities (Bornemann & Singer, 2017; Brewer et al., 2021; Füstös et al., 2013; Schultheis et al., 2019; Zamariola et al., 2019) and lower mental health and somatic symptoms (Brewer et al., 2021; Khalsa et al., 2018; Luyten, Mayes, et al., 2017b; Nobre-Trindade et al., 2021; Sugawara et al., 2020), thus, these same relationships were expected between these variables and the PIQ.

Moreover, caregivers with insecure attachment styles are less likely to have high levels of mentalising abilities (Bouchard et al., 2008; Luyten, Mayes, et al., 2017b; Slade et al., 2005); however, results about the relationship with interoception are mixed. While some studies find both anxious and avoidant styles related to lower interoception (Ferraro & Taylor, 2021), others find that avoidant attachment is related to lower interoception while anxious attachment associates with higher interoception (Oldroyd et al., 2019). Therefore, it was tentatively expected that avoidant attachment style would be negatively associated with the PIQ.

- c) Furthermore, the PIQ was expected to be positively related to parental reflective functioning, considering that higher parental embodied mentalising has been associated with higher parental sensitivity and verbal mentalising (e.g., attuned mind-related comments) (Shai & Meins, 2018; Væver et al., 2022), which points to the relationship between a mind-focused and body-focused parental mentalising or “reading” ability.
- d) Finally, a negative relationship was expected between the PIQ and children’s behavioural problems, as higher parental embodied mentalising, as well as parental reflective functioning have been linked to lower internalizing and externalizing problems in children (Ghanbari et al., 2023; Shai & Belsky, 2017).

2.5.1 Methods

Participants and Procedures. A new sample of parents was recruited through Prolific, with the same inclusion criteria as in Phase 2. After reading the information sheet and giving informed consent (including consent to be contacted for a second stage of the study), participants were asked to answer a sociodemographic survey, the questionnaire as it was finalized in Phase 2, and additional standardised questionnaires that were used to assess construct validity. After one month, all participants were asked to answer the questionnaire again, to evaluate test-retest reliability.

The sample consisted of 511 parents with children between 0 and 10 years of age ($M = 3.97$, $SD = 3.21$), of which 50.29% were girls and 49.51% boys (one case undisclosed). Parents’ mean age was 36.51 years ($SD = 6.30$, range = 22–62),

50.48% identified as women and 49.32 men, 33.46% were first time parents. Most parents (81.60%) self-identified as White English, Welsh, Scottish, Northern Irish, or British. The highest level of education completed for almost half of the parents (44.23%) was an undergraduate degree or equivalent, and more than half (65.56%) were employed full-time. Regarding family and relationships, almost all parents (93.35%) were in a relationship, of which the duration was at least one year for most (98.74%). Demographic information is summarised in Table 2.9.

Table 2.9. Phase 3 – Demographic information for parent sample.

Parameter	Parents (N = 511)
Age ^a	36.51 (6.30)
Gender (%)	
Female	50.48
Male	49.32
Ethnicity (%)	
White English, Welsh, Scottish, Northern Irish, or British	81.60
Other White	5.28
Asian	5.48
Black, African, or Caribbean	5.29
Mixed	2.16
Education level (%)	
Secondary education	30.92
Undergraduate degree or equivalent	44.23
Postgraduate degree	22.11
Other	2.74
Employment (%)	
Employed full-time	65.56
Employed part-time	18.79
Self-employed	4.11
Not working/Parental leave	9.98
Annual household income (%)	
<£20,000	8.22
£20,000 - £39,999	26.41
£40,000 - £59,999	27.79
£60,000 - £99,999	30.34
>£100,000	6.65
Relationship status (%)	
In a relationship	93.35
Single	6.65
Relationship duration (%)	
More than a year	98.74
Relationship satisfaction (0-10) ^a	8.04 (2.00)

Family structure (%)	
Two-parent different sex	87.87
Two-parent same sex	3.91
Single parent	7.83
Child age (years) ^a	3.97 (3.21)
Child sex (%)	
Female	50.29
Male	49.51
Number of children (%)	
One	33.46
Two	47.55
Three or more	18.98

^a Mean (SD)

Additional measures. Other validated self-report questionnaires were used to evaluate the PIQ's construct validity. Relationships with parents' interoceptive sensibility, parents' psychosocial traits and abilities, and children's socioemotional functioning were explored using the measures below.

1) Parents own interoceptive sensibility

- a) The Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2; Mehling, Acree, et al., 2018). This is a 32-item questionnaire that measures multiple features of interoceptive sensibility through self-report. It consists of eight subscales: *Noticing* ($\alpha = 0.80$) (e.g., "I notice when I am uncomfortable in my body"), *Not-Distracting* ($\alpha = 0.86$) (e.g., "I try to ignore pain"), *Not-Worrying* ($\alpha = 0.78$) (e.g., "I start to worry that something is wrong if I feel any discomfort"), *Attention Regulation* ($\alpha = 0.90$) (e.g., "When I am in conversation with someone, I can pay attention to my posture"), *Emotional Awareness* ($\alpha = 0.84$) (e.g., "I notice how my body changes when I am angry"), *Self-Regulation* ($\alpha = 0.84$) (e.g., "I can use my breath to reduce tension"), *Body Listening* ($\alpha = 0.84$) (e.g., "I listen to my body to inform me about what to do"), and *Trust* ($\alpha = 0.92$) (e.g., "I feel my body is a safe place"). Cronbach's alpha for the overall score was 0.92. Participants rate each item according to how often it applies to them generally in daily life, on a scale from 0 ("Never") to 5 ("Always").
- b) The Body Awareness Questionnaire (BAQ; Shields et al., 1989). This is an 18-item scale designed to assess attentiveness to normal non-emotive body processes through self-report. It includes sensitivity to body cycles and rhythms (e.g., "I am

aware of a cycle in my activity level throughout the day”), ability to detect small changes in normal functioning (e.g., “I notice distinct body reactions when I am fatigued”), and ability to predict bodily reactions (e.g., “I can always tell when I bump myself whether or not it will become a bruise”). Participants rate each item on a scale from 1 (“Not true at all of me”) to 7 (“Very true of me”). Cronbach’s alpha in this study was 0.90.

2) Psychosocial features

- a) The Difficulties in Emotion Regulation Scale, Brief Version (DERS-18; Victor & Klonsky, 2016). This is a validated 18-item brief version of the original Difficulties in Emotion Regulation scale by Gratz and Romer (Gratz & Roemer, 2004), which was developed to assess emotion dysregulation and comprises the following dimensions: awareness and understanding of emotions, acceptance of emotions, ability for goal-directed behaviour, which includes being able to refrain from impulsive behaviour when experiencing negative emotions, and access to emotion regulation strategies. The brief version used in this study has demonstrated excellent reliability and validity across different datasets (Hallion et al., 2018; Victor & Klonsky, 2016) and is comprised of the three highest-loading items from each of the original subscales: *Awareness* ($\alpha = 0.83$) (e.g., “I pay attention to how I feel”), *Clarity* ($\alpha = 0.79$) (e.g., “I am confused about how I feel”), *Goals* ($\alpha = 0.89$) (e.g., “When I’m upset, I have difficulty concentrating”), *Impulse* ($\alpha = 0.91$) (e.g., “When I’m upset, I become out of control”), *Nonacceptance* ($\alpha = 0.88$) (e.g., “When I am upset, I feel guilty for feeling that way”), and *Strategies* ($\alpha = 0.88$) (e.g., “When I’m upset, I believe that wallowing in it is all I can do”). Cronbach’s alpha for the overall score was 0.92. Participants rate each item on a scale from 1 (“Almost never”) to 5 (“Almost always”).
- b) The Experiences in Close Relationships – Revised Questionnaire (ECR-R; Fraley et al., 2000). This is a 36-item self-report measure of adult attachment style. It is comprised of two subscales: *Avoidance* ($\alpha = 0.95$), which refers to the individual’s discomfort with intimacy and their pursue of independence; and *Anxiety* ($\alpha = 0.95$), which refers to the individual’s tendency to fear rejection and abandonment. Items represent statements about how individuals might feel in emotionally intimate relationships (e.g., “I’m afraid I will lose my partners love”). Participants rate each

item according to how they generally experience relationships, on a scale from 1 (“Strongly disagree”) to 7 (“Strongly agree”).

- c) The Depression, Anxiety, Stress Scale (DASS-21; Lovibond & Lovibond, 1995). This is a shortened 21-item version of the original 42-item DASS, it includes seven items from each subscale: *Depression* ($\alpha = 0.93$), *Anxiety* ($\alpha = 0.86$), and *Stress* ($\alpha = 0.89$). Each item represents a symptom from one of the subscales (e.g., “I found it difficult to relax”). The scale measures the severity of the symptoms according to their presence over the past week, on a scale from 0 (“Did not apply to me at all”) to 3 (“Applied to me very much, or most of the time”). It has been shown to be a reliable measure of depression, anxiety, and stress features in both clinical and nonclinical populations (Lovibond & Lovibond, 1995).
- d) The Patient Health Questionnaire somatic symptom severity scale (PHQ-15; Kroenke et al., 2002). This scale is comprised of the 15 somatic symptom items from the Patient Health Questionnaire (PHQ), which is a self-report version of the PRIME-MD diagnostic instrument for common mental disorders. It evaluates the severity of 15 somatic symptoms or symptom clusters over the past four weeks, on a scale from 0 (“Not bothered at all”) to 2 (“Bothered a lot”). Cronbach’s alpha for this study was 0.83.

3) Parental abilities

The Parental Reflective Functioning Questionnaire (PRFQ; Luyten, Mayes, et al., 2017b). This is an 18-item self-report measure that assesses parental mentalising, which refers to the parent’s ability to treat their child as a psychological agent. It comprises three subscales: *Interest and Curiosity About Mental States* ($\alpha = 0.74$) (e.g., “I try to see situations through the eyes of my child”), *Certainty About Mental States* ($\alpha = 0.78$) (e.g., “I always know what my child wants”), and *Pre-Mentalising* ($\alpha = 0.68$) (e.g., “My child cries around strangers to embarrass me”). The last subscale (pre-mentalising) represents non-mentalising modes, which can include malevolent attributions to the child’s behaviour, and are mostly characteristic of parents with severe impairments in parental reflective functioning. Participants rate each item on a scale from 1 (“Strongly disagree”) to 7 (“Strongly agree”).

4) Children’s socioemotional functioning

The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). This is a 25-item measure that can be completed by parents, teachers, or young people (only parent ratings were used in this study), and there are two versions, one for children between two and four years old, and one for children older than four. The SDQ evaluates psychological adjustment of children and young people by asking about different behaviours. Items can be categorised into *Externalizing Behaviours* ($\alpha = 0.50/\alpha = 0.60$), which include the subscales *Conduct Problems* (e.g., “Often fights with other children”) and *Hyperactivity* (e.g., “Is restless, overactive...”), and *Internalizing Behaviours* ($\alpha = 0.48/\alpha = 0.50$), which include the subscales *Emotional Problems* (e.g., “Worries a lot”) and *Peer Problems* (e.g., “...tends to play alone”). There is also a *Prosocial Behaviours* subscale (e.g., “Is kind to younger children”) ($\alpha = 0.73/\alpha = 0.73$). Participants rate each item with 0 (“Not true at all”), 1 (“Somewhat true”), or 2 (“Certainly true”). Cronbach’s alpha values indicated are presented first for the 2–4-year-olds and second for the 4+ year-olds versions.

Data analysis. R 3.6.3 for Mac OS X was used for data analysis. The package *lavaan* was used for CFA, while the *stats* and *ppcor* packages were used for statistical hypothesis testing. Given the identical factor structure for both the baby and child versions of the questionnaire, differing only in wording (“your baby” versus “your child”), analyses were performed on the entire sample collectively. First, the factor structure identified in Phase 2 was tested on this sample through confirmatory factor analysis (CFA). Model fit was evaluated using the Comparative Fit Index ($CFI \geq 0.95$), Tucker Lewis Index ($TLI \geq 0.95$), and Root Mean Square Error of Approximation ($RMSEA \leq 0.06$). Cronbach’s Alpha was calculated for the entire questionnaire and for each factor individually. Factor loadings for every item, including the five new items added at the end of Phase 2, were calculated.

Following this, the effects of demographic variables were examined to assess the need for control variables in subsequent analyses. Construct validity was evaluated by examining the relationships between the PIQ and the variables of interest. Descriptive statistics and distribution characteristics were analysed for all questionnaires. Most scales and subscales displayed a normal distribution with some having slight to moderate skewness ($< |1|$), except for the DASS subscales of *Anxiety* and *Depression*, as well as the *Pre-Mentalising* subscale of the PRFQ, which were highly skewed.

Consequently, non-parametric tests were employed to analyse these subscales (as described below).

- a) For interoceptive sensibility, Pearson correlations between all MAIA and PIQ subscales were calculated, applying Bonferroni corrections for multiple comparisons. Additionally, Pearson correlations were computed between the overall PIQ score and the overall MAIA and BAQ scores, with Bonferroni corrections.
- b) For parents' psychosocial traits, partial correlations were calculated to measure the relationship between the PIQ and each variable while controlling for the others. The Spearman method was used for the DASS *Depression* and *Anxiety* subscales, while the Pearson method was applied for all others, with Bonferroni corrections.
- c) For parental reflective functioning abilities, correlations were calculated between the PIQ overall score and the PRFQ subscales. The Spearman method was used for the *Pre-Mentalising* subscale, and Pearson was applied for the remaining subscales, with Bonferroni corrections.
- d) For children's socioemotional functioning, multivariate multiple regression analyses were conducted to evaluate the PIQ's predictive capacity for children's internalising and externalising behaviours, and pro-social behaviour scores.

Finally, test-retest reliability was assessed by calculating the intra-class correlation coefficient (ICC) to measure the agreement between scores at the first and second time points. A two-way random-effects model was used with an absolute agreement definition, applying a "single rater" unit to capture agreement across time points.

2.5.2 Results

Descriptive statistics for each PIQ factor are presented in Table 2.10. All factors were correlated with each other (see Table 2.11) with Cronbach's alpha values as follows: *Attention* ($\alpha = 0.79$), *EA* ($\alpha = 0.83$), *Trust* ($\alpha = 0.79$), *Regulation* ($\alpha = 0.75$), and *Linking* ($\alpha = 0.68$). The Cronbach's alpha estimate for the overall score was $\alpha = 0.91$. *Regulation* and *Linking* had new items added at the end of Phase 2, their previous internal reliability scores were $\alpha = 0.61$ and $\alpha = 0.76$ respectively.

Table 2.10. Phase 3 – Descriptive statistics for each PIQ factor.

	<i>M</i>	<i>SD</i>	min	max	skewness	kurtosis
Attention	4.16	0.52	1	5	-0.93	2.90
EA	3.98	0.71	1	5	-0.99	1.60
Trust	4.05	0.64	1	5	-0.87	1.53
Regulation	3.73	0.70	1	5	-0.50	0.22
Linking	3.89	0.65	1	5	-0.61	0.76

Table 2.11. Phase 3 – Pearson correlations between PIQ factors.

	Attention	EA	Trust	Regulation	Linking
Attention	1	0.71*	0.65*	0.50*	0.64*
EA		1	0.64*	0.38*	0.52*
Trust			1	0.48*	0.57*
Regulation				1	0.59*
Linking					1

**p*-value <0.001

1) Confirmatory Factor Analysis. The model demonstrated good fit indices, CFI = 0.92, TLI = 0.91, RMSEA = 0.056 (95% confidence interval CI [.050, .061]). All items had high loadings (> 0.4) on their respective factor, except for item 22 from the *Linking* subscale, which was marginally below 0.4 (see Table 2.12). The five items added at the end of Phase 2 are identified in bold.

Table 2.12. Phase 3 – Factor loadings for CFA.

Item	Loading
Attention	
1	.63
2	.67
3	.66
4	.52
5	.63
6	.56
7	.50
Epistemic Attitudes	
8	.78
9	.66
10	.73
11	.79

	Trust	
12		.71
13		.77
14		.76
	Regulation	
15		.72
16		.60
17		.65
18		.76
19		.42
	Linking	
20		.67
21		.72
22		.38
23		.68
24		.40

Note: items added at the end of Phase 2 are identified in bold.

2) Relationships with demographic features. Most relationships between the PIQ and demographic features were non-significant or very small. However, a significant gender difference was observed, $t(488.72) = 3.85$, $p < .001$, with women ($n = 258$, $M = 4.05$, $SD = 0.46$) scoring higher than men ($n = 252$, $M = 3.88$, $SD = 0.55$). The effect size (Cohen's $d = 0.34$) indicated a small to medium effect. This difference remained significant even after controlling for child sex in a linear regression model $F(2, 506) = 8.77$, $p < .001$, Adj. $R^2 = .030$.

A one-way ANOVA also showed a significant effect of employment, $F(2) = 5.917$, $p = .003$, with a small effect size ($\eta^2 = 0.024$). Tukey's HSD post hoc test revealed that parents who were employed full-time ($M = 3.92$, $SD = 0.53$) had significantly lower scores than both parents who were employed part-time ($M = 4.06$, $SD = 0.47$, $p = .043$), and parents who were not working ($M = 4.13$, $SD = 0.44$, $p = .013$).

For subsequent correlation analyses, dummy variables (binary variables for each category coded as 0 or 1) for gender and employment were created, for inclusion in partial correlation analyses as a way to control for their effect.

3) Relationships with parents' own interoceptive sensibility. As expected, both the BAQ ($r(506) = 0.50$, $p < .001$) and MAIA's ($r(506) = 0.58$, $p < .001$) overall

scores were positively correlated with the PIQ's overall score, indicating that higher subjective parental interoception is associated with higher individual IS. Table 2.13 shows correlations between all MAIA and PIQ subscales. All MAIA subscales, except for *Not-Distracting* and *Not-Worrying*, were positively correlated with all PIQ subscales ($p < .001$).

Table 2.13. Phase 3 – Pearson correlations between MAIA and PIQ subscales.

PIQ subscales	Noticing	Not-Distracting	Not-Worrying	Attention Regulation	Emotional Awareness	Self-Regulation	Body Listening	Trust
Attention	.44*	-.01	.05	.43*	.43*	.33*	.37*	.29*
EA	.42*	.05	-.02	.40*	.44*	.28*	.45*	.27*
Trust	.38*	.05	.09	.37*	.38*	.33*	.41*	.32*
Regulation	.32*	.07	.13	.35*	.30*	.34*	.37*	.21*
Linking	.42*	.13	.11	.41*	.37*	.29*	.40*	.24*

* p -value $< .001$

4) Relationships with parents' psychosocial traits. Partial correlations were conducted, including gender and occupation as covariates. Regarding emotion regulation, the overall PIQ score had a significant negative correlation with the overall DERS score ($r(500) = -.27, p < .001$). In terms of attachment style, the PIQ was negatively correlated with avoidant attachment ($r(500) = -.15, p = .005$) but showed no significant correlation with anxious attachment ($r(500) = .02, p = 1$). These results indicate that subjective parental interoception is associated with better emotion regulation and decreased avoidant attachment.

Furthermore, no significant associations were found between the PIQ and DASS-21 subscales of *Depression* ($r(500) = -.00, p = 1$), *Anxiety* ($r(500) = .11, p = .10$), and *Stress* ($r(500) = .00, p = 1$), nor with the somatic symptoms scale PHQ-15 ($r(500) = .06, p = 1$).

5) Relationships with parental reflective functioning. Including gender and employment as covariates, partial correlations were conducted using the Spearman method for the *Pre-Mentalising* subscale and Pearson for the others. In line with

expectations, the PIQ overall score was positively correlated with the PRFQ subscales of *Certainty About Mental States* ($r(505) = .41, p < .001$) and *Interest and Curiosity About Mental States* ($r(505) = .38, p < .001$); and negatively correlated with the subscale *Pre-Mentalising* ($r(505) = -.26, p < .001$). These results indicate that subjective parental interoception is associated with better parental reflective functioning.

6) Predicting children's socioemotional functioning. Multivariate regression analyses assessed the PIQ's predictive value for children's externalizing, internalizing, and prosocial behaviours, with gender and occupation included as covariates. For children aged 2 to 4, the PIQ significantly predicted externalising behaviours ($\beta = -1.39, 95\% \text{ CI}[-2.25, -0.53], t = -3.2, p = .002, \text{ Adj. } R^2 = .036$), internalising behaviours ($\beta = -0.86, 95\% \text{ CI}[-1.58, -0.15], t = -2.38, p = .018, \text{ Adj. } R^2 = .028$), and prosocial behaviour ($\beta = 1.18, 95\% \text{ CI}[0.53, 1.84], t = 3.56, p < .001, \text{ Adj. } R^2 = .062$).

Similarly, for children aged 4 to 10, the PIQ significantly predicted externalising behaviours ($\beta = -1.22, 95\% \text{ CI}[-2.05, -0.38], t = -2.88, p = .004, \text{ Adj. } R^2 = .034$), internalising behaviours ($\beta = -1.18, 95\% \text{ CI}[-1.99, -0.38], t = -2.89, p = .004, \text{ Adj. } R^2 = .038$), and prosocial behaviour ($\beta = 1.14, 95\% \text{ CI}[0.69, 1.60], t = 4.99, p < .001, \text{ Adj. } R^2 = .087$). These results indicate that subjective parental interoception can predict children's behavioural problems from age 2 through age 10.

Test-retest reliability. Of the original sample ($N = 511$) who completed the questionnaire at time 1, 84% ($N = 429$) responded again at time 2, one month later. The intra-class correlation coefficient (ICC) was computed to assess the agreement between scores at time 1 and time 2 on the PIQ. The ICC for absolute agreement was good, calculated using a two-way random-effects model with a "single rater" unit, $\text{ICC} = 0.76, 95\% \text{ CI} [0.72, 0.80], p < .001$.

2.6 Discussion

This chapter presents the development and initial validation of the Parental Interoception Questionnaire (PIQ), a self-report measure designed to assess *parental interoception*. As the first self-report instrument for this novel construct, the PIQ

provides an opportunity to generate empirical evidence on parental interoception and its potential role in the parent-child relationship and the development of interoceptive processes. To ensure a rigorous and systematic approach, established procedures for scale development were followed (Boateng et al., 2018; Kyriazos & Stalikas, 2018b), which involved three main phases: item development, scale development, and scale evaluation.

The initial phase sought to generate the questionnaire items and maximise their content validity through evaluations by a panel of experts and the target population. Evaluating content validity of a new self-report measure is critical to ensure that the items accurately measure the intended construct and reflect relevant experiences of the population being examined. Results indicated that, overall, the items adequately measured the domain of interest and were relevant to the real-life experiences of parents. Critical feedback from both experts and the target population led to modifications that improved the questionnaire's accessibility while ensuring its alignment with the theoretical framework, underscoring the importance of incorporating both quantitative and qualitative evaluations in content validity assessment. Nonetheless, future studies could employ additional, more in-depth methods, such as cognitive interviews with the target population, to further enhance the content validity of the measure. This phase resulted in a total of 49 items divided into nine subscales. Given that the subsequent phase involved further item reduction, the retention of 49 items at this stage aligns with established recommendations to generate at least twice the number of desired final items during the item development process (Boateng et al., 2018; Kyriazos & Stalikas, 2018b).

The second phase aimed to prune items and obtain a reliable factor structure. Firstly, the pruning of items based on descriptive statistics and item analysis results ensured that the questionnaire's psychometric properties were not adversely affected by poorly performing items and enhanced the internal consistency of the questionnaire. The EFA results were instrumental in defining the questionnaire's factor structure. Both the Baby and Child groups final models consisted of five factors. Nonetheless, the Baby group displayed weaker loadings and cross-loadings for some items, while the Child group obtained a more robust and theoretically interpretable factor structure that aligned more closely with the original conceptual framework.

With the aim to establish a unified model that could potentially apply across age groups, the factor structure derived from the Child group was tested on the Baby group using CFA. Results supported this approach, with good fit indices and strong item loadings. These findings suggest that the Child group's factor structure can serve as a model across age groups. Nevertheless, the differences in EFA results may reflect developmental or contextual differences in how items are interpreted or how *parental interoception* is conceptualized across these age groups. Therefore, age-related differences in specific factors warrant further exploration.

This phase resulted in a 24-item questionnaire comprising five theoretically meaningful factors: *Attention*, *Epistemic Attitudes*, *Trust and Self-Efficacy*, *Regulation*, and *Linking*. The interpretation of the identified factors reinforces the theoretical framework underpinning the questionnaire. Nevertheless, two notable limitations emerged: the *Regulation* factor retained only two items, which posed a risk to its internal reliability (Nunnally & Bernstein, 1994), and the *Linking* factor comprised only negatively worded items, potentially introducing response biases or “response set effect” (Kyriazos & Stalikas, 2018b; Likert, 1932). These limitations were addressed by adding new items to the respective subscales, which were tested in the subsequent phase. The findings from this phase provide a strong foundation for ensuing validation steps, balancing psychometric rigor with theoretical relevance and practical applicability.

The final phase of the study confirmed the factor structure of the questionnaire in a new sample, with satisfactory CFA fit indices, and provided initial evidence of its construct validity and reliability. Moreover, a more detailed examination of the *Regulation* and *Linking* subscales, which had additional items introduced during the previous phase, was necessary. Internal reliability improved for the *Regulation* subscale (from $\alpha = 0.61$ to $\alpha = 0.75$) but decreased for the *Linking* subscale (from $\alpha = 0.76$ to $\alpha = 0.68$). This might be due to the incorporation of positively worded items into the *Linking* subscale, which initially intended to mitigate response biases; thus, further investigation into its psychometric properties is warranted. Future research could explore its performance when exclusively using positively worded items, as some studies suggest that the inclusion of negatively worded items may be inefficient

(Kyriazos & Stalikas, 2018b; Streiner et al., 2024). Such evaluations should nonetheless consider the possibility of response set effect.

Overall, the questionnaire's subscales demonstrated alpha values ranging from $\alpha = 0.68$ to $\alpha = 0.83$, with and overall $\alpha = 0.91$. These results are comparable to reliability coefficients reported for subscales in other established measures, such as the MAIA ($\alpha = 0.66$ to $\alpha = 0.87$) (Mehling et al., 2012), and the PRFQ ($\alpha = 0.70$ to $\alpha = 0.82$) (Luyten, Mayes, et al., 2017b), during their initial development. While a Cronbach's Alpha coefficient of $\alpha = 0.70$ is generally regarded as an acceptable threshold for reliability in early-stage research, subsequent studies could focus on further enhancing the internal consistency of the subscales, as achieving an alpha value of $\alpha = 0.80$ or higher is often considered indicative of strong psychometric quality (Boateng et al., 2018; Nunnally & Bernstein, 1994). Nonetheless, efforts to enhance reliability must be careful to avoid compromising the questionnaire's content validity and efficiency. As Nunnally and Bernstein (1994) point out, perfect reliability can hinder the measure's ability to comprehensively represent the intended construct. For example, repeatedly measuring the same question in different ways may increase alpha values but limit comprehensiveness and risk participant burden with an unnecessarily lengthy scale (Nunnally & Bernstein, 1994).

Regarding construct validity, the questionnaire demonstrated significant associations and predictive value with several theoretically relevant constructs and some demographic variables. Firstly, the observed gender differences align with existing research on interoceptive sensibility using self-report measures, such as the MAIA, which consistently reports higher scores among women (Grabauskaitė et al., 2017; Re et al., 2023). Similarly, studies on parental reflective functioning indicate that mothers tend to achieve higher scores on the PRFQ compared to fathers (Pajulo et al., 2018; Pazzagli et al., 2018). Although few studies on parental mentalising explicitly address participants' employment status, the differences identified among parents employed full time, part-time, or unemployed could be explained by theories that correlate socioeconomic disadvantage with disadvantages in social learning and mentalising (Luyten, Nijssens, et al., 2017).

The significant association found between the PIQ and measures of interoceptive sensibility, the MAIA-2 and BAQ, aligns with theories suggesting that the ability to detect bodily signals in others is influenced by the sensibility to one's own bodily signals (Fotopoulou & Tsakiris, 2017; Steele et al., 2017). This finding is consistent with previous research linking interoception with recognition of others' emotional state (see Chapter 1, Section 1.2; Hübner et al., 2021) and social constructs like empathy and social connection (Arnold et al., 2019; Ernst et al., 2013; Ferri et al., 2013). Furthermore, the significant negative relationship between the PIQ and emotion regulation difficulties (measured by the DERS-18) confirms the expectations, which stemmed from established links between emotion regulation and both interoception (see Chapter 1, Section 1.2; Bornemann & Singer, 2017; Brewer et al., 2021; Füstös et al., 2013; Zamariola et al., 2019) and parental reflective abilities (i.e., PEM and PRF) (Schultheis et al., 2019). These two constructs are conceptually close to *parental interoception*, further validating the theoretical framework underlying the PIQ.

The observed negative association between the PIQ and avoidant attachment style, but not anxious attachment style (measured by the ECR-R) also aligns with tentative expectations. Previous research on interoception and attachment styles has generated mixed results. While some studies report associations between both anxious and avoidant styles and lower interoceptive sensibility (Ferraro & Taylor, 2021), others suggest that avoidant attachment relates to lower interoception, whereas anxious attachment is linked to higher interoceptive sensibility (Oldroyd et al., 2019). This study's findings align with the latter suggestion and reinforce the need for further investigation into the complex relationship between interoception and attachment.

Findings related to parental reflective functioning (measured by the PRFQ) were theoretically consistent with studies connecting parental embodied mentalising to enhanced parental sensitivity and verbal mentalising (e.g., attuned mind-related comments) (Shai & Meins, 2018; Væver et al., 2022). These results underscore the relationship between mind-focused and body-focused parental mentalising or "reading" abilities. Additionally, the PIQ's predictive validity for children's externalising, internalising, and prosocial behaviours (measured by the SDQ) aligns with existing evidence linking parental mentalising and embodied mentalising to these developmental outcomes (Ghanbari et al., 2023; Shai & Belsky, 2017).

In contrast, no significant associations were found between the PIQ and measures of mental health or somatic symptoms (i.e., DASS-21 and PHQ-15), despite previous research linking both interoception and parental reflective abilities with these variables (Brewer et al., 2021; Khalsa et al., 2018; Luyten, Mayes, et al., 2017b; Nobre-Trindade et al., 2021; Sugawara et al., 2020). This discrepancy may suggest that *parental interoception*, although conceptually related to both interoception and parental mentalising abilities, possesses distinctive dimensions that are less strongly connected to these outcomes. Alternatively, the lack of association may be attributed to sample characteristics, as average scores for mental health and somatic symptoms were within the normal to moderate range, thus limiting variability. Future research should investigate these relationships in a clinical sample to elucidate potential differences.

This chapter presents initial evidence supporting the reliability and validity of the PIQ as a self-report measure for assessing individual differences in *parental interoception*, particularly in large-scale studies. Future research could further enhance the measure by addressing specific areas for improvement, such as increasing the internal consistency of the subscales, with particular attention to the *Linking* subscale. Moreover, future research could test the validity of the PIQ with diverse populations, as the samples in the present studies were predominantly of White ethnic backgrounds in the United Kingdom. Additionally, future studies might further explore age-specific differences in factor structure and item performance, especially among parents of younger children or infants (0- to 3-year-olds), where developmental variations may influence responses. Furthermore, evaluating the validity of the PIQ for parents of adolescent children (ages 11 to 18) could also provide valuable insights into its applicability across different developmental stages. Another relevant direction for future research is to strengthen the construct validity of the questionnaire by examining differences between clinical and non-clinical populations and incorporating complementary assessment methods, such as behavioural tasks, interviews, or observational approaches, alongside self-report measures.

In summary, by integrating robust scale development methods with both theoretical and practical considerations, the PIQ offers a valuable self-report tool for assessing parents' ability to notice and respond to their child's internal bodily signals and states

– parental interoception. This is the first self-report scale designed to measure this novel concept, consisting of 5 subscales and 24 items (see Appendix E for the final version and user instructions).

In conjunction with other behavioural and/or observational measures, the PIQ may contribute to enrich our understanding of how parents notice and regulate their children's interoceptive signals, how they support their children's development of self-regulation, and help identify individual differences in these processes. Although it is not intended as a clinical or educational screening tool, its applications can extend to research in the fields of developmental psychology and health, psychophysiology, and epidemiology, including, for example, longitudinal investigations into potential intergenerational effects of parental interoception on child development. Addressing the identified limitations and extending the PIQ's validation across diverse populations and developmental stages will further strengthen its utility for research.

Chapter 3: Reading children's interoceptive states: can adults discriminate children's heart rates?

3.1 Introduction

Parental interoception, as conceptualised in this thesis, is a socially oriented construct that, similar to individual interoception, encompasses multiple dimensions. The previous chapter focused on developing a self-report tool to assess the sensibility dimension of parental interoception, capturing various features such as attention, regulation, mentalising, and trust. The present chapter extends this work by incorporating the dimension of interoceptive accuracy (IA), which in the parental context is referred to as parental interoception, and in more general cases as interpersonal interoception. Specifically, it introduces a behavioural task designed to objectively assess adults' ability to identify children's interoceptive states, in this case specifically, heart rate.

Research in social and embodied cognition has established that bodily processes are central to the perception and understanding of others' mental states, particularly their emotions. Concepts such as the mirror neuron system (Keysers et al., 2018) and embodied simulation (Bastiaansen et al., 2009; Gallese, 2003) emphasise the role of mirroring mechanisms for inferring emotions, intentions, and goals (i.e., mental states) through the observation of body movements or facial expressions. For instance, disruptions in the mirror neuron network have been shown to impair recognition of bodily and facial emotional expressions, hinder the ability to infer others' emotional states (Gallo et al., 2018; Mazzoni et al., 2017; Paracampo et al., 2017), and reduce the ability to predict and coordinate actions in social interactions (Hadley et al., 2015; Keysers et al., 2018). A comprehensive review of this literature is beyond the scope of this thesis; for detailed overviews see Bastiaansen et al. (2009) and Keysers et al. (2018), and for meta-analytic evidence, see Urgesi et al. (2014).

This body of research has focused on the brain's somatosensory-motor networks and on exteroceptive or proprioceptive processing (e.g., vision, audition, motor activity). More recently, however, scientific interest and research has increasingly turned to the role of interoception in understanding and inferring others' emotional and intentional

states (Ondobaka et al., 2017; Ross & Atkinson, 2020). As reviewed in Chapter 1, Section 1.2, converging behavioural, physiological and neuroimaging evidence suggests that interoceptive signals and abilities are associated with sensitivity to others' emotions. For example, individuals with higher IA show greater sensitivity to facial expressions of happiness, sadness, fear, and disgust (Chick et al., 2020; Terasawa et al., 2014), and higher IS has been linked to faster reaction times when detecting emotional expressions in a face-morphing task (Hübner et al., 2021). Complementing these behavioural findings, Ernst et al. (2013) demonstrated that neural activity during an empathy task increased following interoceptive, but not exteroceptive, attentiveness.

That said, while prior work has linked interoception to the processing of others' emotional states, little is known about whether people can perceive or infer others' interoceptive states. This capacity, which is conceptualised here as a form of "interpersonal interoception" has only recently begun to be investigated. Two studies (Arslanova et al., 2022; Galvez-Pol et al., 2022) employed the "other-HR task" to explore this phenomenon. The paradigm was introduced by Galvez-Pol et al. (2022) and is designed to assess people's ability to identify or infer another person's cardiac activity. Briefly, during the experiment participants observe short video clips of two individuals while receiving visual feedback that mirrors the heart rate of one of them. Their task is to decide which individual's heart rate is being represented.

As noted by Arslanova et al. (2022) and Ondobaka et al. (2017), interoceptive signals are largely hidden, unlike overt emotional expressions or motor behaviours, which are accessible through vision or audition. Nevertheless, subtle, transient changes in appearance do occur alongside interoceptive variations (Arslanova et al., 2022; Galvez-Pol et al., 2022). For example, heartbeat-related changes can produce slight variations in facial colouring (e.g., redness) or micro-movements of the head and eyes (Wu et al., 2012), and psychophysiological methods have even been developed to estimate heart rate from facial videos (Hassan et al., 2017). Research also indicates that people are more sensitive to variations in facial colour than in non-face stimuli (Tan & Stephen, 2013; Thorstenson et al., 2017). Moreover, facial colouration has been shown to influence judgements of others' social and emotional states (Benitez-Quiroz et al., 2018; Young et al., 2018), as well as perceptions of health and physical

fitness (Henderson et al., 2016; Perrett et al., 2020). This evidence suggest that minimal physiological markers may serve as cues for inferring others' interoceptive states.

Indeed, the findings from Arslanova et al. (2022) and Galvez-Pol et al. (2022), using the other-HR task, suggest that individuals can infer others' heart rates by observing videos of their faces in emotionally neutral contexts. Across five experiments, Galvez-Pol et al. (2022) demonstrated that participants were able to identify the person whose heart rate matched the visual feedback at rates significantly above chance level, and that this performance declined when the visual properties of the faces were altered, such as when they were inverted, masked, or presented as static images. Arslanova et al. (2022) replicated this effect, again finding above chance performance. Interestingly, although this ability was not directly related to individual interoceptive abilities in their study, they observed a significant interaction between IS and IA: participants with high sensibility, assessed with the Interoceptive Accuracy Scale (Murphy et al., 2020), but low accuracy, measured with a heartbeat counting task, performed worse at inferring others' heart rates.

Moreover, although the other-HR task does not directly reveal *how* participants identify the correct answer or the mechanisms underlying this ability, Arslanova et al. (2022) explored this by asking participants to describe which cues from the videos, if any, they relied on during the task. The most frequently mentioned cues were general body movements and breathing, followed by perceived state (e.g., appearing nervous or calm), eye movements or blinking, associations formed between a particular individual and a heart rate, and skin colouration (e.g., blushing). Notably, some participants reported relying solely on "general intuition" to complete the task.

Taken together, these two studies demonstrate that adults can, at least to some extent, infer others' cardiac interoceptive states through subtle visual cues. This finding aligns with modern theories on perception and mentalisation, which propose that such abilities rely to some degree on inferential processes shaped by noisy sensory input and prior expectations. In fact, it has been argued that all perception is to some degree an inference (Clark, 2013; Friston, 2010; Gregory, 1980; Kersten et al., 2004).

Nevertheless, this ability has so far been investigated only in adult populations, with children excluded from consideration. The present chapter builds on this work to introduce the Child Body Reading (CBR) task, an adaptation of the other-HR paradigm designed to assess adults' general capacity to detect children's heart rates. This measure has potential applications not only in parent-child research but also in educational and other caregiving contexts, such as teacher-student interactions. To first investigate if adults indeed have this capacity and evaluate the task's psychometric properties, the development and application of this child-oriented task are presented here with a general adult sample, before extending the paradigm to a parental sample in the following chapter.

The Present Study

The primary aim of this study was to investigate whether adults can objectively identify cardiac interoceptive signals in children by looking at videos of their faces. To this end, the *other-HR task* by Galvez-Pol et al. (2022) was adapted into the *Child Body Reading (CBR) task*, which used videos of children as stimuli (see the Methods section for more details). It was expected that participants' performance on the CBR task would be significantly above chance level, indicating an ability to detect children's cardiac signals and replicating results from Arslanova et al. (2022) and Galvez-Pol et al. (2022) in a child-oriented version of the task.

As discussed in Chapter 1, Section 1.1.1, one challenge in measuring IA is that performance often varies with signal strength, with evidence showing that cardiac perception accuracy improves when stronger signals are induced (Jones & Hollandsworth, 1981; Schandry et al., 1993). Accordingly, a stress condition was added to the CBR task to explore whether participants' ability to identify children's cardiac states was similarly influenced by the strength of their own heart rate.

Additionally, a secondary aim of this study was to examine whether the child-oriented interpersonal interoception ability assessed by the CBR task is influenced by participants' individual interoceptive abilities and by relevant psychosocial traits, including emotion regulation, attachment style, and mental health symptoms. Investigating these associations can provide insight into the factors that might shape

adults' ability to infer children's interoceptive states and inform directions for future research. Given the novelty of the task and the exploratory nature of the study, expectations were guided by findings from related areas, as reviewed in Chapter 1. It was anticipated that both IA and IS would be positively associated with performance on the CBR task, as individual interoceptive abilities have been linked to the processing of others' emotional states (see Chapter 1, Section 1.2). However, because Arslanova et al. (2022) reported no direct association but instead an interaction between these dimensions, this possibility was also tested in the present study.

Furthermore, greater difficulties in emotion regulation and increased mental health symptoms were expected to be associated with poorer task performance, consistent with evidence that interoception and mentalising abilities are closely linked to emotion regulation processes (see Chapter 1, Section 1.2; Bornemann & Singer, 2017; Schultheis et al., 2019; Sugawara et al., 2020). Lastly, expectations regarding attachment style were informed by mixed findings, with some studies linking both anxious and avoidant attachment to lower interoceptive ability (Ferraro & Taylor, 2021), while others report reduced interoception for avoidant attachment but increased interoception for anxious attachment (Oldroyd et al., 2019). In line with results from Chapter 2 of this thesis, which showed that only avoidant attachment was negatively related to subjective parental interoception, it was expected that avoidant attachment would also be negatively associated with performance on the CBR task. Nevertheless, these prior findings on attachment style are based on self-reported IS, thus, associations with the objective task in this study may differ, as IS and IA do not always correlate (Brewer et al., 2021).

3.2 Methods

3.2.1 Participants

Participants were recruited through SONA, the UCL Division of Psychology and Language Sciences (PALS) online subject pool. The inclusion criteria included being 18 years old or older and being literate in English. Exclusion criteria included any self-reported conditions that would impact performance, the regularity of the heart rate, or

the results of the experiment, specifically, any existing substance dependency, moderate to severe cognitive impairment or severe mental health condition (e.g., psychosis), existing severe neurological condition (e.g., epilepsy), existing diagnosis of heart-disease, being currently pregnant, current use of neurological, cardiac (e.g., medications that influence blood pressure/cardiovascular functioning) or psychiatric medication, or having low vision/hearing that cannot be corrected. Participants confirmed their eligibility and provided their informed consent in an online survey via UCL Qualtrics. All participants were compensated according to the rate stipulated by the PALS Division at UCL. Ethics Approval was obtained from the UCL Research Ethics Committee (Project number CEHP/2019/577).

An a priori power analysis for the primary hypothesis (above-chance performance) indicated that $N = 24$ would yield ~80% power at $\alpha = .05$. However, a larger sample was recruited to support additional planned and exploratory analyses, account for potential exclusions, and increase estimate precision and generalizability.

Thus, the sample consisted of 65 participants, of which 45 (69%) identified as women and 20 (31%) men, with a mean age of 24.88 years ($SD = 7.84$, range = 18–55). Most participants (58.46%) self-identified as Asian, with 36.92% as Asian Chinese, and almost a third (27.69%) identified as White, including English, Welsh, Scottish, Northern Irish, British, Irish, and other White backgrounds. About a third of participants had completed a postgraduate degree, a third an undergraduate degree or equivalent, and a third secondary education. Most were not working or students (67.69%) and some were employed full-time (15.38%) or part-time (12.31%). Regarding family and relationships, most participants were single (66.15%) and had a two-parent different-sex family structure (83.08%). Only one participant reported being a parent to a 13-year-old child (no outlier values reported in any variable). Demographic information is summarised in Table 3.1.

Table 3.1. Demographic information for adult sample.

Parameter	Participants (N = 65)
Age ^a	24.88 (7.84)
Gender (%)	
Women	69.23

Men	30.77
Ethnicity (%)	
Asian Chinese	36.92
Other Asian	21.54
White English, Welsh, Scottish, Northern Irish, or British	13.85
Other White	13.85
Black, African, or Caribbean	3.08
Arab	1.54
Mixed	6.15
Undisclosed	3.08
Education level (%)	
Secondary education	38.46
Undergraduate degree or equivalent	29.23
Postgraduate degree	29.23
Undisclosed	3.08
Employment (%)	
Employed full-time	15.38
Employed part-time	12.31
Not working/Student	67.69
Self-employed	1.54
Undisclosed	3.08
Annual household income (%)	
<£20,000	21.54
£20,000 - £39,999	13.85
£40,000 - £59,999	21.54
£60,000 - £99,999	10.77
>£100,000	7.69
Undisclosed	24.61
Relationship status (%)	
In a relationship	30.77
Single	66.15
Undisclosed	3.08
Relationship duration (%)	
More than a year	85.00
Between three months and a year	10.00
Undisclosed	5.00
Relationship satisfaction (0-10) ^a	8.21 (1.32)
Family structure (%)	
Two-parent different sex	83.08
Two-parent same sex	1.54
Single parent	10.77
Undisclosed	4.62

^a Mean (SD)

Children sample. To create the stimuli for the CBR task, a sample of 18 children was recruited through study advertisements directed at parents, including at schools and parent centres associated with senior researchers supervising this project. The experiment involved electrocardiogram (ECG) recording with electrodes and required children to sustain attention during several short periods. Therefore, children in primary school (aged 5–11) were selected, as they would be most able to participate in the tasks required. Moreover, at this developmental stage, children are gaining greater independence and parent-child exchanges become more balanced or mutual. Nevertheless, parents still play a driving role for physiological regulation (Shih et al., 2018), thus, collecting information about parental sensitivity during this period would be especially valuable.

Parents were provided with a full information sheet for the study and gave their informed consent for their child to participate and for their video recordings to be used in the task. Children were shown an age-appropriate information sheet, which was explained verbally by the experimenter. They provided both their verbal assent (recorded by the experimenter) and written informed consent using an age-appropriate consent form. Table 3.2 provides demographic information for the children.

Table 3.2. Demographic information for child sample.

Parameter	Children (N = 18)
Age ^a	8.61 (1.24)
Gender (%)	
Girls	50.00
Boys	50.00
Ethnicity (%)	
White English, Welsh, Scottish, Northern Irish or British	21.43
Other White	28.57
Mixed	35.71
Black, African, or Caribbean	14.29

^a Mean (SD)

3.2.2 Design

The study used a within-subjects design to investigate adults' ability to identify children's heart rates, referred to as child-oriented interpersonal interoception. The

CBR task served as the primary measure for this ability, with two conditions: neutral and stress, which were completed in counterbalanced order. In addition, participants' confidence ratings during the CBR task provided a state-like indicator of self-reported interpersonal interoception. To assess individual interoception, participants completed the Heart Rate Discrimination (HRD) task (Legrand et al., 2022) as a proxy measure of interoceptive accuracy and the Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2; Mehling, Acree, et al., 2018) for interoceptive sensibility.

Additionally, psychosocial traits were measured using validated psychometric questionnaires and their relationships with CBR task performance were examined. The Difficulties in Emotion Regulation Scale, Brief Version (DERS-18; Victor & Klonsky, 2016) assessed emotion regulation, the Depression, Anxiety, Stress Scale (Lovibond & Lovibond, 1995) mental health symptoms, and the Experiences in Close Relationships, Revised Questionnaire (ECR-R; Fraley et al., 2000) attachment style. See Table 3.3 for the operationalization of variables measured in this study.

Table 3.3. Operationalization of variables.

	Variable	Operationalization
Primary outcome	Objective interpersonal interoception	CBR task performance
	Subjective interpersonal interoception	CBR task confidence ratings
Predictors	Individual interoception	
	Accuracy	HRD task performance
	Sensibility	MAIA-2 scores
	Psychosocial traits	
	Emotion regulation	DERS-18 scores
	Mental health symptoms	DASS-21 scores
	Attachment style	ECR-R scores

Note: see *Data Analysis* section for further details.

3.2.3 Procedures and Materials

After reviewing the study's information provided in the SONA advertisement, participants were invited to complete an online survey via UCL Qualtrics to assess

their eligibility. Eligible individuals received an online copy of the information sheet, which included the experimenters' contact for any questions or concerns. After providing informed consent, participants completed a sociodemographic survey and additional self-report measures. They were then scheduled for an in-person session at the UCL laboratory, where they completed the CBR and HRD tasks in a counterbalanced order.

Child Body Reading (CBR) task. As mentioned, the CBR task was adapted from an experimental paradigm originally developed by Galvez-Pol et al. (2022). Notable modifications in the adapted CBR task are a change from adults to children in the stimuli videos and an added “stress” condition to compare participants' performance under different stress and arousal levels.

The CBR task is a two-alternative forced choice (2AFC) task. Participants are presented with 10-second videos of children, displaying two side-by-side videos of the same child with cardiac feedback (i.e., flashing square) in between. Participants must choose to which video the heart rate represented in the cardiac feedback corresponds to, either the video on the left or the video on the right. Lastly, they are asked to rate their confidence level, the maximum rating (10) means that they are “Absolutely certain” their choice was the correct one, and the smallest rating (0) means that they are “Not at all certain” or felt like they were guessing (see Figure 3.1A).

The task follows a standardised procedure (see Figure 3.1B). First, the overall aims and description of the task are explained, and the Embrace Plus watch (details below) is placed on the participant's non-dominant hand to monitor their heart rate throughout the experiment. Participants then answer baseline questions about their distress level and emotional state. Next, they are presented with the task instructions, which are both displayed on the screen and verbally explained, followed by five practice trials. After completing the practice trials, participants can ask any questions and then proceed with the two main blocks.

In the neutral block, participants listen to a 30-second recording of classical music at the beginning of the block and again at 25%, 50% and 75% completion. A total of 48 trials is completed in random order, 12 in between each recording. In the stress block,

participants listen to a 40-second recording of baby-crying sounds at the start, with additional 20-second recordings at 25%, 50%, and 75%, also completing 12 trials between each recording and 48 in total in a random order. Throughout both blocks, participants rate their distress level after the first and third recordings. At the end of each block, they provide retrospective ratings of their distress level and emotional state (Figure 3.1C). Finally, at the end of the task, participants answer a few questions about the cues or strategy they used to choose their answers.

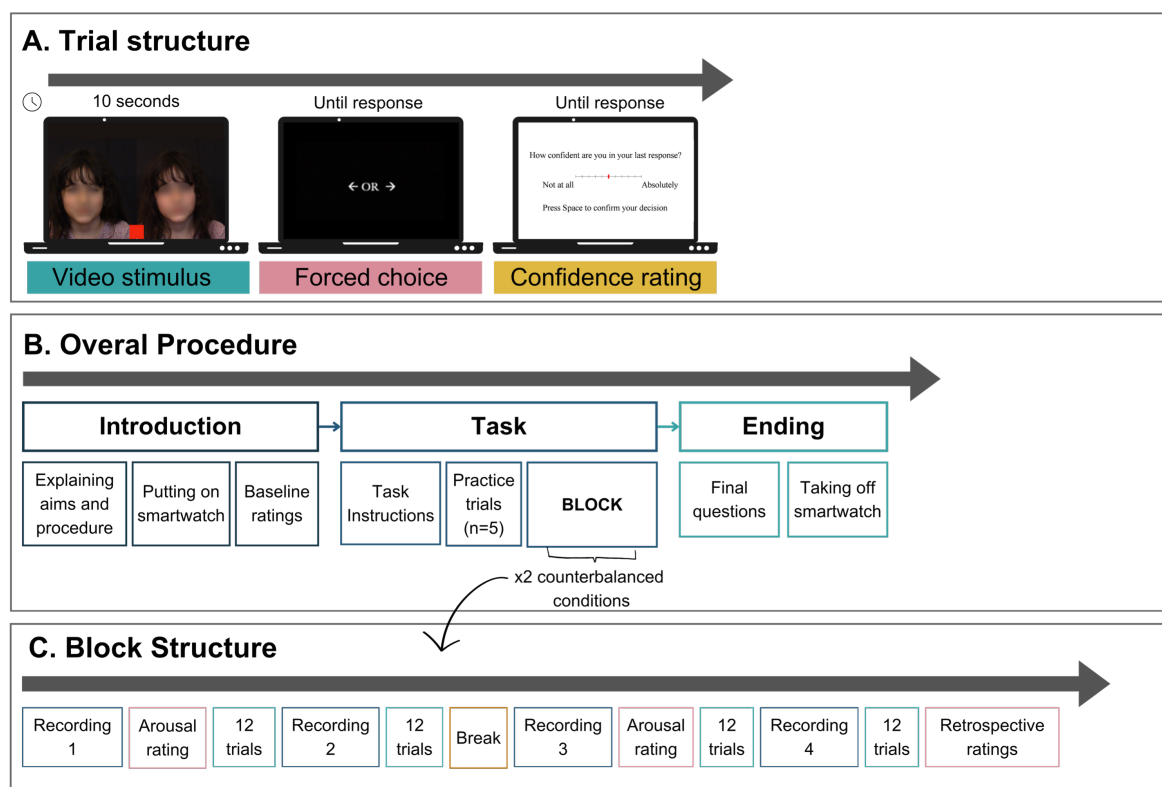


Figure 3.1. CBR task – trials and procedure. **A)** Each trial involved a 10-second stimuli presentation, followed by a forced choice screen displaying two arrows pointing left and right, and ending with a 0-10 confidence rating. **B)** The overall procedure began with an introduction explaining the task and aims, placing the smartwatch, and collecting baseline distress ratings. This was followed by the main task, including instructions, practice trials, and two counterbalanced blocks (stress and neutral conditions). The session ended with final ratings and returning the smartwatch. **C)** During each block, either relaxing music (neutral) or baby crying sounds (stress) played at the start and at 25%, 50% and 75% completion. Twelve trials occurred between each recording (48 total, in random order). Participants provided distress ratings after the first and third recordings, with a break at 50% completion.

Participants' heart rate was monitored using the Embrace Plus smartwatch from Empatica. This is a medical-grade wearable device that records real-time physiological data using ventral electrodermal activity (EDA) and 4-channel multi-wavelength photoplethysmogram (PPG) sensors (see <https://www.empatica.com/en-gb/embraceplus/> for more details). The data obtained from the smartwatch includes the participant's pulse rate, aggregated by minute. Start and end times for each block were recorded by the experimenter to ensure accurate time-locking with the heart rate data.

Stimuli adaptation. As previously mentioned, when adapting the CBR task, stimuli were modified from videos of adults to videos of children to investigate whether adults can identify children's heart rates. One of the key objectives for the task in future studies was to examine whether parents' performance differs when observing their own child compared to an unfamiliar child; therefore, to minimize potential confusion in this comparison, two videos of the same child were presented within each trial, rather than videos of two different children. However, this modification introduced a challenge to the experimental design: the variability in the heart rate across the two videos shown in each trial might be too low, as both videos feature the same child. Specifically, if the number of heartbeats in each video remained consistently the same, there would be no variability in heart rate, making the task overly difficult. In the original study by Galvez-Pol et al. (2022) the heartbeat-count across the videos for all actors ranged from 9 to 14, this means the highest possible difference in beat-count was five. In this study, additional measures were taken when generating the videos to ensure a comparable range.

To manage the variability in heartbeat-count, the videos for each child were categorised into two arousal bands: three in the low arousal (LA) band and three in the high arousal (HA) band, with at least a one-heartbeat difference between the two bands. The heartbeat difference between the two videos reflects the trial's difficulty level, with larger differences indicating easier trials. All possible combinations of LA and HA videos ($n = 9$) were used to create the final video montages. For each LA-HA combination, four different versions were generated by alternating both the side of the screen displaying each video and the source of the cardiac feedback (flashing square), depending on whether it corresponded to the video on the left or right side.

Moreover, during the task, each participant was presented with videos of only two different children in total. Considering the future objective of comparing parents' performance with their own child versus an unfamiliar child, including multiple unfamiliar children would create an imbalance: parents would view their own child more frequently than any single unfamiliar child, thereby introducing a task-related familiarity confound. To address this, only two children were selected for each participant. Several guidelines were followed to pair the children: 1) gender-matched pairs, 2) age-group matched pairs (with children either of the same age or no more than one year apart), 3) similar average heartbeat-counts across their videos, and 4) equal number of videos at each difficulty level, or as closely matched as possible.

Stimuli generation. To create the stimuli for the CBR task, 18 children were pre-recorded following a standardised procedure. Recordings took place in various locations to facilitate recruitment; however, measures were implemented to standardise the procedure and ensure consistency across video recordings. Among the 18 children, six were recorded in the UCL laboratory, seven in a temporary laboratory set up at a private residence near their school, and five in their own homes. Following the information and consent process, electrodes for ECG recording were placed on the child's chest. The session then proceeded with the recording segment, concluding with a brief psychoeducational game (see Figure 3.2C for a summary of the procedure).

To prepare for the recordings, the camera was mounted on a tripod positioned 112 cm away from the stool where the children were instructed to sit. A black fabric was hung on the wall to serve as a neutral background for the videos. A laptop displaying a fixation cross was placed on a small table directly beneath the camera lens. Before starting the recording segment, children were asked to sit on the stool, and the distance between the floor and their eye level was measured. The heights of both the tripod and the laptop were adjusted as needed to align the camera lens with the child's line of sight (see Figure 3.2A). The entire recording segment was video recorded, and the ECG signal was continuously monitored. The 10-second video segments used for the final stimuli videos were selected and edited offline (see next section on processing videos).

Recordings of children's faces capturing moments when they were sitting still, maintaining a neutral expression, and looking directly at the camera were required. In the original task by Galvez-Pol et al. (2022), two-minute recordings of adult actors sitting still and looking at the camera with a neutral expression were used to extract the 10-second segments; however, replicating this procedure with children was not feasible. Therefore, a standardised age-appropriate protocol for recording these videos was developed specifically for this study (see Figure 3.2). Further adjustments were made to accommodate the creation of videos in the low arousal (LA) and high arousal (HA) bands.

Consequently, the recording segment consisted of three main phases: baseline, high arousal, and low arousal (Figure 3.2B). To maintain engagement and ensure the tasks were child-friendly, simple challenges and games were introduced for each phase. During the baseline phase, children were asked to complete a mental arithmetic task while sitting still and looking directly at the fixation cross displayed on the laptop's screen; this was presented as a "mental game", where they counted silently up to 30 and attempted to match the time on a chronometer. In the high arousal phase, children performed 25-30 seconds of a simple physical exercise: stomping their feet rapidly while keeping their arms extended in front, with an added challenge of balancing a ruler on top of their arms. Immediately following the exercise, they were asked to "pretend to be a statue" looking at the fixation cross for 40 seconds. Finally, for the low arousal phase, children engaged in a relaxing breathing exercise, followed by watching a relaxing video on the laptop, during which they were asked to remember the shapes they observed as part of a memory game.

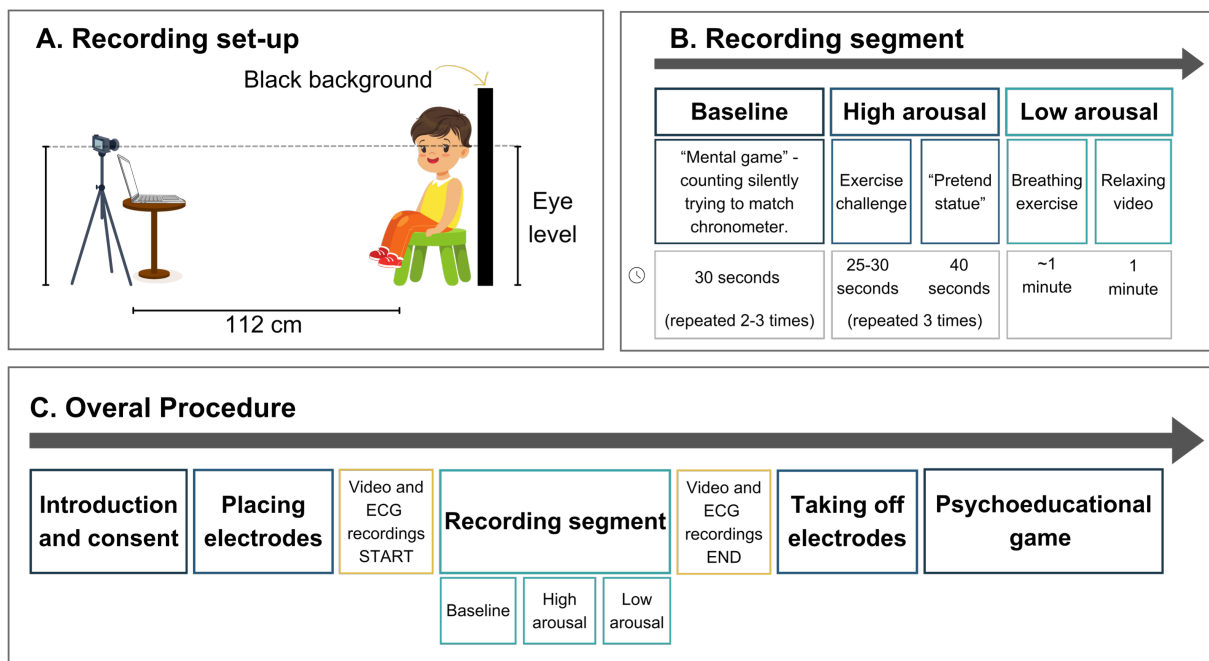


Figure 3.2. Children's recording procedure. **A)** The setup included a camera positioned 112 cm away from the child, a black background, and a laptop displaying a fixation cross beneath the lens. The camera height was matched to the child's eye level. **B)** The recording segment involved a baseline phase (30 seconds, repeated 2-3 times) with a mental game, a high arousal phase (repeated 3 times) with an exercise challenge (~25 seconds) followed by a "statue" recording (40 seconds), and a low arousal phase with a breathing exercise (~1 minute) and a 1- minute relaxing video. **C)** The overall procedure included an introduction and consent phase, placement of ECG electrodes, the recording segment, removal of electrodes, and a final psychoeducational game.

Processing ECG and video recordings. Videos were recorded using a Canon LEGRIA HF R606 camera at 25 fps (see <https://www.canon.co.uk/support/consumer/products/camcorders/legria/hf-r-series/legria-hf-r606.html?type=specifications>), while ECG signals were collected using the MP160 data acquisition system (see <https://www.biopac.com/product-category/research/systems/mp160-systems/>), equipped with an ECG Smart Amplifier (see <https://www.biopac.com/product/smart-amp-ecg/>) and a three-lead configuration from the BIOPAC system. Electrode placement followed the Lead II configuration, with the positive electrode (RED = Vin+) positioned on the lower left rib or left leg, and the negative electrode (WHITE = Vin-) placed on the right clavicle or right arm.

Videos were edited using the free Shotcut software, while ECG signals were processed using both R and MATLAB through a batch file. To align the video recording with the ECG signal, a beep sound was played at the beginning of each recording, with the exact time (to milliseconds) recorded. The videos were then manually trimmed in Shotcut at the start of the beep sound (according to the spectrogram) while the ECG signal was trimmed at the timepoint recorded for the start of the beep sound through an R code. The complete ECG signal was then bandpass filtered between 3 and 40 Hz using the custom MATLAB function *heplab_ecg_filt*.

Subsequently, 10-second segments of the videos were manually selected, prioritising segments where the children were looking at the camera, sitting still, with a neutral expression. The ECG segments corresponding to the selected video segments were then processed. First the start of each heartbeat was identified by detecting the R-peaks in the QRS complex using the *findpeaks* function in MATLAB, with a standard minimum peak height of $\text{mean} \times 1.05$ and peak to peak distance of 10. The graphs with the detected R-peaks were visually inspected and small adjustments to the parameters were made when required. Then, the cardiac feedback was created using the timepoints of the detected R-peaks. Through MATLAB, a small square which changed colours from black to red at the start of each heartbeat was created. The duration of the red colouring was 32 msec (corresponding to 8 frames), after which the square remained black until the start of the next heartbeat. This flashing square served as the cardiac feedback in the final videos. Lastly, the final video montages were created through a MATLAB script.

Heart Rate Discrimination (HRD) task (Legrand et al., 2022). This task was used to assess participants' objective interoceptive ability. It uses Bayesian modelling of psychophysics to obtain a proxy measure for interoceptive accuracy, denoted as alpha (α), that represents participants' bias, and interoceptive precision, denoted as beta (β), which is the uncertainty around the alpha estimate. The task uses a 2-Interval Forced Choice design (2-IFC), each trial asks participants to attend to their cardiac sensations for five seconds and then to decide whether a series of tones is faster or slower than their heart rate. The frequency of the "feedback" tones is determined as their estimated average beats per minute plus or minus an intensity value that is updated by an adaptive staircase procedure. The task also includes an "exteroceptive"

control condition, in which participants indicate whether a series of tones was faster or slower than a previously presented series.

For the interoceptive condition, alpha (α) represents the difference between the true heart rate and the estimated one by the participant, a negative value would indicate underestimation of the cardiac frequency and a positive value overestimation. Beta (β) is the slope of the psychometric function, which represents the precision around the estimated alpha, a larger value would indicate less precision in the decision process. The task is available in the *Cardioception* repository (<https://github.com/emodied-computation-group/Cardioception>).

Self-report measures. Validated self-report questionnaires presented below were used to explore relationships between interpersonal interoception (as measured by the CBR task) and participants' interoceptive sensibility and psychosocial traits.

1) Interoceptive sensibility. The Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2; Mehling, Acree, et al., 2018). This is a 32-item questionnaire consisting of 8 subscales: *Noticing* ($\alpha = 0.77$), *Not-Distracting* ($\alpha = 0.88$), *Not-Worrying* ($\alpha = 0.67$), *Attention Regulation* ($\alpha = 0.88$), *Emotional Awareness* ($\alpha = 0.80$), *Self-Regulation* ($\alpha = 0.87$), *Body Listening* ($\alpha = 0.85$), and *Trust* ($\alpha = 0.85$). Cronbach's alpha for the overall score was 0.89. Participants rate each item according to how often it applies to them generally in daily life, on a scale from 0 ("Never") to 5 ("Always"). More details described in Chapter 2, Section 2.5.1.

2) Emotion regulation. The Difficulties in Emotion Regulation Scale, Brief Version (DERS-18; Victor & Klonsky, 2016). This is a validated 18-item brief version of the original Difficulties in Emotion Regulation scale by Gratz and Romer (Gratz & Roemer, 2004), which assesses emotion dysregulation with six subscales: *Awareness* ($\alpha = 0.65$), *Clarity* ($\alpha = 0.84$), *Goals* ($\alpha = 0.89$), *Impulse* ($\alpha = 0.87$), *Nonacceptance* ($\alpha = 0.86$), and *Strategies* ($\alpha = 0.81$). Cronbach's alpha for the overall score was 0.88. Participants rate each item on a scale from 1 ("Almost never") to 5 ("Almost always"). More details described in Chapter 2, Section 2.5.1.

3) Mental health symptoms. The Depression, Anxiety, Stress Scale (DASS-21; Lovibond & Lovibond, 1995). This is a shortened 21-item version of the original 42-item DASS and measures the severity of the symptoms for each subscale over the past week: *Depression* ($\alpha = 0.90$), *Anxiety* ($\alpha = 0.77$), and *Stress* ($\alpha = 0.85$). Participants rate each item on a scale from 0 (“Did not apply to me at all”) to 3 (“Applied to me very much, or most of the time”). More details described in Chapter 2, Section 2.5.1.

4) Attachment style. The Experiences in Close Relationships – Revised Questionnaire (ECR-R; Fraley et al., 2000). This is a 36-item self-report measure comprised of two subscales: *Avoidance* ($\alpha = 0.92$), the individual’s discomfort with intimacy; and *Anxiety* ($\alpha = 0.95$), the individual’s tendency to fear rejection and abandonment. Participants rate each item according to how they generally experience relationships, on a scale from 1 (“Strongly disagree”) to 7 (“Strongly agree”). More details described in Chapter 2, Section 2.5.1.

3.2.4 Data Analysis

R 3.6.3 for Mac OS X was used for data analysis. In all cases, descriptive statistics were inspected, outliers were identified using Tukey’s method ($1.5 \times \text{IQR}$ rule) as implemented in the *boxplot.stats()* function in R. As previously recommended (Aguinis et al., 2013; André, 2022; Karch, 2023), outliers were removed only when they reflected data errors. In all other cases, robust analytical approaches were applied or, when appropriate, sensitivity analyses were conducted to assess their impact on the findings (specified in each case below). Moreover, normality was tested both by visual inspection of histograms and Q-Q plots, and the Shapiro-Wilk test; non-parametric tests were used if needed. In the case of linear regression models, the package *lme4* was used, alongside the *tab_model* function from the *sjPlot* package to summarise results in R. Assumptions of linearity, normality of residuals, and homoscedasticity were checked, and no visible violations were found in any model.

Stimuli check. First, a stimuli check was conducted to test whether any one of the children in the stimuli influenced participant’s performance, given that the stimuli were newly created. The average performance by child with corresponding descriptive

statistics was calculated. One outlier was found, whose videos had a higher overall performance score ($M = 0.79$, $SD = 0.41$) than those of the other children. Nevertheless, the Shapiro-Wilk test and visual inspection found a normal distribution of performance by child ($W = 0.96$, $p = .578$). Additionally, a technical issue occurred during one of the recordings, resulting in the ECG signal and video being synchronised only to the second rather than the millisecond, as with the rest. Sensitivity checks for the main task analyses were conducted excluding trials that included these two children (see Appendix F); however, the results did not differ significantly, therefore, the analyses presented here include the full children sample.

To formally test whether performance was statistically equivalent between child 1 and child 2 for each participant, a two one-sided test of equivalence (TOST) was conducted, which assesses equivalence by testing both upper and lower bounds of a predefined difference. The equivalence margin (ϵ) was set using a commonly applied approach, calculated as the average of the two groups' standard deviations, halved. This resulted in an equivalence margin of 0.065. The TOST was performed using a paired design, as each participant contributed data for both children.

CBR task performance. Participants' average performance was calculated as the percentage of correct responses. No outliers were identified for performance on the CBR task. First, the effects of demographic variables were examined to assess the need for control variables in subsequent analyses. Participants' average performance was tested against 0.5 with a one-sample t -test. An additional measure of performance was calculated using signal detection theory (SDT), to obtain a bias-free discriminability score (d'), and a choice bias score (c). Since d' was almost perfectly correlated with participant's average performance ($r = .99$, $p < .001$), it was not used in further analysis as they would be redundant. Additional psychometric and qualitative components were also examined, including difficulty level, response bias, and participant reports on the cues or strategies used to perform the task.

Regarding difficulty level, the difference in beat counts between both videos in each trial was calculated and used as an index for difficulty, the higher the beat difference, the easier the trial. To test the effect of difficulty, the mean of the beat differences for all trials was calculated for each participant. A linear regression was then conducted,

including CBR task performance as the outcome variable, centered around 0.5 for interpretability, and the mean-centered average beat difference score as the predictor.

Response bias was tested using exact binomial tests, both for the tendency to choose left or right, and the propensity to select the high-arousal versus the low-arousal video, a new aspect of the adapted task, as the original included only resting-state videos. Binomial tests determine whether the proportion of left versus right, or HA versus LA, responses is statistically different from chance (50%). Additionally, a simple linear regression was used to test the effect of the SDT estimate for choice bias (c) on CBR task performance.

Next, the effect of stress was tested. Manipulation checks were conducted both for self-report distress ratings and objective heart rate measurement. The two distress ratings in each condition were averaged and compared with the baseline rating. Four outliers were identified in the neutral condition, and ten at baseline; however, most of these had ratings of 4 or 5 on a 1–7 scale, which, while above the group average, were still considered plausible. Only one participant was excluded due to an implausible response pattern, reporting the maximum distress rating for both the neutral and baseline conditions and the minimum rating for the stress condition, suggesting a likely misunderstanding of the scale. Moreover, the distributions for all conditions were visibly skewed, requiring the use of non-parametric tests. A Friedman rank sum test was conducted to compare the ratings in each condition, using Wilcoxon signed rank test for pairwise comparisons and Kendall's W for effect size estimation.

For heart rate measurements, the average heart rate during each block was computed and compared against a baseline measurement, which was calculated as the average in the 10 minutes before starting the experiment. Seven outliers were identified across all conditions, with values falling outside typical physiological ranges (e.g., below 40 bpm or above 230 bpm), suggesting there likely were measurement or technical errors. Given their implausibility, these values were excluded from analyses. Distribution was normal in all conditions; thus, parametric testing was employed. An ANOVA test was conducted to compare the heart rate average in each condition, using paired t -tests for pairwise comparisons and Partial eta squared (η^2_p) as effect size

estimation. Finally, to test the effect of stress on CBR task performance, a paired t -test was conducted comparing performance during the neutral and stress conditions.

Regarding participants' confidence ratings during the CBR task, three outliers were identified across conditions with values either above 8.60 or below 2.10 (on a 0–10 scale). Because the experiment randomly allocated the cursor to values between 3 and 7 on each trial, these averages suggest that participants intentionally moved the cursor to the extremes, likely reflecting genuine over- or under-confidence rather than measurement error. Therefore, sensitivity analyses are presented both with and without outliers. To examine state-like self-reported interpersonal interoception, the average confidence rating for each participant was calculated overall and for each condition. Differences between the neutral and arousal conditions were assessed with one-sample t -tests when outliers were excluded, and Wilcoxon signed-rank tests when they were included. A Pearson correlation between average confidence overall and average performance was conducted without outliers, whereas a percentage bend correlation was used when outliers were included. Finally, differences in confidence between correct and incorrect trials were also explored to investigate alignment with objective performance, using a one-sample t -test when excluding outliers and a Wilcoxon signed-rank test when including them.

Lastly, participants' reports on the cues and strategies used to perform the task were analysed qualitatively. The specific questions asked were *“Could you tell us which cues from the videos did you use to perform this task?”* and *“Did you use a strategy to choose your answer? If so, please explain”*. Responses were explored and categorised into themes using an inductive approach, allowing patterns to emerge from the data rather than imposing a priori categories.

Relationships with interoceptive accuracy and sensibility. No outliers were found for alpha (α), a simple linear regression was conducted with CBR task performance as the outcome variable and alpha as the predictor. Given that alpha contained negative and positive values, the same test was conducted with absolute alpha values, to check if bias in general, regardless of direction, had an effect. Additionally, the same test was conducted with squared alpha values, to check for non-linear effects. Moreover, two outliers were found for interoceptive precision (β),

with higher beta scores than the rest. Sensitivity analyses are presented in the results, including linear regression tests both including and excluding the outliers, with CBR task performance as the outcome variable and beta as the predictor. When including the outliers, a robust linear regression model was fitted using the *lmrob* function from the *robustbase* package in R, which applies MM-estimation. This method combines a high breakdown point and high statistical efficiency, down-weighting the influence of extreme values rather than excluding them (Wilcox, 2011).

For interoceptive sensibility, one outlier was found with a higher overall score in the MAIA-2 than the rest, however, its exclusion did not yield any significant differences in results, therefore results presented include the full sample. Partial correlations were performed to examine relationships between CBR task performance and MAIA-2 overall and subscale scores, with Bonferroni corrections for multiple comparisons applied.

Finally, to examine if there was an interaction effect between objective and subjective interoception, as in Arslanova et al. (2022), a linear regression model was fitted including interoceptive accuracy (alpha), interoceptive sensibility (MAIA-2 overall score), and their interaction term as predictors of interpersonal interoception (average CBR task performance). Response bias (*c*) and mean centered average difficulty were included as covariates.

Relationship with psychosocial traits. Regarding emotion regulation, no outliers were found for DERS-18 scores and even though the distribution deviated from normality ($W = 0.956$, $p = .020$), visual inspection showed only slight divergences, thus, the Pearson method was considered robust enough for the correlation analysis between DERS-18 overall score and CBR task average performance.

For mental health symptoms, two outliers were found across the *Depression* and *Stress* subscales of the DASS-21, with values in the severe and extremely severe ranges. Given that these scores are frequently present even among the general population, sensitivity analyses were carried out for these two variables, performing the statistical test both including (using robust methods) and excluding the outliers. Additionally, all DASS-21 subscales presented a left-skewed distribution upon visual

inspection, confirmed by the Shapiro-Wilk test (*Anxiety*: $W = 0.940$, $p = .004$; *Depression*: $W = 0.841$, $p < .001$; *Stress*: $W = 0.939$, $p = .003$). Therefore, spearman method was used for the correlation analyses between DASS-21 subscales and CBR task average performance, with Bonferroni corrections applied to p -values.

Finally, for attachment style, no outliers were found in either the *Avoidant* or *Anxious* attachment subscales of the ECR-R, and distributions for both were approximately normal, only *Anxious* attachment had a slight positive skew. Therefore, Pearson correlations were carried out between the two subscales and CBR task average performance, with Bonferroni corrections applied.

3.3 Results

3.3.1 Stimuli Check

Performance by child was examined to assess any potential child-related biases. Average scores for all children ranged from .46 to .79. A two one-sided test of equivalence (TOST) confirmed that performance in both the Child 1 group ($M = .59$, $SD = .15$) and the Child 2 group ($M = .61$, $SD = .12$), was statistically equivalent (mean difference: $M = -.02$, 95% CI [-0.05, 0.01], $\epsilon = 0.062$, $p = .008$).

3.3.2 CBR Task Performance

Effects of demographic variables. Most relationships between performance in the CBR task and demographic features were very small and non-significant. However, a significant gender difference was observed, $t(36.35) = -2.10$, $p = .043$, where women ($n = 44$, $M = .58$, $SD = .11$) scored lower than men ($n = 20$, $M = .64$, $SD = .11$) with a medium effect size (Cohen's $d = 0.57$). Additionally, a t -test showed that participants average performance was higher when the stimuli depicted boys ($n = 33$, $M = .63$, $SD = .11$) versus girls ($n = 31$, $M = .56$, $SD = .10$), $t(60.07) = -2.67$, $p = .010$.

Effect of difficulty level. A simple linear regression examining the relationship between each participant's average difficulty and their average performance found no significant effect ($\beta = 0.04$, 95% CI [-0.04, 0.11], $p = .339$, Adj. $R^2 = .001$).

Response biases. An exact binomial test was conducted to determine whether participants were more likely to choose one option (*left* or *right*) over the other, i.e., response bias. The results found no significant deviation from a 50/50 distribution, with participants choosing *right* 50.68% of the time (95% CI [.4941, .5195], $n = 6012$, $p = .296$). Additionally, a simple linear regression indicated no significant effect of the SDT estimate for response bias (c) on participants performance ($\beta = 0.004$, $p = .938$, Adj. $R^2 = -.017$).

Given that the stimuli in this task included a high arousal and low arousal video in each trial, an additional binomial test was conducted to determine if participants were more likely to choose one of these options over the other. These results did find a significant deviation from a 50/50 distribution, with participants choosing high arousal 57.85% of the time (95% CI [.5659, .5910], $n = 6012$, $p < .001$).

Performance against chance level. Participants average performance was .60 ($SD = .11$), with scores ranging from .33 to .80. This was significantly above chance level, as shown by a one-sample t -test against 0.5 ($t(63) = 7.02$, $p < .001$, $d = 0.88$). The significant result remained even after controlling for the effects of gender, child sex, response bias (c), and difficulty with a linear regression model ($F(4, 54) = 2.96$, $p = .028$, Adj. $R^2 = .119$), which showed that, overall, participants performed significantly above chance ($\beta = .54$, 95% CI [.50, .58], $p < .001$), men performed marginally better than women ($\beta = .05$, 95% CI [-.01, .11], $p = .087$), and average performance was significantly higher when the stimuli depicted boys versus girls ($\beta = .08$, 95% CI [.03, .14], $p = .004$).

Given that both gender and child sex influenced CBR task performance, an additional linear regression model was fitted to test if there was an interaction between these two variables, also including response bias (c) and difficulty as covariates. The overall model was significant, $F(5,53) = 3.36$, $p = .010$, Adj. $R^2 = .169$, and there was a significant interaction between participant gender and child sex, $\beta = .12$, $p = .044$. Post-hoc comparisons of estimated marginal means revealed that men rating boys ($n = 9$, $M = .71$, $SD = .03$) were significantly ($p = .002$) more accurate than women rating girls ($n = 22$, $M = .55$, $SD = .02$), men rating girls ($n = 11$, $M = .55$, $SD = .03$, $p = .007$), and women rating boys ($n = 22$, $M = .60$, $SD = .02$, $p = .041$; see Figure 3.3). The

Tukey method was used to adjust p -values for multiple comparisons. No other pairwise differences were significant. Given the differences in sample size for each group, particularly less men participants, these results should be interpreted with caution.

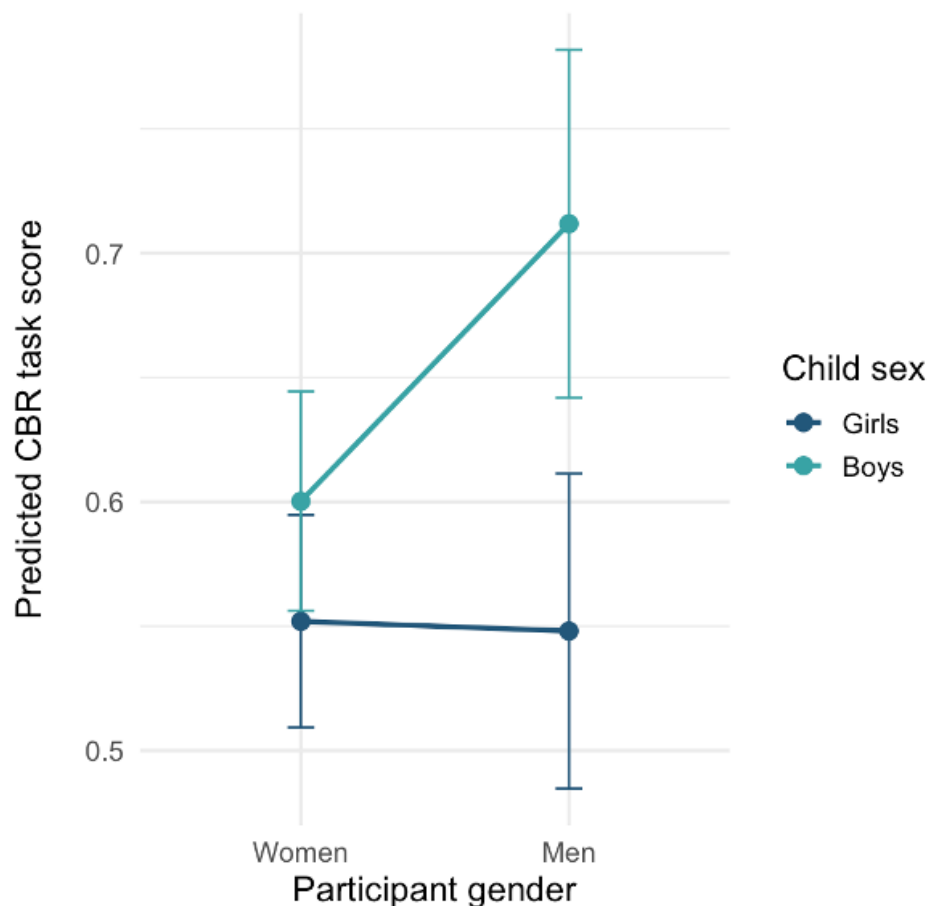


Figure 3.3. Predicted CBR task scores by participant gender and child sex. Estimated marginal means from the linear regression model are shown, with error bars representing 95% confidence intervals. The interaction between participant gender and child sex was significant, indicating that men rating boys performed significantly better than the other participant-child sex combinations.

Effect of stress. First, manipulation checks were made. A Friedman test showed a significant effect of condition on self-report stress ratings, $\chi^2(2, N = 62) = 93.78, p < .001$, with a large effect size (Kendall's $W = .76$). Follow-up Wilcoxon signed-rank tests with Bonferroni corrections indicated that stress ratings were significantly higher in the stress condition compared to both the neutral ($p < .001$) and baseline ($p < .001$) conditions. No significant difference was found between the baseline and neutral

conditions ($p = .140$). For objective heart rate measures, a repeated-measures ANOVA showed no significant effect of condition on average heart rate $F(2, 157) = 0.02, p = .980$.

Participant's performance in the CBR task did not differ between the neutral ($M = .60, SD = .12$) and stress ($M = .59, SD = .12$) conditions, as shown by a paired t -test ($t(61) = 0.13, p = .900$).

Confidence ratings. Participants' confidence ratings during the CBR task were analysed. No significant difference was found in average confidence between the neutral and stress conditions when including outliers ($V = 874.50, p = .477$) or when excluding outliers, $t(58) = 0.06, p = .952$. Overall average confidence was not correlated with task performance (excluding outliers: $r = .06, p = .641$; including outliers: $r = .08, p = .530$); however, confidence was significantly higher on correct compared with incorrect trials (excluding outliers: $t(60) = -5.18, p < .001$; including outliers: $V = 297, p < .001$). All patterns remained consistent regardless of outlier inclusion, indicating that extreme confidence ratings did not materially affect these findings. See table 3.4 for descriptive statistics in each group.

Table 3.4. Descriptive statistics for CBR task confidence ratings.

Condition/Group	Including outliers			Excluding outliers		
	<i>M</i>	<i>SD</i>	range	<i>M</i>	<i>SD</i>	range
Overall	5.64	1.19	1.77–8.71	5.61	0.98	3.46–8.08
Neutral	5.64	1.17	2.05–8.62	5.61	0.99	3.48–8.04
Stress	5.68	1.28	1.49–9.46	5.64	1.04	2.92–8.12
Correct trials	5.76	1.19	1.81–8.40	5.73	0.95	3.59–8.13
Incorrect trials	5.38	1.28	1.81–8.41	5.35	1.12	2.71–8.00

Cues and strategies. Participants provided qualitative information regarding the cues and strategies they used to perform the task. Their responses were explored and grouped, resulting in nine overarching categories: facial movements, body movement, facial expression or emotion, breathing, intuition, comparing videos, posture, comparing with own heart rate, and imagining child's thoughts. Table 3.5 presents the frequency of each category and sub-category. The frequencies indicate the number of

participants who reported using each cue; because some participants mentioned more than one strategy, the total frequency exceeds the number of participants. Fifty-eight participants provided a response and there was a total of 162 comments; the average number of cues reported by each participant was 2.79 ($SD = 1.15$, range = 1–5).

Table 3.5. Cues and strategies used by participants to complete CBR task.

Category	Frequency
Facial movements (total)	50
Mouth/lips/smile	25
Eyes/blinking	22
Nose	3
Body movement (total)	45
General	31
Neck/throat	7
Shoulder	3
Head	3
Chest	1
Facial expression or emotion	32
Breathing	18
Intuition	6
Comparing videos	4
Posture	1
Comparing with own heart rate	1
Imagining child's thoughts	1
No specific strategy	4

3.3.3 Relationships With Interoceptive Accuracy and Sensibility

The predictive value of interoceptive accuracy (alpha) for CBR task performance was examined using linear regression analyses. The initial model, with only alpha as a predictor, revealed a weak but statistically significant negative association ($F(1,55) = 4.65$, $p = .035$, Adj. $R^2 = .061$). Specifically, greater overestimation of the heart rate (higher alpha values) was associated with lower CBR performance ($\beta = -0.002$, 95% CI $[-0.004, -0.0002]$, $p = .035$). When gender and child sex were added as covariates, model fit improved ($F(3,53) = 4.49$, $p = .007$, Adj. $R^2 = .157$); however, the predictive effect of interoceptive accuracy was attenuated ($\beta = -0.002$, 95% CI $[-0.002, -0.001]$, $p = .091$). Nonlinear effects were not found ($F(1, 55) = 0.903$, $p = .339$, Adj. $R^2 = -.001$) and no effect was found using absolute alpha values ($F(1, 55) = 0.255$, $p = .616$, Adj. $R^2 = -.013$).

Regarding interoceptive precision (beta), the initial robust linear regression analysis including only beta as a predictor revealed a marginal negative association with CBR task performance, $b = -0.007$, $SE = 0.003$, $t(62) = -1.97$, $p = .053$ Adj. $R^2 = .054$. Specifically, higher beta scores (indicating lower precision) were associated with lower CBR task performance, CI [-0.013, -0.001]. When gender and child sex were added as covariates, model fit improved (Adj. $R^2 = .147$); however, the predictive effect of beta was no longer significant, $b = -0.004$, $SE = 0.004$, $t(59) = -1.02$, $p = .312$. A standard linear regression model excluding outliers showed similar results ($F(3, 51) = 4.79$, $p = .005$, Adj. $R^2 = .174$), with no significant effect for beta ($\beta = -0.004$, $p = .281$).

For interoceptive sensibility, partial correlations were carried out, including the dummy variables for gender and child sex to control for their effects. No significant associations were found between CBR task performance and the MAIA-2 overall score ($r = -.10$, $p = .425$) or any of its subscales (see Table 3.6).

Table 3.6. Correlations between CBR task performance and MAIA-2 subscales.

MAIA-2 subscale	<i>r</i>	<i>p</i>
Noticing	-.14	1
Not-distracting	-.28	.304
Not-worrying	.00	1
Attention Regulation	.07	1
Emotional Awareness	.26	.440
Self-regulation	-.24	.672
Body Listening	-.08	1
Trust	-.05	1

Note: p -values were adjusted using Bonferroni corrections.

Then, to examine whether the interaction between interoceptive accuracy and interoceptive sensibility predicted CBR task performance, a linear regression model was fitted. The model ($F(5, 48) = 1.03$, $p = .410$, Adj. $R^2 = .003$) showed no significant effects for accuracy ($\beta = -0.00$, $p = .730$), sensibility ($\beta = -0.03$, $p = .308$), or their interaction ($\beta = -0.00$, $p = .464$).

3.3.4 Relationships With Psychosocial Traits

To test the association between CBR task performance and psychosocial traits, partial correlations were carried out, including the dummy variables of gender and child sex to control for their effects.

Regarding emotion regulation, there was no association between CBR task performance and DERS-18 overall score ($r = .19, p = .143$). In terms of mental health symptoms, a significant positive association was found between CBR task performance and anxiety ($r = .43, p = .002$), as well as stress, both including ($r = .34, p = .019$) and excluding outliers ($r = .32, p = .039$). This suggests that higher anxiety and stress were related to better performance. No significant association was found between CBR task performance and depression, either including ($r = .29, p = .061$) or excluding ($r = .21, p = .326$) outliers. For attachment style, no association was found between CBR task performance and anxious attachment ($r = .18, p = .309$) or avoidant attachment style ($r = -.05, p = 1$).

3.3.5 Summary of Results

Performance in the CBR task was consistent across the children depicted in the stimuli for each participant, indicating no child-specific bias. No meaningful effect of demographic factors was found apart from an interaction between participant gender and child sex, which revealed that men rating boys were more accurate than any other combination. Overall, participants performed significantly above chance level, even after accounting for gender, child sex, difficulty and response bias. Confidence ratings were higher for correct trials, but overall confidence was unrelated to average performance and did not differ between the stress and neutral conditions. Participants reported using a variety of cues and strategies to complete the task, most often relying on facial and body movements, facial expressions, and breathing. In relation to individual interoceptive abilities, possible trends emerged for IA, with negative marginal effects of alpha and beta. However, no associations with IS or interaction effects of IA with IS were observed. Exploring other psychosocial traits, higher stress and anxiety symptoms were significantly correlated with higher CBR task performance. Emotion regulation, depression, and attachment styles were not related to performance.

3.4 Discussion

The main aim of the present chapter was to investigate adults' capacity to infer children's interoceptive states, referred to here as child-oriented interpersonal interoception. To this end, the newly developed Child Body Reading (CBR) task was employed to test whether participants could identify children's heart rates by watching videos of their faces. Assessing and understanding this ability is relevant to the broader question of how adults (e.g., parents, teachers, caregivers) support children's development of interoceptive and self-regulatory skills. A secondary aim was to explore the influence of individual interoceptive abilities, specifically interoceptive accuracy (IA) and interoceptive sensibility (IS), as well as psychosocial factors including emotion regulation, mental health symptoms, and attachment style, in order to identify possible traits associated with this ability.

The study showed that adults could identify children's cardiac signals with above-chance accuracy, even after controlling for the effects of participant gender, child sex, task difficulty, and response bias. This finding aligns with the few studies that have investigated interpersonal interoception in an adult-only paradigm (Arslanova et al., 2022; Galvez-Pol et al., 2022), suggesting that adults are not only able to infer the heart rate of other adults, but also of children. Furthermore, participant's average confidence was not correlated with average performance but was significantly higher following correct versus incorrect responses. This pattern replicates results from Arslanova et al. (2022) and indicates that while high performers were not necessarily more confident overall, participants had some metacognitive sensitivity of their ability (i.e., their confidence ratings could distinguish between correct and incorrect responses).

Given that the CBR task was newly developed, adapted from the other-HR task (Galvez-Pol et al., 2022), several aspects of its validity were examined. These included the use of new child video stimuli, task difficulty, and participants' response biases. An equivalence test showed that performance was consistent across the different children depicted for each participant, indicating no child-specific bias. In addition, average task difficulty did not influence average performance, suggesting that difficulty levels were balanced across participants.

Participants did not show a preference for left- or right-sided responses; however, they were more likely to choose the high-arousal video over the low-arousal one. Importantly, this bias did not significantly affect overall accuracy, as confirmed by analyses with both average performance scores and the bias-free discriminability measure (d') from Signal Detection Theory (SDT). d' was almost perfectly correlated with average performance, and the SDT response bias parameter (c) had no effect. One plausible explanation is that high-arousal states are more salient and capture attention more readily than neutral or resting states. This interpretation is consistent with developmental theories that emphasise the role of parents or caregivers in detecting and responding to children's altered physiological states in order to support regulation and homeostasis (Atzil & Barrett, 2017; Ciaunica & Crucianelli, 2019; Filippetti, 2021; Fotopoulou & Tsakiris, 2017). Infants, for instance, often display attention-grabbing behaviours such as crying when hungry, which direct caregivers' focus towards their needs (Fotopoulou & Tsakiris, 2017). Thus, it is possible that high-arousal states in the videos contained subtle or transient cues with similar attention-grabbing effects, without affecting accuracy. Collectively, the results discussed so far support the validity of the CBR task as an objective measure of child-oriented interpersonal interoception; nevertheless, future studies should also measure response biases based on arousal levels in the stimuli and control for this when necessary.

Furthermore, participants reported using a range of visual cues to complete the CBR task. The most frequently mentioned cues were facial movements (e.g., mouth, blinking, nostrils) and body movements (e.g., neck, shoulders, head, chest), followed by facial expressions or emotions and breathing. These reports align with Arslanova et al. (2022), who found that participants relied primarily on general movement, breathing, perceived state, and eye movement or blinking. Given that interoceptive signals are largely hidden (Arslanova et al., 2022; Ondobaka et al., 2017), it is plausible that individuals would look for perceptual cues, in this case visual, to infer others' interoceptive states such as heart rate. In fact, heartbeat activity has been shown to produce micro-movements of the head and eyes (Wu et al., 2012), which is consistent with some of the cues reported by participants. This suggests that participants can, to some extent, detect subtle and transient changes in appearance that accompany interoceptive variations. Therefore, the ability measured by this task

might be similar to other mentalising abilities, where people, for example, infer the emotions or mental states of others, even though these are not explicitly accessible.

Although these insights shed light on how participants approach the task and the visual cues they use, the precise mechanisms underlying the ability to infer others' interoceptive states remain unknown. Additional confounds, such as prior beliefs about children's heart rates, participants own physiological state, or other perceptual biases, might also play a role. Future studies should therefore consider methods to objectively assess these factors. For example, participants could be asked to estimate each child's resting heart rate, eye-tracking could be used to identify which visual cues are attended to, or additional visual perception tasks could be employed to clarify the role of perceptual processes.

Regarding the experimental manipulation, stress induction was only partially effective: it increased subjective distress but did not alter participants' cardiac states. This outcome contrasts with previous studies showing baby crying sounds to be effective in elevating adult's heart rates, both in parent and non-parent samples (Joosen et al., 2013; Out et al., 2010; Zeskind, 1987). One possible explanation is that participants may have quickly recovered from any short-term effects on their heart rate. Moreover, neither average performance nor average confidence differed between the stress and neutral conditions. Several possibilities could account for this, either the induced subjective distress was not strong enough, it was not particularly relevant for the non-parent sample (given that the manipulation consisted of baby-crying sounds), or it may require a physiological correlate, such as elevated heart rate, to have an effect. Evidence from other behavioural tasks of interoceptive accuracy indicates that stronger cardiac signals can facilitate performance (Jones & Hollandsworth, 1981; Schandry et al., 1993); however, this could not be tested in the present study given the absence of an induced aroused cardiac state. Future studies employing the CBR task should therefore consider alternative manipulations that target the physiological state more directly.

A secondary aim of this study was to examine possible factors underlying child-oriented interpersonal interoception. Overall, demographic characteristics did not significantly influence CBR task performance, apart from participant gender and child

sex. Specifically, men demonstrated higher accuracy than women when rating boys, but not when rating girls, whereas women had similar performance with both girls and boys. The interpretation of gender differences here is complex, particularly given the contradictory findings reported in previous research on interoception and mentalisation.

The existing literature on gender differences in interoception is mixed. Some studies suggest that men typically perform better on measures of cardiac interoceptive accuracy (Grabauskaitė et al., 2017; Prentice et al., 2022; Prentice & Murphy, 2022), whereas others report no gender differences (Haruki et al., 2025; Herbert et al., 2007). By contrast, research generally finds women to be more sensitive to others' emotional expressions (Hoffmann et al., 2010; Montagne et al., 2005; Thompson & Voyer, 2014), although exceptions exist (Fischer et al., 2018). As Prentice et al. (2022) point out, these findings are difficult to reconcile given the theoretical and empirical links between interoception and emotional processes. The authors propose that gender differences may reflect variation in the attribution of meaning to physiological changes. For instance, women may be more likely to interpret an elevated heart rate as emotionally meaningful (e.g., due to stress or anxiety) whereas men may be more likely to interpret as a neutral physiological reaction (e.g., due to caffeine intake).

In the present study, however, men were only more accurate than women when rating boys, but not girls. A possible explanation is that it might be easier for men to catch interoceptive cues from children of their own gender, as they might express these in similar ways. If this is true, it would mean that boys and girls display different cues or have different expressions of their interoceptive states. While there is no direct evidence of this, a meta-analysis by Chaplin and Aldao (2013) found that boys and girls differ in their facial, vocal, and behavioural expressions of externalising emotions (e.g., anger, disgust) and internalizing emotions (e.g., sadness, fear). Nevertheless, this difference did not seem to apply to women, perhaps because they are more generally attuned to emotional cues rather than physical, as suggested by Prentice et al. (2022). Future studies could test whether such a difference exists for interoceptive states and should explore these gender differences in larger and more balanced samples.

With respect to individual interoceptive abilities, marginal effects suggested tentative trends. Greater overestimation of the heart rate (higher alpha) and reduced precision (higher beta) in the Heart Rate Discrimination (HRD) task were marginally associated with poorer interpersonal interoception ability, as measured by CBR task performance. These findings are consistent with theoretical accounts proposing that sensitivity to one's own bodily signals facilitates the detection of bodily signals in others (Fotopoulou & Tsakiris, 2017; Steele et al., 2017), and with evidence linking IA to the processing of others' emotional states (see Chapter 1, Section 1.2). However, caution is warranted in interpreting HRD alpha scores. Because the most accurate scores are those approaching zero (with negative values indicating under-estimation and positive values over-estimation of the heart rate), the interpretation of a linear relationship is not straightforward.

In contrast, interoceptive sensibility, as measured by the MAIA-2, was not associated with CBR task performance. Although a relationship was expected based on research linking IS and to emotion recognition in others, previous findings also indicate that self-report and objective measures of interoception, even within the same modality, are not always correlated (Brewer et al., 2021; Murphy et al., 2019). Therefore, this finding indicates that participants' subjective beliefs about how they notice, pay attention to, regulate, and mentalise their own interoceptive signals and states are not necessarily related to their objective ability to infer children's interoceptive states. Furthermore, the significant interaction between IA and IS reported by Arslanova et al. (2022) was not replicated in this study. Notably, the measures used for IA and IS differed across studies: the present study employed the HRD task and the MAIA-2 for IA and IS respectively, whereas Arslanova et al. (2022) used the heart beat counting task and the Interoceptive Accuracy Scale (IAS).

Moreover, the lack of association between CBR task performance and emotion regulation skills diverges from the expectations. Emotion regulation processes have been linked to both interoception and mentalisation (see Chapter 1, Section 1.2; Bornemann & Singer, 2017; Schultheis et al., 2019; Sugawara et al., 2020), and interoceptive accuracy has been associated with more effective use of emotion regulation strategies (Füstös et al., 2012; Weiss et al., 2014). The absence of a similar finding in this study could suggest that trait-like emotion regulation skills are less

strongly related to interpersonal interoception than to individual interoception. Alternatively, the study may not have had sufficient power to detect an effect. Future work should explore this in larger samples and could employ behavioural and physiological measures of emotion regulation to provide more insight on this relationship.

Regarding mental health symptoms, higher anxiety and stress were associated with better performance on the CBR task. The relationship between interoception and mental health is complex. The present finding aligns with studies reporting heightened cardiac interoceptive accuracy in individuals with anxiety disorders (Domschke et al., 2010; Van der Does et al., 2000), but contrasts with evidence of reduced accuracy in similar populations (Bogaerts et al., 2006; De Pascalis et al., 1984; Ewing et al., 2017; Van Den Bergh et al., 2004). Several explanations have been proposed for why anxiety or stress might enhance cardiac interoceptive accuracy. For instance, cardiac signals may be more salient to individuals with anxiety disorders, or they may pay greater attention to them due to heightened preoccupation with internal states, a form of hypervigilance (Brewer et al., 2021; Khalsa et al., 2018). This interpretation could extend to interpersonal interoception, suggesting that anxiety and stress may increase attention not only to one's own cardiac signals but also to those of others.

Furthermore, as discussed, the ability assessed with the CBR task resembles mentalising capacities, in which individuals infer emotions or mental states of others. However, the present findings diverge from prior research, which generally shows that higher anxiety is linked to poorer mentalising abilities (Chevalier et al., 2023; Sloover et al., 2022). One possible explanation is methodological: different approaches or measures used may capture distinct dimensions of the broader construct, whether mentalisation or, in this case, interpersonal interoception. Indeed, a recent meta-analysis by Chevalier et al. (2023) found that while anxious individuals commonly exhibit impairments in recognizing and interpreting mental states, the effect size was larger when mentalisation was assessed via questionnaires and interviews, but absent when using experimental tasks such as the Reading the Mind in the Eyes Test. Therefore, it is plausible that subjective interpersonal interoception (assessed via questionnaires) would be impaired in individuals with anxiety, whereas performance on objective tasks may be preserved or even heightened, potentially reflecting

increased preoccupation or hypervigilance toward others' internal states. These findings seem to indicate that increased accuracy in inferring children's cardiac states might not be inherently adaptive or beneficial. It could be that the relationship between interpersonal interoception and mental health is not linear; the most adaptive outcome could lie between extremes of very high and very low accuracy.

In contrast, no associations were observed between CBR task performance and either depression or attachment style, despite previous research linking interoception with both variables (Eggart et al., 2019; Ferraro & Taylor, 2021; Oldroyd et al., 2019; Pollatos et al., 2009). Notably, much of the prior work on attachment style has been based on self-reported interoceptive sensibility and, as noted earlier, self-report and objective measures of interoception are not always correlated (Brewer et al., 2021; Murphy et al., 2019). It may also be that the CBR task taps a more perceptual or attentional process or may not have sufficiently engaged attachment-related processes. Future research could examine this by using stimuli with greater relational salience (e.g., familiar children) or by developing more interactive paradigms.

With respect to depression, interoceptive impairments in the cardiac domain are typically negative, that is, characterized by poorer accuracy, rather than the heightened accuracy sometimes observed in anxiety. The absence of such effects here might indicate that depressive symptoms primarily affect self-focused interoception and do not generalize to interpersonal interoception. Another possibility is that limited variability in symptom severity within this sample reduced the likelihood of detecting associations. Future studies should examine interpersonal interoception in clinical populations compared with healthy controls, ideally using both subjective and objective measures to capture its multidimensional nature.

Overall, the present chapter provides evidence that the CBR task is a valid tool for assessing child-oriented interpersonal interoception and demonstrates that adults can, to some extent, discriminate children's heart rates. This suggests that, although interoceptive signals are not directly observable, they can be inferred in ways comparable to how emotions and mental states of others are read. These findings extend previous work using the adult other-HR task to a child-oriented context and

establish a foundation for the following chapter, which will investigate interpersonal interoception in a parent-child sample (i.e., parental interoception).

Some of the findings relating to psychosocial factors were more difficult to interpret and did not fully align with initial expectations. The results suggest that adults' ability to infer children's interoceptive states may be influenced, at least to some degree, by individual interoceptive accuracy as well as by anxiety and stress symptoms. Although these effects were small and preliminary, they provide initial indications of traits that could either facilitate or constrain this ability and raise the possibility of a non-linear relationship with psychopathology. In particular, higher accuracy in inferring children's cardiac states may not be inherently adaptive; rather, both very high and very low accuracy could be maladaptive, with the most beneficial outcomes lying somewhere in between. Importantly, these findings highlight the need for replication in larger samples and further investigation in clinical populations.

Beyond validating the CBR task, the findings have broader implications for caregiving and educational contexts. Adults' sensitivity to children's interoceptive cues could, in some cases, help parents, teachers, and other caregivers detect children's physiological and emotional states, supporting timely regulation and fostering interoceptive development in diverse environments (e.g., at home or at school). However, the adaptive value of this ability remains unclear based on the current findings, and it may depend on its degree or context. In addition to studying clinical populations, future research could further explore differences across adults with varying levels of familiarity or experience with children, as well as across different caregiving settings.

Chapter 4: Objective and Subjective Parental Interoception – Relationships with Individual Interoception, Psychosocial Traits and Child Outcomes

4.1 Introduction

The previous chapter examined child-oriented interpersonal interoceptive ability in adults using a newly adapted paradigm, the Child Body Reading (CBR) task. Before this, Chapter 2 developed a self-report tool to assess subjective parental interoception, the Parental Interoception Questionnaire (PIQ). The present chapter builds on this work to assess interpersonal interoception in a parent sample (i.e., parental interoception). This is operationalised on two levels: 1) an objective dimension, captured through the CBR task, and 2) a subjective dimension, assessed both via the PIQ and participants' confidence ratings during the CBR task. These two levels correspond to the distinction between interoceptive sensitivity, or accuracy (IA) and interoceptive sensibility (IS), as defined in the individual interoception literature (see Chapter 1, Section 1.1.1).

Understanding how interoception (i.e., the processing of internal bodily signals) develops has become a key aim across developmental, psychological and neuroscientific fields. Interoception plays a fundamental role both in maintaining bodily homeostasis and in supporting emotional processes. With respect to homeostasis, which refers to the continuous process by which bodily systems sustain integrity and health, interoceptive signals inform the brain of the physiological state of the rest of the body, guiding homeostatic control (Craig, 2015; Fotopoulou & Tsakiris, 2017; Khalsa et al., 2018). Although debates remain on the precise scope of interoception (see Chapter 1, Section 1.1), most contemporary perspectives agree on a broad definition where interoception encompasses the processing, representations, and awareness of all bodily signals that serve homeostatic purposes (Brewer et al., 2021; Ceunen et al., 2016; Craig, 2002; Critchley & Garfinkel, 2017; Khalsa et al., 2018; Quadt et al., 2018).

Beyond its role in homeostasis, a substantial body of research demonstrates that interoception also plays a key role on emotional processes (see Chapter 1, Section

1.2). Briefly, neurobiological evidence, for example, indicates that interoceptive and emotional processes rely on overlapping neural substrates, such as the insula and anterior cingulate cortex (Barrett & Simmons, 2015; Craig, 2008; Critchley, 2005; Kleckner et al., 2017; Lindquist et al., 2016; Terasawa et al., 2013). Physiological and behavioural evidence further show that changes in heart rate, skin conductance, or vagal tone covary with fluctuations in emotional states (Asutay et al., 2021; Ekman et al., 1983; Schwartz et al., 1981), and that interoceptive ability influences the effectiveness of emotion regulation strategies such as cognitive reappraisal (Kever et al., 2015; Pollatos et al., 2015; Schuette et al., 2021). For instance, individuals with higher interoceptive accuracy show more effective downregulation of arousal and greater tolerance of negative affect (Füstös et al., 2012; Weiss et al., 2014). These findings highlight the importance of interoceptive processes for emotional functioning, further underlining the value of investigating how interoception develops in the parent-child context and what factors would contribute to healthy or impaired interoception and self-regulation abilities.

Theoretical propositions point to parent-child interactions as crucial in the development of interoception, considering infants' dependency on parents to maintain homeostasis (e.g., regulating their hunger, sleep, and body temperature). These theories argue that while infants can engage in some basic self-regulating behaviours, such as looking away from light or sucking on a dummy, they alone cannot change certain neurophysiological states to meet core bodily needs. In these cases, infants rely on their parents or caregivers to respond appropriately, for example, offering a bottle when hunger cues emerge, rocking them when they are distressed or tired, or covering them when cold. Over time, these interactions help the child understand interoceptive and perceptual cues in ways that support self-regulation (Atzil & Barrett, 2017; Ciaunica & Crucianelli, 2019; Filippetti, 2021; Fotopoulou & Tsakiris, 2017).

Direct empirical evidence supporting these propositions is currently lacking; however, existing evidence from related areas of child-parent interaction provides indirect support (see Chapter 1, Section 1.3). Briefly, research shows that parental behaviours such as affective touch, breastfeeding, rocking, and even non-proximal actions like praising and imitating can reduce child sympathetic activity and support parasympathetic functioning (Fairhurst et al., 2014; Graziano et al., 2012; Manzotti et

al., 2019; Van Puyvelde et al., 2019). Moreover, physiological and neurological synchrony, where parent and child bodily systems and neural activity co-vary during interactions (Feldman, 2007b; Nguyen et al., 2021), as well as maternal sensory predictability (Davis et al., 2019) have been linked to positive emotional and cognitive development, while synchrony disruption predicts difficulties such as school maladjustment and reduced empathy (Feldman, 2007a; Harrist et al., 1994).

Not only do parents influence their children's physiological states, but their capacity to perceive and respond to children's mental and emotional states is also fundamental for development. This parental ability has been widely investigated through constructs such as parental reflective functioning, maternal sensitivity, maternal mind-mindedness, and parental insightfulness. While they refer to specific parental capacities, all of these constructs emphasise the importance of treating the child as a psychological agent with independent thoughts and feelings (Medrea & Benga, 2021; Sharp & Fonagy, 2008). These parental qualities have been associated with children's secure attachment, language acquisition, socio-emotional skills, and behavioural adjustment (see Chapter 1, Section 1.3.2 for more details and specific references). More recently, the concept of parental embodied mentalising highlights the importance of interpreting children's mental states through their body movements, with longitudinal studies showing links to later attachment, language, and socio-emotional outcomes (Shai & Belsky, 2017; Shai et al., 2022; Shai & Meins, 2018). Also, Crucianelli et al. (2019) found that, during mother-infant interactions, mothers with poor mind-mindedness exhibited touch behaviours that were not contingent with their infants' emotions, suggesting that mind-mindedness can influence how parents regulate infants through touch. However, this work has yet to extend to parents' ability to read children's interoceptive states, such as bodily sensations of hunger or fatigue.

Importantly, previous research on parental mentalisation abilities (reviewed above and discussed in more detail in Chapter 1, Section 1.3.2) has primarily focused on the parent-child dyad, with limited attention to whether these qualities extend to, or differ in, interactions with unfamiliar children or other familiar but more distant children (e.g., nieces, nephews, family friends). Only a small number of studies have examined how relational familiarity or closeness influences mentalising capacities. For instance, Laurita et al. (2020) demonstrated that in young adults, neural activity within networks

associated with social cognitive processing was observed when participants made judgements about highly familiar others, such as romantic partners, but not for more distal individuals such as friends or acquaintances. Interestingly, this effect of closeness was not observed among older adults. Similarly, in a questionnaire study, Hill and McMahon (2016), found that the frequency of mothers' mind-minded comments was correlated when describing their child and partner, whereas this frequency was significantly lower in their descriptions of a famous person.

Further evidence comes from Szczypiński et al. (2020), who reported that adults with regular experience working with children (e.g., teachers, babysitters, sports instructors) performed significantly better than those without such experience on tasks assessing the recognition of children's mental states. Adults working with children also showed heightened neural activation in the posterior superior temporal sulcus (a region linked to mentalising) when interpreting children's cues compared to adult's cues. Collectively, these findings suggest that relational closeness or familiarity can influence mentalising abilities, though this potential bias has not been explicitly tested in parent-child relationships. Addressing this gap, the present study also examined whether parents' performance on the CBR task differed when assessing their own child versus other familiar or unfamiliar children. This approach allowed the investigation of a relational familiarity bias in parental interoceptive ability, as well as the disentangling of potential confounds arising from non-relevant familiarity (e.g. perceptual rather than relational familiarity).

As reviewed above, despite a wealth of concepts and findings on the role of parent-child interactions and parental capacity to read the child's mental states in the development of emotional regulation, there has been less attention in how such interactions relate to interoception. The present chapter addresses this gap by focusing specifically on parents' ability to identify and respond to their children's interoceptive states to provide initial evidence of a parental interoception ability, both subjective and objective, and its relation to individual interoception, psychosocial traits, and children's socioemotional outcomes.

The Present Study

The primary aim of this study was to investigate whether parents can objectively identify cardiac interoceptive signals in their own child and familiar or unfamiliar children using the CBR task described in the previous chapter. It was expected that parents would perform significantly above chance level overall, indicating an ability to detect children's cardiac signals and replicating findings from the previous chapter and from prior research on adult-only paradigms (Arslanova et al., 2022; Galvez-Pol et al., 2022).

In addition, the present study refined the manipulation of the CBR task "stress" condition. While the previous chapter found no differences in performance between the neutral and stress conditions, manipulation checks demonstrated that only subjective distress increased during the stress condition, while objective heart rate measurements did not. To address this, the stress manipulation was modified to induce a purely physiological arousal state designed to elicit higher heart rate (see Methods). This condition is referred to in this chapter as the arousal condition, rather than stress, with the aim to examine whether parents' ability to identify children's cardiac states is influenced by their own physiological state.

A secondary aim was to examine how subjective and objective parental interoceptive abilities relate to a) parent's individual interoception, b) relevant psychosocial factors such as emotion regulation, mental health symptoms, and attachment, and c) children's socioemotional functioning. Investigating these associations can provide insight into the factors that might shape parents' ability to infer children's interoceptive states, the effects on child outcomes, and directions for future research. Given the novelty of the task and the exploratory nature of the study, expectations were guided by findings from earlier chapters of this thesis as well as related areas of research, as reviewed in Chapter 1.

It was expected that parents' IA would be positively associated with CBR task performance, considering that i) the ability to detect bodily signals in others is theorised to be influenced by the sensibility to one's own bodily signals (Fotopoulou & Tsakiris, 2017; Steele et al., 2017), and ii) individual interoceptive abilities have been associated with emotion recognition in others (see Chapter 1, Section 1.2; Hübner et al., 2021). Additionally, Chapter 3 suggested a possible trend in which greater

overestimation of one's own heart rate was associated with lower CBR task scores. Regarding IS, no strong associations were expected with CBR task performance, in line with findings from Chapter 3 and previous research showing that self-report and objective measures of interoception are not always correlated (Brewer et al., 2021). Furthermore, Arslanova et al. (2022) reported no direct association between interpersonal interoception and either IA or IS, but rather an interaction between these dimensions. Although this finding was not replicated in Chapter 3, it was also tested in the present study.

Furthermore, greater difficulties in emotion regulation and increased mental health symptoms were tentatively expected to be associated with poorer task performance, considering evidence linking interoception and mentalising abilities to emotion regulation processes (see Chapter 1, Section 1.2; Bornemann & Singer, 2017; Schultheis et al., 2019; Sugawara et al., 2020). However, results from Chapter 3 suggested the opposite, with positive trends between CBR task performance and anxiety and stress symptoms.

Expectations regarding attachment style were also informed by mixed findings, with some studies linking both anxious and avoidant attachment to lower interoceptive ability (Ferraro & Taylor, 2021), while others report reduced interoception for avoidant attachment but increased interoception for anxious attachment (Oldroyd et al., 2019). Results from Chapter 2 and Chapter 3 of this thesis were also mixed, showing that only avoidant attachment was negatively related to self-reported parental interoception, while neither anxious nor avoidant attachment was associated with CBR task performance. Accordingly, these correlations were more exploratory, and no strong expectations were made.

Finally, a positive relationship was expected between CBR task performance and children's socioemotional functioning, as higher parental embodied mentalising and parental reflective functioning have been linked to lower internalizing and externalizing problems in children (Ghanbari et al., 2023; Shai & Belsky, 2017). This is also consistent with results from Chapter 2, in which subjective parental interoception predicted children's behavioural problems. However, this remained a tentative

hypothesis, given evidence that objective and subjective measures of interoception do not necessarily converge (Brewer et al., 2021; Murphy et al., 2019).

4.2 Methods

4.2.1 Participants

This study was part of a larger project that encompassed additional measures and analyses, including self-other distinction and metacognitive elements that are beyond the scope of the present thesis. For this study, participants were recruited through study advertisements directed at parents posted on digital and physical locations where potential participants were likely to be found, such as Facebook groups for parents, the UCL Parents and Carers Together (PACT) network, family university days, local libraries and local parent forums and associations. Additionally, as part of the recruitment efforts, two public events were organised at a local school where children and parents took place in the experiment.

All participants received a full information sheet. Parents confirmed their own and their children's eligibility and provided informed written consent for both. Children were given an age-appropriate information sheet, which was also explained verbally, and provided verbal consent (witnessed and recorded by the experimenter) as well as written consent by writing their name in an age-appropriate form. All participants were compensated according to the rate stipulated by the PALS Division at UCL. Ethics Approval was obtained from the UCL Research Ethics Committee (Project number 22457/002).

The inclusion and exclusion criteria were the same as in Chapter 3 (see Section 3.2.1 *Participants*), with the addition of being a parent of a child 5–11 years old for inclusion. Inclusion criteria for children were being 5–11 years old and understanding English language, and exclusion criteria included any moderate to severe cognitive impairment or severe mental health condition (e.g., psychosis), existing severe neurological condition (e.g., epilepsy), existing diagnosis of heart-disease, or having low vision/hearing that cannot be corrected. An a priori power analysis for the own child versus unfamiliar child comparison, assuming a medium effect size, indicated that 51

participants would be required to achieve 80% power at $\alpha = .05$. To account for potential exclusions, a slightly larger sample was recruited.

The sample consisted of 57 parent-child dyads. Parents predominantly identified as women (80%), with a mean age of 42.77 years ($SD = 6.76$, range = 29–58). The majority (58%) identified as White, including 28% English, Welsh, Scottish, Northern Irish or British, and 30% from other White backgrounds. A further 16% identified as Black, including 7% African, 7% Caribbean, and 2% from other Black backgrounds. Parents of Asian ethnicity made up 9% of the sample (3% Indian, 2% Chinese, 2% Bangladeshi, and 2% from other Asian backgrounds). Additionally, 10% identified as of mixed ethnicity, and 7% as belonging to other ethnic groups, including one Latin and one Turkish participant.

In terms of education, over half of the parents (53%) had completed a postgraduate degree, 40% an undergraduate degree or equivalent, and 7% reported secondary education or other vocational qualifications. Moreover, 39% were employed full-time, 30% were self-employed, 16% were employed part-time and 10% were not currently working or on parental leave. Most parents (79%) were in a relationship, and the majority (84%) reported a two-parent, different-sex family structure; the remainder (16%) were single parents. Demographic characteristics for parents are summarised in Table 4.1.

Table 4.1. Demographic information for parent sample.

Parameter	Parents (N = 57)
Age ^a	42.77 (6.76)
Gender (%)	
Female	80.36
Male	19.64
Ethnicity (%)	
White English, Welsh, Scottish, Northern Irish or British	28.07
Any other White background	29.82
Black, African, or Caribbean	14.04
Any other Black background	1.75
Mixed	10.53
Asian Indian, Chinese, or Bangladeshi	7.02
Any other Asian background	1.75

Latin	1.75
Turkish	1.75
Unknown	3.51
BMI ^a	24.40 (4.50)
BMI Category (%)	
Normal weight	55.10
Overweight	26.53
Obese	12.24
Underweight	6.12
Education level (%)	
Postgraduate degree	52.63
Undergraduate degree or equivalent	40.35
Secondary education	3.51
Other vocational qualifications	3.51
Employment (%)	
Employed full-time	38.60
Self-employed	29.82
Employed part-time	15.79
Not working/Parental leave	10.53
Unknown	5.26
Annual household income (%)	
<£20,000	7.02
£20,000 - £39,999	10.53
£40,000 - £59,999	14.03
£60,000 - £99,999	8.77
>£100,000	36.84
Unknown	22.81
Relationship status (%)	
In a relationship	78.95
Single	21.05
Relationship duration (%)	
More than a year	97.83
Unknown	2.17
Relationship satisfaction (0-10) ^a	8.10 (1.95)
Family structure (%)	
Two-parent different sex	83.93
Single parent	16.07
Number of children	
1	28.07
2	42.11
3	28.07
4	1.75

^a Mean (SD)

The child sample included 35 boys (61%) and 22 girls (39%), with a mean age of 8.07 years ($SD = 1.89$, range 5–11). Most children (52%) were of White ethnicity, with 26% being English, Welsh, Scottish, Northern Irish or British, and 26% from other White

backgrounds. A further 15% were of Black ethnicity (7% African, 3% Caribbean, and 5% other Black backgrounds) and 8% were of Asian ethnicity (4% Indian, 2% Chinese, and 2% Bangladeshi). Nearly one-fifth (18%) were of mixed ethnicity, and 7% belonged to other ethnic groups, including one Latin and one Turkish child.

4.2.2 Design

The study used a within-subjects experimental design to investigate parental interoception. The Child Body Reading (CBR) task, presented in the previous chapter, was used as a primary measure for parents' ability to identify children's heart rate, with two within-subject factors: stimulus type (own child vs. unfamiliar child) and condition (neutral vs. arousal). For a subset of the sample ($N = 10$), additional to the own and unfamiliar children, a familiar child stimulus type was used (e.g., friend or classmate). Although it was not practically possible to test this additional control condition with all parents, testing an additional child in a subset of parents allowed the examination of potential confounds of non-relevant familiarity (e.g. perceptual as opposed to relational familiarity). Performance on this task was taken as a proxy measure for objective parental interoception, while the Parental Interoception Questionnaire (PIQ; developed in Chapter 2) assessed self-reported parental interoception. In addition, parents' confidence ratings during the CBR task provided a further state-like indicator of self-reported parental interoception. As mentioned, these two levels of interoception correspond to the distinction between interoceptive accuracy (IA) and interoceptive sensibility (IS), as defined in the individual interoceptive literature (see Chapter 1, Section 1.1.1).

Regarding individual interoception, parents completed the Heart Rate Discrimination (HRD) task (Legrand et al., 2022) as a measure of objective interoceptive ability (IA) and the Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2; Mehling, Acree, et al., 2018) for subjective interoception (IS). Additionally, psychosocial traits were measured using validated psychometric questionnaires (see *Materials*), and their relationships with parents' objective and subjective parental interoception were examined.

Data was also collected on child outcomes, specifically, children's behavioural problems and emotion regulation, via parental questionnaires. The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) was used to measure socioemotional functioning and the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997) assessed emotion regulation abilities. These measures were used to explore whether parental interoceptive accuracy or sensibility (CBR task and PIQ and scores) predicted child outcomes. See Table 4.2 for the operationalization of variables measured in this study.

Table 4.2. Operationalization of variables.

	Variable	Operationalization
Primary outcome	Objective parental interoception	CBR task performance
Predictors	Subjective parental interoception	PIQ scores and CBR task confidence ratings
	Individual interoception Accuracy	HRD task performance
	Sensibility	MAIA-2 scores
	Psychosocial traits	Scores on validated psychometric questionnaires (see <i>Materials</i>)
Secondary outcomes	Child behavioural problems	SDQ scores
	Child emotion regulation	ERC scores

Note: see *Data Analysis* section for further details.

4.2.3 Procedures and Materials

Parents who expressed interest in participating were invited to complete an online screening survey hosted on UCL Qualtrics. Those who met the eligibility criteria were provided with an online copy of the participant information sheet and redirected to book two in-person sessions, scheduled at least one week apart. Prior to the first session, parents received a link to complete an online survey (via UCL Qualtrics) that included sociodemographic questions and a series of psychometric measures (see *Materials* below).

During the first in-person session, children participated in the recording procedure as described in Chapter 3, Section 3.2.3 (see Figure 3.2), while parents completed the

HRD task in a separate room. Participants were given the option to complete their tasks sequentially if either the child or the parent preferred not to be separated. For school-based events, the first session took place at the school site. In these cases, parents did not participate, and children completed the recording procedure in turns, along with additional group activities involving psychoeducational materials. Before the second session, the child's ECG and video recordings were processed following the procedure outlined in Chapter 3, Section 3.2.3 (see *Processing ECG and video recordings*), to obtain the videos used as stimuli for the CBR task. Finally, the second session was attended only by parents, who completed the CBR task. In the case of school-based events, parents were given the option to complete this second session either at the school or in the laboratory, and they completed both the CBR and the HRD tasks during this session.

Child Body Reading (CBR) task. The task is described in Chapter 3, Section 3.2.3 (see Figure 3.1) and was used to measure objective parental interoceptive ability. Briefly, it is a two-alternative forced choice (2AFC) task in which each trial presents two videos of a child accompanied by visual cardiac feedback. Participants must identify the video corresponding to the displayed heart rate and then rate their confidence on their choice on a scale of 0 ("Not at all certain") to 10 ("Absolutely certain"). The task comprises 96 trials, divided into a "neutral" and an "arousal" block. For this study, two modifications were made, one to the stimulus type and one to the manipulation for the "arousal" (previously "stress") condition. For the stimulus type modification, parents rated their own and an unfamiliar child, rather than two unfamiliar children. Additionally, a subset of parents ($N = 10$) completed a supplementary block with a familiar and an unfamiliar child. This block was counterbalanced either at the beginning or end of the regular procedure and was always a "neutral" block.

For the manipulation modification, given that baby crying sounds did not increase participants heart rate in the previous study, the manipulation for the "arousal" condition was changed to represent a physiological arousal condition elicited by physical exercises. The exercises included jogging on the spot, jumping jacks, and stomping the feet with the arms straight up while sitting, and they were performed for one minute at a time. Parents were given the option to change to another exercise if they could not or did not want to complete any one of the options, and they were

encouraged to tell the experimenter if they needed to stop before the full minute was over. Instead of rating their distress, as with the baby crying sounds manipulation, participants rated their arousal level (based on heart rate).

Heart Rate Discrimination (HRD) task (Legrand et al., 2022). This task was used as described in Chapter 3, Section 3.2.3, to measure parents' cardiac interoceptive ability. Briefly, it is a 2-Interval Forced Choice design (2-IFC) using Bayesian modelling to estimate two parameters: alpha (α), the bias between perceived and actual heart rate, and beta (β), the precision of this estimate. Participants compare their heart rate to tone sequences following a 5-second focus period. Tone frequency is adjusted via an adaptive staircase procedure. The task is available at: <https://github.com/embodied-computation-group/Cardioception>.

Self-report measures for parent traits. Validated self-report questionnaires presented below were used to explore relationships between parental interoception (as measured by the CBR task) and parents' interoceptive sensibility and psychosocial traits.

1) Interoceptive sensibility. The Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2; Mehling, Acree, et al., 2018). This is a 32-item questionnaire comprising eight subscales: *Noticing* ($\alpha = 0.84$), *Not-Distracting* ($\alpha = 0.90$), *Not-Worrying* ($\alpha = 0.65$), *Attention Regulation* ($\alpha = 0.90$), *Emotional Awareness* ($\alpha = 0.92$), *Self-Regulation* ($\alpha = 0.87$), *Body Listening* ($\alpha = 0.92$), and *Trust* ($\alpha = 0.90$). Cronbach's alpha for the overall score was 0.92. Participants rate each item according to how often it applies to them generally in daily life, on a scale from 0 ("Never") to 5 ("Always"). More details described in Chapter 2, Section 2.5.1.

2) Subjective parental interoception. The Parental Interoception Questionnaire (PIQ), developed in Chapter 2, consisting of 24 items and five subscales: *Attention* ($\alpha = 0.82$), *Epistemic Attitudes* ($\alpha = 0.83$), *Trust and Self-Efficacy* ($\alpha = 0.65$), *Regulation* ($\alpha = 0.65$), and *Linking* ($\alpha = 0.60$). Cronbach's alpha for the overall score was 0.90. Parents rate each item according to how much they agree that it applies to them generally in daily life, on a scale from 1 ("Strongly disagree") to 5 ("Strongly agree").

3) *Emotion regulation.* The Difficulties in Emotion Regulation Scale, Brief Version (DERS-18; Victor & Klonsky, 2016). This is a validated 18-item brief version of the original Difficulties in Emotion Regulation scale by Gratz and Romer (Gratz & Roemer, 2004), which assesses emotion dysregulation with six subscales: *Awareness* ($\alpha = 0.82$), *Clarity* ($\alpha = 0.69$), *Goals* ($\alpha = 0.84$), *Impulse* ($\alpha = 0.88$), *Nonacceptance* ($\alpha = 0.66$), and *Strategies* ($\alpha = 0.79$). Cronbach's alpha for the overall score was 0.87. Participants rate each item on a scale from 1 ("Almost never") to 5 ("Almost always"). More details described in Chapter 2, Section 2.5.1.

4) *Mental health symptoms.* The Depression, Anxiety, Stress Scale (DASS-21; Lovibond & Lovibond, 1995) was used to measure parents' mental health symptoms. This is a shortened 21-item version of the original 42-item DASS and measures the severity of the symptoms for each subscale over the past week: *Depression* ($\alpha = 0.82$), *Anxiety* ($\alpha = 0.77$), and *Stress* ($\alpha = 0.86$). Participants rate each item on a scale from 0 ("Did not apply to me at all") to 3 ("Applied to me very much, or most of the time"). More details described in Chapter 2, Section 2.5.1.

5) *Attachment style.* The Experiences in Close Relationships, Revised Questionnaire (ECR-R; Fraley et al., 2000) was used to measure parents' attachment style. This is a 36-item self-report measure comprised of two subscales: *Avoidance* ($\alpha = 0.94$), the individual's discomfort with intimacy; and *Anxiety* ($\alpha = 0.93$), the individual's tendency to fear rejection and abandonment. Participants rate each item according to how they generally experience relationships, on a scale from 1 ("Strongly disagree") to 7 ("Strongly agree"). More details described in Chapter 2, Section 2.5.1.

Self-report measures for child traits. Validated questionnaires completed by parents were used to explore relationships between parental interoception (as measured by the CBR task) and child traits.

1) *Emotion regulation.* The Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997). This is a 24-item measure of children's ability to manage and cope with emotions, rated by parents, teachers, or caregivers (i.e., adults that are very familiar with the child). The scale comprises two subscales: *Emotion Regulation* ($\alpha = 0.61$), which reflects processes central to adaptive regulation, including expression,

self-awareness, and contextual appropriateness (e.g., “Is a cheerful child”, “Can say when she feels sad, angry or mad, fearful or afraid”); and *Emotional Lability or Negativity* ($\alpha = 0.79$), which includes lack of flexibility, angry reactivity, intensity, and mood swings (e.g., “Exhibits wide mood swings...”, “Responds angrily to limit-setting by adults”). Parents rated each item on a 4-point Likert scale according to how often the child exhibits each behaviour or emotional state, from 1 (“Rarely or Never”) to 4 (“Almost Always”).

2) Socioemotional functioning. The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). This is a 25-item parent-rated measure evaluating psychological adjustment of children and young people by asking about different behaviours. Items can be categorised into *Externalizing Behaviours* ($\alpha = 0.80$), *Internalizing Behaviours* ($\alpha = 0.72$), and *Prosocial Behaviour* ($\alpha = 0.75$). Participants rate each item with 0 (“Not true at all”), 1 (“Somewhat true”), or 2 (“Certainly true”). More details described in Chapter 2, Section 2.5.1.

4.2.4 Data Analysis

R 3.6.3 for Mac OS X was used for data analysis. In all cases, descriptive statistics were inspected, outliers were identified using Tukey’s method ($1.5 \times \text{IQR}$ rule) as implemented in the *boxplot.stats()* function in R. As previously recommended (Aguinis et al., 2013; André, 2022; Karch, 2023), outliers were removed only when they reflected data errors. In all other cases, robust analytical approaches were applied or, when appropriate, sensitivity analyses were conducted to assess their impact on the findings (specified in each case below). Moreover, normality was tested both by visual inspection of histograms and Q-Q plots, and the Shapiro-Wilk test; non-parametric tests were used if needed. In the case of linear regression models, the package *lme4* was used, alongside the *tab_model* function from the *sjPlot* package to summarise results in R. Assumptions of linearity, normality of residuals, and homoscedasticity were checked, and no visible violations were found in any model.

CBR task performance. Participants’ average performance was calculated as the percentage of correct responses. No outliers were identified for performance on the CBR task, and the distribution was only slightly positively skewed. First, the effects

of demographic variables were examined to assess the need for control variables in subsequent analyses. Then, participants' average performance was tested against 0.5 with a one-sample *t*-test. An additional measure of performance was calculated using signal detection theory (SDT) to obtain a bias-free discriminability score, *d*'-prime (*d*'), and a choice bias score (*c*). Since *d*-prime was almost perfectly correlated with participant's average performance ($r = .98, p < .001$), it was not used in further analysis, as they would be redundant. Additional psychometric and qualitative components were also examined, including difficulty level, response bias, and participant reports on the cues or strategies used to perform the task.

As in the previous chapter, the difference in beat counts between both videos in each trial was calculated and used as an index for difficulty, the higher the beat difference, the easier the trial. To test the effect of difficulty, the mean of the beat differences for all trials was calculated for each participant. A simple linear regression was then conducted, including CBR task performance as the outcome variable, centered around 0.5 for interpretability, and the mean-centered average beat difference score as the predictor.

Response bias was tested using exact binomial tests, both for the tendency to choose left or right, and the propensity to select the high-arousal versus the low-arousal video. Additionally, a one-sample *t*-test against zero was conducted to determine whether the SDT response bias estimate (*c*) differed from zero. A simple linear regression was then used to examine the effect of *c* on CBR task performance, with performance scores centered around 0.5 for interpretability.

Afterward, the effects of stimuli type (own vs. unfamiliar child) and experimental condition (neutral vs. arousal) were tested. Nine of the 57 participants had completed the previous version of the stress manipulation (involving baby crying sounds rather than physical exercises) and were therefore excluded from these analyses. Before the main analyses, manipulation checks were conducted both for self-report arousal ratings and objective heart rate measurement. The two arousal ratings in each condition were averaged and compared with the baseline rating. Two outliers were identified in the neutral condition scoring 7 on a 1–7 scale, and one in the arousal condition, scoring 3.5; however, while above and below the group average

respectively, these values were still considered plausible and were not excluded. Moreover, the distributions for all conditions were visibly skewed, requiring the use of non-parametric tests. A Friedman rank sum test was conducted to compare the ratings in each condition, using Wilcoxon signed rank test for pairwise comparisons and Kendall's W for effect size estimation.

For heart rate measurements, the average heart rate during each block was computed and compared against a baseline measurement, which was calculated as the average in the 10 minutes before starting the experiment. Seven outliers were identified across all conditions. For two participants, the values fell outside typical physiological ranges (i.e., below 40 bpm), suggesting there likely were measurement or technical errors. Given their implausibility, these values were excluded from the analyses. Distribution was normal in all conditions, only slightly skewed at baseline, therefore, parametric tests were considered robust enough. An ANOVA test was conducted to compare the heart rate average in each condition, using paired t -tests for pairwise comparisons and Partial eta squared (η^2_p) as effect size estimation.

Descriptive statistics for CBR task performance were examined for each group. No outliers were found in either the neutral or arousal, nor the own child or unfamiliar child conditions. All distributions were close to normal with very slight skewness, accordingly, parametric testing was performed. To examine the effects of stimuli type (own vs. unfamiliar child) and experimental condition (neutral vs. arousal) on performance, two paired t -tests were conducted. Then, a generalized linear mixed-effects model with binomial error distribution was used to explore if there was an interaction effect. Trial-level performance accuracy (Correctness: 0 = incorrect, 1 = correct) was included as the dependent variable. Experimental condition and stimuli type were included as fixed effects along with their interaction, while mean centered difficulty level was included as a covariate. To account for repeated-measures participant ID was included as a random intercept.

Additionally, to examine potential confounds of non-relevant familiarity (e.g., perceptual as opposed to relational familiarity), a Wilcoxon signed-rank test was conducted in a subset of participants ($N = 10$), comparing parents' CBR task performance with a familiar versus an unfamiliar child. Given the very small sample

size of this subset, the findings should be regarded as exploratory, providing only tentative indications of a possible pattern rather than firm evidence. For this reason, this condition was not included in more complex analyses.

To examine state-like self-reported parental interoception, the average confidence rating for each participant was calculated overall and for each condition. Eight outliers were identified across conditions with values either above 9 or below 2.40 (on a 0–10 scale). Because the experiment randomly allocated the cursor to values between 3 and 7 on each trial, these averages suggest that participants intentionally moved the cursor to the extremes, likely reflecting genuine over- or under-confidence rather than measurement error. Therefore, sensitivity analyses are presented both with and without outliers. Notably, given that the subset of parents that completed the familiar child condition included only 10 parents, no participants were excluded in this condition, and results from this subset should be considered exploratory. Differences between own-child versus unfamiliar-child, as well as neutral versus arousal conditions were assessed with one-sample *t*-tests when outliers were excluded, and Wilcoxon signed-rank tests when they were included. A Pearson correlation between average confidence overall and average performance was conducted without outliers, whereas a percentage bend correlation was used when outliers were included. Finally, differences in confidence between correct and incorrect trials were also explored to investigate alignment with objective performance, using a one-sample *t*-test when excluding outliers and a Wilcoxon signed-rank test when including them.

Lastly, parents' reports on the cues and strategies used to perform the task were analysed qualitatively. The specific questions asked were *"Could you tell us which cues from the videos did you use to perform this task?"* and *"Did you use a strategy to choose your answer? If so, please explain"*. Responses were explored and categorised into themes using an inductive approach, allowing patterns to emerge from the data rather than imposing a priori categories.

Relationships with interoceptive accuracy and sensibility. Relationships between CBR task performance and interoceptive accuracy (indexed by alpha), interoceptive sensibility (as measured by the MAIA-2), and subjective parental interoception (as measured by the PIQ) were explored next. Two outliers were

identified in the alpha variable with values of -35.6 and -34.3. The overall sample range for alpha was -35.55–15.75, consistent with previous research (Jeganathan et al., 2025; Legrand et al., 2022). Due to the design of the HRD task, alpha values have fixed lower and upper limits (-40, 40). As the outliers are close to the lower bound, they may reflect a limitation of the task itself. Nevertheless, further inspection was made to determine whether these values represented measurement or technical error, or whether the participants showed additional abnormal patterns. Although both participants reported moderate to extremely severe levels of anxiety and stress on the DASS-21, their scores on the exteroceptive condition of the HRD task, average performance on the CBR task, and responses on other questionnaires showed no extreme or abnormal patterns. As such, results both excluding and including the outliers are presented. When including outliers, robust statistical methods were employed to account for their potential influence. Regarding the MAIA-2 and PIQ overall scores, no outliers were identified and both variables demonstrated normal distributions.

Correlations between variables were first examined using Pearson's method, and for correlations involving alpha, percentage bend correlations were also computed when including the outliers, using the *pbcor* function from the *WRS2* package in R. This robust method provides a more reliable estimate of the correlation in the presence of extreme values (Wilcox, 2011). Furthermore, given that alpha contained negative and positive values, additional analyses using the absolute alpha values were conducted to explore whether bias in general, regardless of direction, was associated with CBR task performance. A correlation between MAIA-2 and PIQ scores was also conducted, to investigate the relationship between individual and parental interoception in the subjective dimension.

Next, to examine if there was an interaction effect between objective and subjective interoception, as in Arslanova et al. (2022), a linear regression model was fitted including interoceptive accuracy (alpha), interoceptive sensibility (MAIA-2 overall score), and their interaction term as predictors of parental interoception (average CBR task performance). Response bias (*c*) and mean centered average difficulty were included as covariates. When including the outliers from the alpha variable, a robust linear regression model was fitted using the *lmrob* function from

the *robustbase* package in R, which applies MM-estimation. This method combines a high breakdown point with high statistical efficiency, down-weighting the influence of extreme values rather than excluding them (Wilcox, 2011).

Relationships with psychosocial variables. Relationships between CBR task performance, and psychosocial variables were explored. Regarding emotion regulation, no outliers were found for DERS-18 overall score, and the distribution was approximately normal, with very slight positive skewness. Accordingly, a Pearson's correlation analysis was conducted between performance and DERS-18 overall score. For mental health symptoms, seven outliers were identified in the *Anxiety* subscale and four in the *Depression* subscale, with values between the moderate and extremely severe levels. Given that these scores are frequently present even among the general population, results both excluding and including the outliers are presented and robust statistical methods were used when including them to account for their potential influence. Additionally, these subscales presented a left-skewed distribution upon visual inspection, confirmed by the Shapiro-Wilk test (*Anxiety*: $W = 0.788$, $p < 0.001$; *Depression*: $W = 0.820$, $p < .001$). Consequently, both Spearman and percentage bend correlations were conducted for the *Anxiety* and *Depression* subscales and Pearson's correlation for the *Stress* subscale.

For attachment style, one outlier was found for each of the ECR-R subscales, *Avoidant* and *Anxious* attachment, with mean values above six on a 1–7 Likert scale. Again, as these values are realistically plausible, results both excluding (using Pearson's correlation) and including the outliers (using percentage bend correlations) are presented. Distributions for these variables were also positively skewed (*Anxious*: $W = 0.902$, $p < 0.001$; *Avoidant*: $W = 0.953$, $p = .034$). Finally, to test whether subjective parental interoception was related to these psychosocial variables, replicating results from Chapter 2, the same correlations were tested with the PIQ overall score.

Effects of parental interoception on child outcomes. To investigate if parental interoception could predict child emotion regulation and socioemotional functioning, linear regression models were fitted with CBR task performance as the main predictor. The first child outcome was emotion regulation (as measured by the ERC). No outliers were identified for the *Emotion Regulation* subscale, and the distribution was

approximately normal. For the *Emotional Lability* subscale, one outlier was identified with a value of 42 (the possible range for this subscale is 15–60), and the distribution had a very slight positive skew. While the outlier was a higher value than the rest of the sample, it was considered plausible, and no other aberrant scores were identified for this participant.

Two simple linear regression models were fitted with mean centered CBR task performance as predictor for a) the *Emotion Regulation* score, and b) the *Emotional Lability* score. For *Emotional Lability* a robust linear regression model with MM-estimation was also fitted when including the outlier. Afterwards, predictive value of parental interoception on child behavioural problems was tested using the SDQ subscales. No outliers were identified in any of the subscales; however, their distributions did present a positive skew for *Internalizing* ($W = 0.912, p < 0.001$) and *Externalizing* ($W = 0.950, p = .030$) behaviours, and a negative skew for *Prosocial Behaviour* ($W = 0.898, p < 0.001$). Simple linear regression models were fitted with mean centered CBR task performance as predictor for each SDQ subscale. Finally, to test whether subjective parental interoception was related to these child outcomes, replicating results from Chapter 2, the same linear regression models were tested with the PIQ overall score as predictor.

4.3 Results

4.3.1 CBR Task Performance

Effects of demographic variables. Most relationships between performance on the CBR task and demographic variables were very small and not statistically significant. Regarding gender, women ($n = 45, M = .60, SD = .10$) and men ($n = 11, M = .58, SD = .10$) performed similarly, as indicated by a Wilcoxon rank-sum test ($W = 262.5, p = .765$). Likewise, a t -test showed no significant difference in average performance when the stimuli depicted girls ($n = 22, M = .58, SD = .10$) versus boys ($n = 35, M = .60, SD = .10$), $t(47.08) = -0.47, p = .641$. There was no significant correlation between average performance and BMI ($r = -.12, p = .409$), nor between performance and child age ($r = .14, p = .254$). Additionally, average performance did not differ significantly by parent ethnicity ($\chi^2(6) = 7.30, p = .294$), child ethnicity ($\chi^2(6)$

= 5.70, $p = .457$), or parental education level ($\chi^2(3) = 1.97$, $p = .578$), as indicated by Kruskal-Wallis tests.

Effect of difficulty level. A simple linear regression examining the relationship between each participant's average difficulty and their average performance showed a marginal effect ($\beta = 0.03$, 95% CI [-0.01, 0.05], $p = .053$, Adj. $R^2 = .049$). Consequently, difficulty level was added as a covariate in any further linear regression models involving CBR task performance.

Response biases. An exact binomial test showed there was significant response bias with participants choosing the right-side option 52.4% of the time (95% CI [.5102, .5370], $n = 5424$, $p = .001$). An additional binomial test showed there was also significant response bias towards the high arousal video, with participants choosing this option 60% of the time (95% CI [.5877, .6139], $n = 5424$, $p < .001$). Also, the SDT estimate for response bias (c) was significantly different from 0 ($t(56) = -4.82$, $p < .001$); however, it had no significant effect on participants' average performance ($\beta = -0.01$, 95% CI [-0.07, -0.04], $p = .618$, Adj. $R^2 = -.014$).

Performance against chance level. Participants average performance was .59 ($SD = .10$), with scores ranging from .42 to .85. This was significantly above chance level, as shown by a one-sample t -test against 0.5 ($t(56) = 6.81$, $p < .001$, $d = 0.90$). The significant result remained even after controlling for difficulty with a linear regression model ($F(1,55) = 3.91$, $p = .053$, Adj. $R^2 = .049$), which showed that, overall, participants performed significantly above chance ($\beta = 0.09$, 95% CI [0.07, 0.12], $p < .001$), and difficulty had a marginal effect ($\beta = 0.03$, 95% CI [-0.01, 0.05], $p = .053$).

Effects of arousal and stimuli type (own vs. unfamiliar child). First, manipulation checks were made. A Friedman test showed a significant effect of condition on self-reported arousal ratings, $\chi^2(2, N = 48) = 64.17$, $p < .001$, with a large effect size (Kendall's $W = .67$). Follow-up Wilcoxon signed-rank tests with Bonferroni corrections indicated that arousal ratings were significantly higher in the arousal condition compared to both the neutral ($p < .001$) and baseline ($p < .001$) conditions. No significant difference was found between the baseline and neutral conditions ($p = 1$). For objective heart rate measures, a repeated-measures ANOVA revealed a

significant effect of condition on average heart rate, $F(2, 84) = 30.77$, $p < .001$, with a large effect size ($\eta^2_p = .42$, 95% CI [.29, 1.00]). Post hoc paired-samples t -tests with Bonferroni corrections indicated that average heart rate was higher in the arousal condition compared to both the neutral ($p < .001$) and baseline ($p < .001$) conditions. The difference between the baseline and neutral conditions was marginally significant ($p = .057$).

Participant's performance in the CBR task did not differ between the neutral ($M = .59$, $SD = .12$, range = .38–.88) and arousal ($M = .59$, $SD = .11$, range = .42–.90) conditions, $t(46) = 0.03$, $p = .977$. Similarly, performance did not differ between trials featuring the participant's own child ($M = .59$, $SD = .14$, range = .35–.90) and those showing an unfamiliar child ($M = .59$, $SD = .11$, range = .42–.83), $t(56) = 0.18$, $p = .861$. Finally, a generalized linear mixed-effects model revealed no significant main effects of condition (OR = 0.96, CI [0.83, 1.13], $p = .652$) or child stimulus type (OR = 0.95, CI [0.82, 1.12], $p = .561$), and no significant interaction between them (OR = 1.14, CI [0.91, 1.42], $p = .250$).

An additional Wilcoxon signed-rank test was conducted with a subset of parents ($N = 10$) to examine potential confounds of relational familiarity. While the previous analyses compared performance in trials featuring parents' own child with trials featuring an unfamiliar child, this additional analysis compared CBR task performance with a familiar ($M = .56$, $SD = .10$, range = .42–.71) versus another unfamiliar ($M = .53$, $SD = .09$, range = .38–.67) child. Results showed no difference between conditions, $V = 30.50$, $p = .373$. Given the limited sample size, these findings are best regarded as suggestive.

Confidence ratings. Parents' confidence ratings during the CBR task were analysed. Average confidence was significantly higher for their own child compared with an unfamiliar child, both when excluding outliers ($t(49) = 6.80$, $p < .001$) and when including them ($V = 1437$, $p < .001$). Average confidence was also significantly higher for the familiar child compared with another unfamiliar child ($V = 49$, $p = .027$) in the subset. In contrast, no significant differences emerged between the neutral and arousal conditions when including outliers ($V = 456.5$, $p = .256$); however, when excluding outliers a significant difference was observed, $t(38) = -2.15$, $p = .038$, where

confidence was higher in the arousal condition. Overall average confidence was not correlated with average task performance (excluding outliers: $r = -.06$, $p = .656$; including outliers: $r = -.05$, $p = .688$); however, confidence was significantly higher on correct compared with incorrect trials (excluding outliers: $t(49) = -4.74$, $p < .001$; including outliers: $V = 303$, $p < .001$). Apart from differences between the neutral and arousal condition, all other patterns remained consistent regardless of outlier inclusion, indicating that extreme confidence ratings did not materially affect these findings. See table 4.3 for descriptive statistics in each group.

Table 4.3. Descriptive statistics for CBR task confidence ratings.

Condition/Group	Including outliers			Excluding outliers		
	<i>M</i>	<i>SD</i>	range	<i>M</i>	<i>SD</i>	range
Overall	5.56	1.81	0.40–9.41	5.78	1.08	3.07–8.22
Own child	5.86	1.87	0.60–9.79	6.11	1.14	3.19–8.81
Unfamiliar child ¹	5.25	1.80	0.20–9.43	5.46	1.14	2.95–7.96
Familiar child	4.87	1.90	0.54–6.98	N/A	N/A	N/A
Unfamiliar child ²	4.34	1.64	1.24–6.78	N/A	N/A	N/A
Neutral	5.41	1.94	0.50–9.53	5.74	1.14	2.68–8.05
Arousal	5.52	2.00	0.31–9.20	5.96	0.97	3.96–8.40
Correct trials	5.63	1.80	0.50–9.43	5.87	1.08	3.21–8.13
Incorrect trials	5.40	1.83	0.24–9.44	5.61	1.13	2.94–8.32

¹ compared with own child

² compared with familiar child

Cues and strategies. Participants provided qualitative information regarding the cues and strategies they used to perform the task. Their responses were explored and categorised, resulting in nine overarching categories: facial movements, body movement, facial expression or general appearance, breathing, posture, facial colouring, comparing videos, intuition, and knowledge about own child. Table 4.4 presents the frequency of each category and sub-category. The frequencies indicate the number of participants who reported using each cue; because some participants mentioned more than one strategy, the total frequency exceeds the number of participants. Fifty-three parents provided a response and there was a total of 139 comments; the average number of cues reported by each parent was 2.62 ($SD = 1.29$, range = 1–5).

Table 4.4. Cues and strategies used by participants to complete CBR task.

Theme	Frequency
Facial movements (total)	37
Eyes/blinking	23
Mouth/lips	9
Nose/nostrils	4
General	1
Body movement (total)	36
General	17
Chest	8
Neck/throat/swallowing	6
Shoulders	3
Head	2
Facial expression or general appearance	26
Breathing	20
Posture	4
Facial colouring	2
Comparing videos	4
Intuition	3
Knowledge about own child	3
No specific strategy	3

4.3.2 Relationships With Interoceptive Accuracy and Sensibility

Table 4.5 presents correlations between CBR task performance and interoceptive variables. Among these, only individual interoceptive accuracy, measured by the bias (alpha) in the HRD task, had a significant negative association with CBR task performance. This means that greater overestimation of the heart rate (higher alpha values) was related to lower CBR task performance. Sensitivity analyses comparing results with and without outliers indicated that outliers had only a slight influence on the strength of the association.

Table 4.5. CBR task performance and interoceptive variables correlations.

Variable	<i>r</i>	p-value
Alpha ¹	-0.31	0.046
Alpha ²	-0.29	0.054
Absolute alpha ¹	-0.10	0.548
Absolute alpha ²	-0.08	0.604
MAIA-2 overall score	-0.13	0.327
PIQ overall score	-0.12	0.395

¹ Excludes outliers, Pearson's method used.

² Includes outliers, percentage bend correlation used.

Regarding subjective interoception, PIQ and MAIA-2 overall scores were significantly correlated ($r = 0.32$, $p = .019$), such that higher IS was linked with higher parental interoception. Next, to examine whether the interaction between interoceptive accuracy and interoceptive sensibility predicted CBR task performance, two linear regression models were fitted. In the robust regression model including outliers (Adj. $R^2 = .016$), neither interoceptive accuracy ($\beta = -0.006$, $p = .294$), interoceptive sensibility ($\beta = -0.019$, $p = .367$), nor their interaction ($\beta = 0.001$, $p = .461$) significantly predicted performance. A standard linear regression model excluding outliers ($F(5, 36) = 1.41$, $p = .245$, Adj. $R^2 = .047$) showed similar results, with no significant effects for accuracy ($\beta = -0.008$, $p = .274$), sensibility ($\beta = -0.014$, $p = .615$), or their interaction ($\beta = -0.002$, $p = .460$).

4.3.3 Relationships With Psychosocial Traits

Relationships between parents' psychosocial traits and both CBR task performance and PIQ overall scores were subsequently explored. A significant positive correlation was found between performance and overall difficulties in emotion regulation, as measured by the DERS-18 ($r = 0.27$, $p = .044$), suggesting that parents reporting greater emotion regulation difficulties performed better on the CBR task. In turn, a significant negative correlation was found between overall DERS-18 and overall PIQ scores ($r = -0.27$, $p = .045$), indicating that parents reporting greater emotion regulation difficulties also reported lower subjective parental interoception. Regarding mental health symptoms assessed by the DASS-21, no statistically significant correlations were observed with either CBR task performance or PIQ overall score (see Table 4.6), although the relationship between performance and stress showed a marginal positive effect, suggesting that higher stress was related to better performance.

Table 4.6. CBR task performance and DASS-21 subscales correlations.

DASS-21 Variable	CBR task performance		PIQ overall score	
	<i>r</i>	<i>p</i> -value	<i>r</i>	<i>p</i> -value
Anxiety ¹	.02	.897	-.22	.139
Anxiety ²	-.02	.856	-.17	.206
Depression ¹	.10	.459	.06	.694
Depression ²	.13	.335	-.01	.936
Stress	.24	.071	-.02	.874

¹ Excludes outliers, Spearman's method used.

² Includes outliers, percentage bend correlation used.

In terms of attachment style (measured via the ECR-R), a significant positive correlation was found between CBR task performance and anxious attachment when the outlier was excluded ($r = .28, p = .042$), suggesting that higher attachment anxiety was related to better performance. The effect size remained similar, though the statistical significance became marginal when using a percentage bend correlation that included the outlier ($r = .25, p = .063$). In turn, the relationship with PIQ overall score was negative, indicating that higher attachment anxiety was related to lower PIQ scores. This was significant only when using a percentage bend correlation that included the outlier ($r = -.29, p = .034$), but not when excluding the outlier ($r = -.23, p = .104$).

No significant relationships were found between task performance and avoidant attachment, either excluding the outlier ($r = .20, p = .148$), or when including it using a robust correlation method ($r = .21, p = .123$). Similarly, no significant associations were found between avoidant attachment and PIQ overall score, either excluding the outlier ($r = -.18, p = .200$), or when including it using a percentage bend correlation ($r = -.18, p = .208$).

4.3.4 Effects of Parental Interoception on Child Outcomes

Simple linear regression models were fitted to investigate whether objective parental interoception (i.e., CBR task performance) or subjective parental interoception (i.e., PIQ overall score) could predict child emotion regulation and socioemotional functioning. With CBR task performance as predictor, no significant effect was found for the *Emotion Regulation* subscale in the ERC ($\beta = -1.31, p = .749, \text{Adj. } R^2 = -.018$). For the *Emotional Lability* subscale, a marginally significant effect emerged when the outlier was excluded ($\beta = 14.25, p = .056, \text{Adj. } R^2 = 0.054$), which was slightly reduced in a robust regression model that included the outlier ($\beta = 13.92, p = .082, \text{Adj. } R^2 = .050$). With PIQ overall score as predictor, no significant effects were found for *Emotion Regulation* ($\beta = 1.42, p = .093, \text{Adj. } R^2 = .037$) or *Emotional Lability*, either excluding the outlier ($\beta = -2.10, p = .185, \text{Adj. } R^2 = -.016$) or including it using a robust regression model ($\beta = -2.52, p = .113, \text{Adj. } R^2 = .032$).

Regarding child behavioural problems, task performance did not significantly predict Externalising Behaviour ($\beta = 1.44, p = .772, \text{Adj. } R^2 = -.018$) or Prosocial Behaviour ($\beta = 2.13, p = .404, \text{Adj. } R^2 = -.006$) but was marginally associated with Internalising Behaviour ($\beta = 7.83, p = .059, \text{Adj. } R^2 = 0.051$). Similarly, PIQ overall score did not significantly predict *Externalising Behaviour* ($\beta = -1.39, p = .177, \text{Adj. } R^2 = .017$) or *Internalising Behaviour* ($\beta = -1.18, p = .176, \text{Adj. } R^2 = .017$) but had a significant effect with *Prosocial Behaviour* ($\beta = 1.05, p = .047, \text{Adj. } R^2 = .058$).

4.3.5 Summary of Results

Overall, parents performed significantly above chance on the CBR task and performance was not meaningfully influenced by demographic factors such as gender, child sex or age, BMI, or ethnicity. While participants showed biases toward choosing certain responses, such as preferring the right-side option and the higher-arousal videos, these biases did not systematically impact overall performance. Importantly, neither experimental condition (neutral versus arousal) nor stimuli type (own/familiar versus unfamiliar child) affected average performance. In contrast, average confidence was higher when rating their own or a familiar child and also on correct versus incorrect trials, suggesting some alignment with objective performance. However, overall mean confidence was not correlated with average performance. Parents reported relying on a range of cues and strategies to complete the task, most often noticing facial or body movements and breathing.

Exploring underlying factors, CBR task performance was modestly linked to IA but not IS or subjective parental interoception. Parents reporting greater difficulties with emotion regulation tended to perform better on the CBR task, though they rated themselves lower on subjective parental interoception. A marginal relationship suggested that higher stress levels may be associated with better task performance, and attachment patterns also played a role, with anxious attachment showing a positive marginal association as well. Finally, parental interoception showed a few connections with child outcomes: objective performance was marginally associated with higher emotional lability and child internalising problems, while subjective parental interoception predicted higher prosocial behaviour.

4.4 Discussion

In this chapter, objective and subjective parental interoception were investigated, providing initial evidence of a parental interoception ability and its relation to individual interoception, psychosocial traits, and children's socioemotional outcomes. The study showed that, overall, parents can identify children's cardiac signals with above-chance accuracy, replicating results from non-parent samples in the previous chapter and previous studies on adult-to-adult tasks (Arslanova et al., 2022; Galvez-Pol et al., 2022). Moreover, while parents' average confidence was not correlated with average performance, it was significantly higher following correct responses compared to incorrect ones. This pattern indicates that, while parents who performed well were not necessarily more confident overall, confidence ratings were sensitive to trial-by-trial accuracy, which replicates what the previous chapter and what Arslanova et al. (2022) found.

In terms of psychometric elements of the CBR task, this study found a slight response bias for right-sided responses (choosing this 52.4% of the time) and a significant bias for selecting high-arousal videos (60%) over low-arousal ones. Importantly, neither of these biases significantly affected overall accuracy, as confirmed by analyses with both average performance scores and the bias-free discriminability measure (d') from Signal Detection Theory (SDT). D' was almost perfectly correlated with average performance, and the SDT response bias parameter (c) had no effect on performance. Moreover, there was also a marginal effect of average difficulty (indexed as the difference in heart beats between the two videos displayed in each trial) on CBR task performance. These elements are discussed in turn below.

First, a slight bias towards right-sided responses could reflect a motor or attentional preference. It might be that right-handed participants, who were the majority, preferred responses on their dominant side. Future studies could test this hypothesis statistically. The bias could also reflect a default guessing strategy, where participants choose this option when they are uncertain. While the bias was relatively small, it highlights the importance of counterbalancing and considering side-preferences in the interpretation of 2AFC results. Second, as discussed in Chapter 3, bias towards the high-arousal videos could mean that these are more salient and capture parents'

attention more than the low-arousal videos, in which children are in a neutral or resting state. Developmental accounts of how infants often display attention-grabbing behaviours to capture caregivers' attention so they can support their regulation and homeostasis align with this interpretation (Atzil & Barrett, 2017; Ciaunica & Crucianelli, 2019; Filippetti, 2021; Fotopoulou & Tsakiris, 2017). High-arousal states in the videos might have elicited a similar attention pull, without compromising accuracy.

The experimental manipulation of arousal provides further insight into this phenomenon. Physical exercises were effective in inducing both subjective arousal and objective increased heart rate. However, average performance was not affected by the increased arousal. This diverges from findings in individual interoceptive accuracy, where stronger cardiac signals typically facilitate performance (Jones & Hollandsworth, 1981; Schandry et al., 1993). One explanation could be that while heightened cardiac states enhance their perception; they do not necessarily provide useful information for inferring other's cardiac states. It could be that, when inferring others' internal states, stronger signals from the other capture attention (as in the high-arousal stimuli) but stronger signals in one's own body are either not relevant or potentially distracting.

In terms of stimuli difficulty, the marginal effect on performance suggests that difficulty levels were slightly unbalanced across participants, although this did not systematically affect performance. The small effect of difficulty on performance in this sample could be due to the personalisation differences in design, where parents' answered trials of their own child, thus, limiting the range of difficulty levels available for manipulation to only those present in their own child's heart rate stimuli. Future studies using the CBR task should be careful in measuring response biases based on arousal levels and difficulty levels, especially if the stimuli will be personalised to each participant, and control for this when necessary.

Furthermore, participants reported using a range of visual cues to complete the CBR task. The most frequently mentioned cues were facial movements (e.g., mouth, blinking, nostrils) and body movements (e.g., neck, shoulders, head, chest), followed by facial expressions or general appearance and breathing. These reports are similar to the previous chapter and to Arslanova et al. (2022), who found that participants

relied primarily on general movement, breathing, perceived state, and eye movement or blinking. This provides further support to the idea that, even though individuals do not have direct sensory access to others' interoceptive states, they can, to some reliable extent, detect subtle and transient changes in appearance that accompany interoceptive variations and use such noisy, indirect, and partial information to infer others' interoceptive signals, in this case cardiac.

Looking at the effects of relational familiarity, there was no difference in average performance when parents rated their own versus an unfamiliar child, and tentative results from a subset of the sample ($N = 10$) similarly suggested no difference when rating a familiar versus an unfamiliar child. In contrast, parents' average confidence was significantly higher for their own compared with an unfamiliar child, and also significantly higher for a familiar versus an unfamiliar child in the subset. Only a few studies have investigated relational familiarity or closeness in mentalising capacities, results found that neural activation (Laurita et al., 2020) and mentalisation in the form of mind-minded comments (Hill & McMahon, 2016) were higher when participants judged or described close others, such as romantic partners or one's own children, compared to more distant individuals, such as acquaintances or famous persons. In the present study, however, this did not translate into better performance but only into stronger subjective beliefs about their own accuracy.

The previous findings suggest that while relational closeness influences feelings of certainty or subjective perception, it does not necessarily enhance accuracy in judging children's cardiac states. Several mechanisms could explain this pattern. Parents may believe they know their child better (indeed, three parents explicitly reported using this as a strategy), they may have relied more on heuristics or prior knowledge (e.g., "my child always blinks a lot when they are tired") when rating their own child, which feels subjectively reliable but might not necessarily lead to higher accuracy, or it could be that the design of the CBR task reduced the relevance of relational knowledge (e.g., by making the videos as similar as possible across children, thereby standardizing or constraining the available cues). Future studies could test this hypothesis under more ecologically valid conditions or during live interactions.

Interestingly, parents' average confidence was significantly higher during the arousal condition, suggesting a similar pattern as with relational familiarity, with physiological activation influencing subjective beliefs but not actual accuracy. Potentially, being able to feel their own heart rate more gave parents' a sense of confidence in rating others' cardiac states, even if it did not necessarily make them more accurate. It should be noted that the confidence effect in this condition was only significant when outliers in average confidence were excluded, indicating that the effect might be obscured by extreme variability in responses. Future studies could replicate with larger samples or examine more closely why some parents report extremely low or high confidence.

A secondary aim of this study was to investigate potential factors underlying parental interoception. Overall, demographic characteristics did not significantly influence CBR task performance. This finding diverges from the results presented in Chapter 3, in which participant gender and child sex had a significant interaction where men were more accurate when rating boys. One possible explanation for this contrasting result may be due to sample characteristics. The parent sample in the present study had a less balanced gender distribution (80% women compared to 69% in Chapter 3), with relatively few fathers (only 11 men). These sample characteristics may have obscured possible gender differences. Alternatively, beyond sample limitations, parents may generally be more familiar with children than younger adults without children and therefore rely less on gender-related similarities or strategies when completing the task. Future research should examine gender differences in larger and more balanced parental samples to clarify whether such differences emerge once these limitations are addressed.

With respect to individual interoceptive abilities, greater overestimation of the heart rate (higher alpha) in the Heart Rate Discrimination (HRD) task was marginally associated with poorer parental interoception, as measured by CBR task performance. These findings are consistent with a) results from the previous chapter, b) theoretical accounts proposing that sensitivity to one's own bodily signals facilitates the detection of bodily signals in others (Fotopoulou & Tsakiris, 2017; Steele et al., 2017), and c) evidence linking IA to the processing of others' emotional states (see Chapter 1, Section 1.2). Nevertheless, as noted in the previous chapter, HRD alpha scores should be interpreted with caution, since values near zero are the most accurate, with

negative scores indicating underestimation and positive scores overestimation of heart rate, complicating linear interpretations.

In contrast, neither individual interoceptive sensibility, as measured by the MAIA-2, nor subjective parental interoception, as measured by the PIQ, were correlated with CBR task performance. This was expected following similar results in the previous chapter and is consistent with previous research showing that self-report and objective measures of interoception do not always converge (Brewer et al., 2021; Murphy et al., 2019). Nevertheless, MAIA-2 and PIQ scores were positively correlated with each other. These results suggest that parents' subjective beliefs – both about their own interoception and their ability to notice, attend to, understand, and respond to their children's interoceptive states – are not necessarily indicative of their actual accuracy in inferring their children's cardiac states. However, individual and parental interoception do relate to one another within each dimension, objective or subjective.

Regarding emotion regulation and mental health symptoms, higher CBR task performance was associated with more emotion regulation difficulties and showed a possible trend toward higher stress. These results appear to contradict existing literature, as emotion regulation processes are typically linked to both interoception and mentalisation (see Chapter 1, Section 1.2; Bornemann & Singer, 2017; Schultheis et al., 2019; Sugawara et al., 2020), and interoceptive accuracy has been associated with more effective use of emotion regulation strategies (Füstös et al., 2012; Weiss et al., 2014). Because these findings are contrary to expectations, they are difficult to interpret. One possibility is that parents are not habitually very accurate when inferring children's interoceptive states, and that this general bias may actually serve a beneficial function. Indeed, research on interoception in clinical and psychopathology contexts suggests that high accuracy or heightened attentiveness is not always adaptive (Brewer et al., 2021; Domschke et al., 2010; Murphy et al., 2017; Paulus & Stein, 2010).

If higher accuracy is in fact not always the most adaptive outcome, then successfully regulating children may be less dependent on detecting their exact physiological state and more on projecting or predicting their states. Supporting this, Kirsch et al. (2023) found that mothers tend to rely more heavily on their own bodily feelings when judging

their own child's states compared to another child's, demonstrating an egocentric bias. Importantly, parents' role in children's regulation extends beyond noticing and understanding their current state, it also involves supporting anticipatory ("allostatic") regulation by considering cultural, social, physical and other shared contextual factors (Atzil & Barrett, 2017; Fotopoulou & Tsakiris, 2017; Fotopoulou et al., 2022). Thus, this bias could in fact support children's adaptive regulation in relation to their broader environment.

In contrast to the CBR task findings, self-reported parental interoception, as measured by the PIQ, was associated with fewer emotion regulation difficulties. As mentioned, in the individual interoception research, interoceptive accuracy (IA) and interoceptive sensibility (IS) are not always correlated (Brewer et al., 2021), and in the present study, objective and subjective parental interoception were likewise unrelated. Accordingly, it is plausible that these two dimensions show different associations with emotion regulation. This finding suggests that, while increased accuracy in objective parental interoception may not always be adaptive, parents' subjective beliefs about their ability to notice, attend to, understand, and regulate their child's bodily needs are linked to healthier emotion regulation. Future work could employ behavioural and physiological measures of emotion regulation to provide deeper insight on its relationship with both objective and subjective parental interoception.

In contrast, no associations were observed between either CBR task performance or PIQ scores and depression or anxiety, despite previous research linking atypical interoception with both (Eggart et al., 2019; Murphy et al., 2017; Paulus & Stein, 2010; Pollatos et al., 2009). The absence of such effects here might indicate that these symptoms primarily affect self-focused interoception and do not extend to parental interoception, although the previous chapter did find a marginal effect of anxiety in a non-parent sample. Another possibility is that the relatively limited variability in symptom severity within this sample reduced the likelihood of detecting associations. Future studies could examine parental interoception in clinical populations compared with healthy controls.

Regarding attachment style, anxious attachment was marginally associated with better objective parental interoception (i.e., CBR task performance) and worse

subjective beliefs (i.e., lower PIQ scores), while avoidant attachment did not show links with either measure. These findings partially align with previous research in which reduced interoception is linked to avoidant attachment but increased interoception to anxious attachment (Oldroyd et al., 2019). Research on mentalisation has found that caregivers with insecure attachment styles, both anxious and avoidant, are less likely to have high levels of mentalising abilities (Bouchard et al., 2008; Luyten, Mayes, et al., 2017b; Slade et al., 2005). One explanation for the pattern in the current findings could be that anxious attachment involves hypervigilance to social or relational stimuli, which might extend to bodily cues in the self (Oldroyd et al., 2019) and others. This hypervigilance might enhance accuracy on objective tasks but might also undermine confidence, as it is persistently looking out for threats, leading to lower self-report scores. This pattern is similar to results about emotion regulation, where objective performance was related to more difficulties and subjective beliefs to less difficulties, further suggesting that objective and subjective dimensions of parental interoception are not necessarily related and that high objective accuracy might not necessarily be the most adaptive outcome. It may be that emotion regulation and attachment-related biases, such as projection, hypervigilance, or self-doubt, shape self-perceptions on parental interoception ability but do not directly reflect objective performance.

Nevertheless, it is also important to note that the CBR task measures objective performance only within the cardiac modality. Emotion regulation, mental health symptoms, and attachment style may relate differently to parental interoceptive performance in other modalities. Future studies could therefore extend parental interoception tasks to additional modalities and use larger samples and longitudinal designs to clarify whether associations with emotion regulation and attachment reflect causal relationships or bidirectional influences.

In terms of child outcomes, results showed that higher CBR task performance marginally predicted greater child emotional lability and higher child internalising behaviours, whereas higher PIQ scores marginally predicted greater child prosocial behaviour. This pattern underscores differences between objective and subjective dimensions of parental interoception and further suggests that greater objective accuracy may not always be associated with the most adaptive outcomes. In this study, child emotional lability referred to the tendency to react with anger, intensity,

mood swings, and inflexibility, while internalising behaviours encompassed emotional and peer-related difficulties such as anxiety, sadness, and challenges in social interactions.

A possible mechanism explaining these results is that the link between higher CBR task performance and less adaptive child outcomes is mediated by parental factors, given that parents with higher stress, emotion regulation difficulties, and anxious attachment also showed marginally higher CBR task accuracy. Supporting this interpretation, research has shown that parents with greater emotion regulation difficulties are more likely to have children who display similar difficulties and internalising symptoms (Zimmer-Gembeck et al., 2022). It is possible that parental hypervigilance and difficulties with regulation are transmitted to children through negative parenting behaviours, such as unsupportive responses to negative emotions, lack of warmth, or hostility. This interpretation aligns with theories of parental emotion socialisation, which highlight the role of caregivers in shaping children's regulatory and emotional abilities (Eisenberg et al., 1998).

Overall, the present chapter demonstrates that parents can, to some extent, discriminate children's heart rates. It also shows that this ability appears to be similar regardless of relational familiarity with the child, although parents' confidence in their judgements is higher when evaluating their own or a familiar child compared to an unfamiliar child. This further supports idea that, although interoceptive signals are not directly observable, they can be inferred in ways comparable to how emotions and mental states of others are read and provides further evidence of the divergence between the objective and subjective dimensions of interoception. These findings extend previous work using the adult other-HR task to a child-oriented context and build on results from Chapter 3 by situating them within a parental framework.

Nevertheless, some of the findings relating to individual differences did not fully align with initial expectations. The results suggest that parents' ability to infer children's interoceptive states may be influenced, at least to some degree, by individual interoceptive accuracy as well as by emotion regulation difficulties, stress, and anxious attachment. Although these effects were small and preliminary, they provide initial indications of traits that could either facilitate or constrain this ability and raise the

possibility of a non-linear relationship with psychopathology. In particular, higher accuracy in inferring children's cardiac states may not be inherently adaptive; rather, both very high and very low accuracy could be maladaptive, with the most beneficial outcomes lying somewhere in between. Importantly, these findings highlight the need for replication in larger samples and further investigation across clinical populations, interoceptive modalities, and methods (e.g., more ecologically valid approaches such as live parent-child interactions, longitudinal designs).

Altogether, the work presented in this chapter provides an initial step toward understanding parental interoception as a multidimensional construct, possibly influenced by individual differences in broader psychosocial traits in ways that may not always be linear or straightforward, as it may have both adaptive and maladaptive consequences depending on its degree and context.

Chapter 5: Discussion

The main aim of this thesis was to investigate **parental interoception**, defined as parents' ability to identify and respond to their children's interoceptive signals and states. Understanding how interoception is developed has become a key aim for researchers in developmental, psychological and neuroscientific fields. Theoretical propositions point to parent-child interactions as crucial in this process, considering infants' dependency on parents for their homeostatic control (Atzil & Barrett, 2017; Ciaunica & Crucianelli, 2019; Filippetti, 2021; Fotopoulou & Tsakiris, 2017). Research on related parental behaviours and capacities (e.g., affective touch, synchrony, mentalisation) provides indirect support for the parental role in interoceptive development (see Chapter 1, Section 1.3); however, direct empirical evidence and suitable measures were previously lacking.

Additionally, secondary aims were to identify potential underlying factors of parental interoception, and related child outcomes. Thus, the present thesis also investigated how parental interoception relates to a) parent's individual interoception (about their own body), b) relevant psychosocial factors such as emotion regulation, attachment, and mental health symptoms, and c) children's socioemotional functioning. Findings from all empirical chapters are collectively discussed below in relation to each main aim, along with specific limitations and suggestions for future directions. Finally, general limitations and future directions are discussed before concluding.

5.1 Measuring Objective and Subjective Ability to Infer Children's

Interoceptive States – Parental Interoception

A central aim of this thesis was to investigate whether parents can “read” their children's interoceptive signals and states. Because this ability had not yet been explicitly studied, the development of specialised tools was also a key objective. Across the empirical chapters of this thesis, both subjective and objective measures of parental interoception were developed and employed to investigate this capacity.

The Parental Interoception Questionnaire (PIQ), developed in Chapter 2, was designed to assess the subjective dimension of parental interoception, capturing

parents' perceived ability to notice, attend to, understand, and regulate their children's internal bodily signals and sensations. Exploratory factor analyses yielded a theoretically meaningful structure with five subscales: *Attention*, *Epistemic Attitudes*, *Trust and Self-Efficacy*, *Regulation*, and *Linking*. This structure was validated for parents of children 0–10 years old.

The subscales obtained reflect distinct but related aspects of parents' beliefs about their ability. Attention captures the ability to detect and discriminate children's bodily states as well as to sustain and direct attention towards them. Epistemic Attitudes reflects the extent to which parents consider children's bodily signals as having practical and communicative value. Trust and Self-Efficacy concern the belief that this information is reliable and can be acted upon. Regulation refers to parents' ability to actively regulate their children's bodily needs and states. Finally, Linking captures the ability to connect bodily changes with children's feelings (e.g., fear, happiness, anger) and homeostatic emotions (e.g., hunger, pain, fatigue).

In terms of psychometric properties, the PIQ demonstrated good test-retest reliability and acceptable internal reliability of its subscales, comparable to reliability levels reported for other established measures during their initial development, such as the MAIA (Mehling et al., 2012), and the PRFQ (Luyten, Mayes, et al., 2017b). Subsequent studies could aim to further enhance the internal consistency of the subscales, particularly the *Linking* subscale, which showed the lowest reliability. Nonetheless, efforts to maximise reliability must be balanced against preserving content validity and efficiency. As Nunnally and Bernstein (1994) caution, perfect reliability can hinder the measure's ability to comprehensively represent the intended construct and risk participant burden.

The PIQ expands the range of self-report tools in the field of interoception while also contributing to the assessment of parental mentalising, thereby bringing together insights from both fields. In relation to parental reflective functioning, the subscales of *Epistemic Attitudes* and *Trust*, for example, parallel the PRFQ subscale of *Interest and Curiosity*, as they reflect a tendency to seek information. However, the PIQ captures dimensions that are embodied rather than purely cognitive or "higher order". For instance, whereas the PRFQ includes items such as "I wonder a lot about what my

child is thinking and feeling” or “I believe there is no point in trying to guess what my child feels”, the PIQ instead asks questions like “I regularly observe my child’s body signals... to obtain information about their emotional state” or “I am confident that my child’s body will let me know what is good for them”. From the interoceptive perspective, the PIQ parallels multidimensional measures of IS, particularly the MAIA. The PIQ subscales of *Attention*, *Regulation*, and *Linking* echo aspects of the MAIA, such as noticing, self-regulation, and emotional awareness, but uniquely adapt these dimensions to the parent-child context by emphasising the “reading” of children’s bodily states rather than awareness of one’s own. In this way, the PIQ integrates theories and research of parental mentalisation and interoception, providing a framework that highlights parental beliefs at the intersection of bodily and mentalising processes.

Existing measures of individual IS have been found to measure different features of this dimension, for example, distinctions have been made between self-reported attention to bodily signals and self-reported accuracy in perceiving those signals (Desmedt et al., 2022; Murphy et al., 2020). The PIQ was deliberately developed as a multidimensional tool, considering that capturing features such as regulation, trust, and mentalisation, in addition to attention, would be relevant for a parental measure. Nevertheless, such differences in scope should be contemplated when attempting to replicate findings or compare results across IS measures.

Furthermore, subjective parental interoception (PIQ scores) was significantly associated with parental reflective functioning. This finding indicates a relationship between body-focused and mind-focused parental mentalising or “reading” abilities. Previous research has established links between mental and bodily forms of mentalisation, such as comparisons of verbal and non-verbal aspects of mentalisation, including touch and body movements. For example, lower levels of mind-mindedness (i.e., fewer attuned mind-related comments) have been associated with less contingent touch during mother-infant interactions (Crucianelli et al., 2019), while parental embodied mentalising has been linked to greater mind-mindedness and maternal sensitivity (Shai & Meins, 2018; Væver et al., 2022). Notably, however, the present thesis provides the first self-report measure for parental “reading” of actual interoceptive states. The observed association between the reading of bodily states

and reading of mental states tentatively suggests that parental interoception may work in similar ways as other parental mentalising abilities.

Importantly, Chapter 2 and Chapter 4 demonstrated significant associations between PIQ scores and relevant demographic and psychosocial factors, as well as predictive value for certain child outcomes. In Chapter 2 there were gender differences, with mothers obtaining higher scores, and effects of employment status, with parents working full time reporting lower scores than those working part-time or not working. Across both chapters, subjective parental interoception (PIQ scores) related to greater IS and emotion regulation. Associations with attachment style were also observed, though with some variation. PIQ related to decreased avoidant attachment in Chapter 2 and decreased anxious attachment in Chapter 4. Regarding child outcomes, the PIQ predicted child prosocial behaviour in both chapters, and additionally predicted internalising and externalising behaviours in Chapter 2. These findings will be discussed in more detail in Section 5.3; however, it is worth noting here that they underscore the PIQ's value as a tool for assessing individual differences in subjective parental interoception, particularly in large-scale studies. They also suggest meaningful variability in how parents perceive their ability to read their children's interoceptive states (i.e., subjective parental interoception).

In summary, the PIQ provides a reliable and valid self-report measure of parental interoception. It can be meaningfully applied in research to identify individual differences and deepen our understanding of how parents read their children's interoceptive signals.

To investigate the objective dimension of parental interoception the Child Body Reading (CBR) task was developed, adapted from a behavioural paradigm by Galvez-Pol et al. (2022). By showing participants videos of children's faces alongside cardiac feedback stimuli, the task evaluates participant's accuracy in discriminating children's heart rates only by looking at their faces. Chapters 3 and 4 employed the CBR task and demonstrate its validity in assessing objective accuracy in the cardiac modality, showing that adults, both non-parents and parents, are in fact able to infer children's cardiac states with above-chance accuracy. This is the first evidence explicitly

assessing this ability with children stimuli, expanding the limited evidence of this capacity in adult-to-adult paradigms (Arslanova et al., 2022; Galvez-Pol et al., 2022).

The psychometric evaluation of the CBR task across both samples indicated good overall robustness. There were some influences of response biases and stimuli difficulty that warrant consideration but did not systematically affect participants' average performance, also confirmed by Signal Detection Theory (SDT) analyses. On the one hand, the biases shown towards the high-arousal stimuli (i.e., videos where children displayed heightened cardiac states) could reflect greater salience of physiologically activated child states, which naturally capture adult attention. This interpretation is consistent with developmental theories emphasising caregivers' sensitivity to children's altered physiological states as a mechanism for supporting regulation and homeostasis (Atzil & Barrett, 2017; Ciaunica & Crucianelli, 2019; Filippetti, 2021; Fotopoulou & Tsakiris, 2017). Infants' behaviours such as crying can be seen as adaptive attention-grabbing signals, and high-arousal states in the videos might have elicited a similar attention pull, without compromising accuracy.

Interestingly, physiological arousal in parents themselves had no impact on their objective parental interoceptive sensitivity (CBR task performance). This contrasts with evidence from individual interoceptive accuracy tasks, where stronger cardiac signals typically facilitate perception (Jones & Hollandsworth, 1981; Schandry et al., 1993). Possibly, heightened cardiac states enhance their perception but do not necessarily provide useful information for inferring other's cardiac states and may be irrelevant or even distracting. By contrast, stronger signals from the other (as in the high-arousal stimuli) are more likely to capture attention, although the findings suggest this has no effect on accuracy. This could be due to the nature of the task, which requires participants to match cardiac feedback to the correct stimulus (i.e., it is a discrimination task). Perhaps if participants were instead asked to identify which of the two videos showed the child with the highest heart rate, their accuracy might improve.

On the other hand, stimulus difficulty showed only a marginal influence on performance, and only in the parent sample (Chapter 4). Slight imbalances in difficulty level across participants emerged in this sample because parents' trials included personalised stimuli of their own child, thus limiting the range of difficulty levels

available for manipulation to only those present in their own child's heart rate stimuli. While this effect was minor and did not systematically bias overall performance, it highlights the need for careful design when stimuli are personalised. Future studies employing the task or any adaptation should aim to balance difficulty levels across conditions and participants whenever possible, ensure that these levels are appropriately measured, and control for any potential confounding effects of stimuli difficulty.

Moreover, participants qualitative reports on the cues and strategies they used to complete the CBR task provided further insight into the mechanisms underlying this ability and what the behavioural task captures. In both samples, participants frequently mentioned facial and body movements, facial expressions, emotions or general appearance, and breathing. Given that interoceptive signals are largely hidden (Arslanova et al., 2022; Ondobaka et al., 2017), it is plausible that individuals would rely on such perceptual cues to infer others' interoceptive states such as heart rate. Indeed, heartbeat activity has been shown to produce micro-movements of the head and eyes (Wu et al., 2012), which is consistent with some of the cues reported by participants. These reports support the idea that, even though people do not have direct sensory access to others' interoceptive states, they can, to some reliable extent, detect subtle and transient changes in appearance that accompany interoceptive variations and use this noisy, indirect, and partial information to infer another person's interoceptive signals, in this case cardiac rhythm.

Overall, this finding suggests that interpersonal or parental interoceptive "reading" ability is similar to other mentalising or theory of mind processes, where opaque emotions and mental states of others are inferred from behaviour and from partial, indirect sensory data. For example, the mirror neuron system and embodied simulation theories (Bastiaansen et al., 2009; Gallese, 2003; Keysers et al., 2018) emphasise mirroring mechanisms where the observation of body movements or facial expressions of others activates somatosensory-motor networks. Also, interoceptive inference and predictive coding frameworks (Barrett & Simmons, 2015; Fotopoulou & Tsakiris, 2017; Ondobaka et al., 2017) suggest that such mentalising abilities rely to some degree on inferences, which are shaped not only by sensory cues but also by prior beliefs or expectations (i.e., predictions or top-down mechanisms). Future studies

could explore the factors that contribute to and can influence these interoceptive inferences, ranging from prior beliefs and appraisal beliefs to the quality and quantity of sensory signals.

In summary, results from both chapters demonstrate that the CBR task yields valid and reliable performance measures, despite minor response biases and uneven stimulus difficulty. In addition, the qualitative reports highlight the cues participants rely on and provide insight into how interoceptive states are inferred. Taken together these findings support the CBR task as a promising tool for measuring child-oriented interpersonal interoception in the cardiac domain, while also identifying key psychometric considerations for future use.

Furthermore, findings from Chapters 2 and 4 indicate that subjective and objective parental interoception do not always converge. This was observed both with the PIQ (trait-like beliefs) and confidence ratings from the CBR task (state-like beliefs). Interestingly, in parents (Chapter 4), confidence increased under arousal manipulation and when rating their own or a familiar child, suggesting that physiological activation and relational familiarity can inflate subjective beliefs without necessarily improving accuracy. Together, these findings suggest that measures of subjective and objective parental interoception capture distinct aspects of this construct.

These results align with evidence from the individual interoceptive literature, where subjective self-report and objective interoceptive abilities often diverge (Brewer et al., 2021; Murphy et al., 2019). Objective tasks typically target a single physiological axis (e.g., cardiac signals), while self-report questionnaires often integrate beliefs about multiple bodily signals. Additionally, subjective beliefs may be shaped by cognitive and emotional factors such as memory and mood, which can diverge from actual perceptual accuracy. In the parental context, these processes may operate alongside relational factors (e.g., familiarity, caregiving motivations), further inflating subjective confidence without necessarily affecting accuracy. Thus, some differences between subjective and objective measures are likely in both individual and parental interoception, and possibly the mechanisms are amplified or extended in interpersonal settings.

As a parental ability, the CBR task was designed to capture possible effects of relational familiarity. Nevertheless, the findings showed no difference in performance between parents' own child, a familiar and an unfamiliar child. In contrast, parents' average confidence was higher for their own and a familiar compared with an unfamiliar child. Previous research and existing measures of parental mentalising abilities have primarily focused on the parent-child dyad, with limited attention to whether these qualities extend to, or differ in, interactions with unfamiliar or more distant children (see Chapter 4 Introduction). Only a few studies have investigated relational familiarity or closeness within mentalising capacities, results from these have found that neural activation (Laurita et al., 2020) and mentalisation in the form of mind-minded comments (Hill & McMahon, 2016) were higher when judging or describing close others, such as romantic partners or one's own children, compared to more distant individuals, such as acquaintances or famous persons. In the current findings, however, this did not translate into better performance but only into stronger subjective beliefs about their own accuracy.

The findings suggest that while relational closeness influences feelings of certainty or subjective perception, it does not necessarily enhance accuracy in judging children's cardiac states. Several mechanisms could explain this pattern. Parents may believe they know their child better (as some parents explicitly reported), they may have relied more on heuristics or prior knowledge (e.g., "my child always blinks a lot when they are tired") when rating their own child, which feels subjectively reliable but might not necessarily lead to higher accuracy, or it could be that the design of the CBR task reduced the relevance of relational knowledge (e.g., by making the videos as similar as possible across children, thereby standardizing or constraining the available cues). Future studies could test this hypothesis under more ecologically valid conditions or during live interactions.

Importantly, Chapter 3 and Chapter 4 demonstrated that objective parental interoceptive ability (CBR task performance) is related to relevant demographic and psychosocial factors and shows predictive value for certain child outcomes. Performance was associated with individual interoceptive accuracy in both samples, relationships with stress and anxiety were observed in Chapter 3 and with emotion regulation difficulties and stress in Chapter 4. Anxious attachment was also related to

performance in Chapter 4 and predictive value was found for child emotional lability and internalising behaviours. These results will be discussed further in Section 5.3; nevertheless, it is worth noting here that they emphasise the usefulness of the CBR task in evaluating individual differences in objective parental interoception, particularly in the cardiac domain.

Overall, the CBR task offers the first objective measure of parental interoception, distinguishing it from traditional interoceptive accuracy tasks (see Chapter 1, Section 1.1.1) and from parental mentalising assessments that typically rely on interviews or observations (Sharp & Fonagy, 2008). Within interoception research, the task introduces an interpersonal and child-oriented dimension of IA, which may be valuable not only in parental contexts but also in educational and caregiving settings. Within the parental mentalising literature, it contributes a psychophysiological method that explicitly targets the reading of interoceptive states, rather than solely external bodily states (e.g., PEM) or mental states. Taken together with existing measures across both fields, the CBR task offers a valuable addition; nevertheless, future research on parental interoception should aim to examine a variety of interoceptive modalities and incorporate more ecological, interactive assessments of parent-child interactions.

Summary. Collectively, the findings discussed in this section demonstrate that the PIQ and the CBR task can be used to measure subjective and objective parental interoception respectively. It is also evident from the results that, as previously found in the individual interoceptive literature (Brewer et al., 2021; Murphy et al., 2019), measures of subjective and objective interpersonal or parental interoception capture different aspects of this construct. The findings also suggest that interpersonal or parental interoceptive reading ability is similar to other mentalising or theory of mind processes, where opaque emotions and mental states of others are inferred from behaviour and from partial, indirect sensory data. Moreover, both measures showed significant relationships with relevant psychosocial factors and child outcomes, demonstrating their value in assessing individual differences.

Both measures show acceptable psychometric properties, although some considerations should be made. For the PIQ, differences in scope with other IS measures should be considered when linking or comparing with studies using different

questionnaires and future studies could work on improving internal reliability of the subscales. For the CBR task, stimuli difficulty and response biases, especially toward the high-arousal stimuli, should be appropriately measured in any future studies.

5.2 Relationships With Individual Interoception

Previous research has found that individual interoceptive abilities are linked to the processing of others' emotions (see Chapter 1 Section 1.2) and some theoretical propositions extend this to bodily states, suggesting that sensitivity to one's own interoceptive signals would facilitate their detection in others (Fotopoulou & Tsakiris, 2017; Steele et al., 2017). Therefore, a secondary aim of this thesis was to test whether individual interoception was indeed linked to interpersonal or parental interoception.

Across studies, the evidence suggests that such links occur only within the same dimension of interoception, subjective or objective, but not across them. On the subjective side, Chapters 2 and 4 showed that parental interoceptive sensibility (PIQ scores) correlated significantly with individual interoceptive sensibility, as measured by the MAIA-2 and BAQ. On the objective side, both Chapters 3 and 4 found tentative associations between individual interoceptive accuracy on the HRD task and interpersonal or parental accuracy on the CBR task. Specifically, greater heart rate overestimation (higher alpha scores) was marginally linked to poorer CBR task performance. While the linear interpretation of alpha scores is not straightforward, given that the most accurate values are those closest to zero, this seems to suggest that the perception of one's own cardiac signals is indeed linked to the discrimination of cardiac signals in others.

These findings support theories proposing that sensitivity to one's own interoceptive signals would facilitate their detection in others (Fotopoulou & Tsakiris, 2017; Steele et al., 2017) and are conceptually consistent with research linking interoception with recognition of others' emotional state (see Chapter 1 Section 1.2) and to broader social constructs such as empathy and social connection (Arnold et al., 2019; Ernst et al., 2013; Ferri et al., 2013). As mentioned, within social and embodied cognition research, concepts such as the mirror neuron system and embodied simulation have been used

to explain how mirroring mechanisms support the inference of others' mental states and emotions (Bastiaansen et al., 2009; Gallese, 2003; Keysers et al., 2018). The present findings indirectly suggest that these mirroring processes might extend beyond somatosensory-motor networks and exteroceptive or proprioceptive modalities (e.g., vision, audition, motor activity) to include interoceptive processing.

In contrast, cross-dimensional associations were absent in this thesis. Self-reported interoceptive sensibility (MAIA-2) did not relate to objective CBR task performance in either sample. These null findings coincide with previous evidence that subjective and objective measures of interoception may diverge (Brewer et al., 2021; Murphy et al., 2019), highlighting the importance of distinguishing between beliefs about interoception and objective ability and further supporting the idea that these two dimensions measure distinct aspects of the same overarching construct and may relate differently to other psychosocial traits.

Summary. Taken together, the findings in this section suggest that individual and interpersonal or parental interoception are indeed related, but in a dimension-specific manner: subjective beliefs about one's own signals align with subjective beliefs about others, while objective accuracy in one's own interoception somewhat aligns with objective accuracy in detecting others' states. This pattern of results suggests that mirroring mechanisms known to support theory of mind and inference of others' mental states might also extend to interoceptive processing.

5.3 Relationships With Psychosocial Factors

An additional aim of this thesis was to identify potential psychosocial factors that could underlie or relate to interpersonal or parental interoception. Interoception plays an important role in emotional processes, with ample evidence from neurobiological, physiological, and behavioural research (see Chapter 1 Section 1.2). In turn, impaired or atypical interoception has been linked to a variety of mental health conditions that affect self-focused emotional control, such as mood and anxiety disorders (see Chapter 1 Section 1.2.1). Moreover, mentalisation and parental mentalising abilities have also been linked to emotion regulation (Schultheis et al., 2019), mental health symptoms (Luyten, Mayes, et al., 2017b; Nobre-Trindade et al., 2021), and attachment

styles (Bouchard et al., 2008; Luyten, Mayes, et al., 2017b; Slade et al., 2005). Therefore, relationships between interpersonal or parental interoception and emotion regulation, mental health symptoms, and attachment styles were investigated.

With respect to emotion regulation and mental health, subjective and objective measures of interpersonal and parental interoception showed distinct patterns. Subjective parental interoception (PIQ scores) was linked to fewer emotion regulation difficulties in both Chapters 2 and 4, supporting the idea that parental interoceptive sensibility is linked to reflective and regulatory processes. In contrast, no associations were observed between the PIQ and mental health symptoms. The absence of such effects might indicate that these symptoms primarily relate to self-focused interoception and do not extend to subjective parental interoception. Another possibility is that the relatively limited variability in symptom severity within the samples reduced the likelihood of detecting effects.

Relationships with objective parental interoception (CBR task performance) were less consistent with expectations. In non-parent adults (Chapter 3), accuracy was unrelated to emotion regulation skills, but positively associated with anxiety and stress, echoing some findings that higher anxiety may sharpen interoceptive accuracy through hypervigilance to bodily signals (Domschke et al., 2010; Van der Does et al., 2000). In parents (Chapter 4), however, better accuracy was linked to greater emotion regulation difficulties and showed a trend toward higher stress. This suggests that higher accuracy in detecting children's cardiac states may not always be adaptive; it could reflect over-attentiveness to bodily cues at the expense of broader regulatory processes. A possibility is that successful regulation of children depends less on detecting their exact physiological state and more on projecting or predicting it. Kirsch et al. (2023) found that mothers often rely more on their own bodily feelings when judging their child's states, reflecting an egocentric bias. Importantly, parents' role extends beyond responding to immediate signals to supporting anticipatory ("allostatic") regulation by considering cultural, social, physical and contextual factors (Atzil & Barrett, 2017; Fotopoulou & Tsakiris, 2017; Fotopoulou et al., 2022). Such biases could therefore facilitate children's adaptive regulation within their broader environment.

Regarding attachment style, subjective and objective measures also diverged. PIQ scores were negatively associated with avoidant attachment in Chapter 2 and with anxious attachment in Chapter 4. In turn, CBR task performance was positively associated with anxious attachment in parents (Chapter 4) but not in a non-parent adult sample (Chapter 3). One explanation is that anxious attachment involves hypervigilance to relational cues, which could enhance accuracy on objective tasks but simultaneously undermine subjective confidence, leading to lower self-report scores. This mirrors the dissociation observed with emotion regulation, where higher objective performance was linked to more difficulties but higher subjective beliefs to fewer. Moreover, a possible explanation for the lack of association in the non-parent sample could be that attachment-related processes were not sufficiently engaged due to the unfamiliarity of the stimuli.

This pattern, where greater accuracy is not necessarily adaptive, also resonates with theoretical formulations and evidence from the parental mentalising literature. In this field, both very high and very low levels of mentalising are considered maladaptive. For instance, healthy parental reflective functioning is characterised by genuine curiosity about the child's internal states and an acknowledgement of their opacity, whereas excessive certainty about those states reflects intrusive or "hypermentalising" tendencies and has been linked to anxious attachment (Luyten, Mayes, et al., 2017b; Luyten, Nijssens, et al., 2017). Some developmental theories further emphasise that mentalising and parental sensitivity or responsiveness are not meant to be perfect; rather, some degree of incongruence can be beneficial and may facilitate the child's individuation and differentiation from the parent (Fotopoulou & Tsakiris, 2017; Mahler, 1974; Winnicott, 1965). Although the mechanisms underlying objective parental interoception may differ (i.e., recognising the opacity of internal states is not equivalent to being less accurate in perceiving them), these parallels may nonetheless guide novel theoretical explanations and hypotheses for testing. For instance, future work could directly examine whether parental interoception indeed shows a non-linear relationship with mental health, whether attachment anxiety or parental stress moderate its impact on child outcomes, or whether its adaptive value shifts with children's developmental trajectory (e.g., higher accuracy may be more beneficial during infancy but less so in later stages).

Summary. Overall, the results suggest that psychosocial correlates of interpersonal and parental interoception depend on both the dimension of measurement (objective vs. subjective) and the construct under study. Subjective beliefs about parental interoception (PIQ) appear to align with adaptive patterns, including better emotion regulation and less avoidant attachment, whereas objective performance (CBR task) showed less straightforward or even counterintuitive associations, particularly with stress, anxiety, emotion regulation, and anxious attachment. These findings support the view that interoception is multidimensional and that higher accuracy is not inherently beneficial; instead, the most adaptive outcomes may lie in flexible, context-dependent balances between extremes. Nevertheless, it is also important to note in terms of the objective dimension that the CBR task evaluates performance only within the cardiac modality. Emotion regulation, mental health symptoms, and attachment style may relate differently to parental interoceptive performance in other modalities. Future research should extend these investigations to other interoceptive modalities, clinical populations, and longitudinal designs to clarify causal pathways and reach broader and more definitive conclusions.

5.4 Effect on Child Outcomes

The concept of parental interoception was introduced in this thesis given its potential relevance for the development of interoception. If parents' ability to infer or "mentalise" their children's interoceptive signals is linked to children's own regulation processes, this might be reflected in children's socioemotional outcomes. Research shows that parents influence children's physiological regulation (see Chapter 1 Section 1.3.1) and that parents' ability to read and respond to their children's mental states impacts socioemotional development (see Chapter 1 Section 1.3.2). Therefore, one final aim for this thesis was to investigate whether parental interoception predicts children's socioemotional outcomes, including emotion regulation skills and behavioural problems.

The findings provide preliminary support for this possibility, although results from subjective (PIQ) and objective (CBR task) measures diverged. Subjective parental interoception significantly predicted children's prosocial behaviour in both Chapter 2 and Chapter 4 and was negatively associated with internalizing and externalizing

behaviours in Chapter 2. These results suggest that parents' subjective beliefs about their ability to notice, interpret, and respond to children's bodily signals are linked to more adaptive socioemotional development. As reviewed in Chapter 1 Section 1.3.2, parental responsiveness to children's mental and emotional states plays a crucial role in their cognitive and socioemotional development; the present findings extend this work by suggesting that responsiveness to children's interoceptive states may also contribute.

In contrast, results from the CBR task revealed a more complex pattern. Greater accuracy was marginally associated with less adaptive child outcomes, including higher emotional lability and internalising behaviours. Emotional lability refers to reactivity, mood swings, and inflexibility; while internalising behaviours include difficulties such as anxiety, sadness, and peer-related challenges. One possible mechanism explaining these results, informed by earlier results in this thesis, is that greater accuracy may be tied to parental hypervigilance, stress, or regulation difficulties, which in turn could negatively affect parenting behaviours. Supporting this interpretation, research has shown that parents with greater emotion regulation difficulties are more likely to have children who display similar difficulties and internalising symptoms (Zimmer-Gembeck et al., 2022). It is possible, then, that heightened parental sensitivity to children's bodily signals, when driven by anxious mechanisms, transmits vulnerability through negative parenting practices such as unsupportive responses to children's emotions, lack of warmth, or hostility. This interpretation aligns with theories of parental emotion socialisation, which emphasise caregivers' role in shaping children's emotional and regulatory capacities (Eisenberg et al., 1998).

Some limitations should be considered, the main one being that child socioemotional outcomes in this thesis were assessed exclusively through parent-reported measures. Beyond the general limitations of self-report methods (discussed below), it is important to note that, because parents rated both their child outcomes and their own traits, these results rely on a single informant, which might provide a restricted perspective. Biases present in parents could influence both sets of ratings. More comprehensive approaches would involve obtaining reports from multiple sources, such as children themselves (with age-appropriate methods) or other relevant adults, such as teachers.

Future research could also benefit from incorporating behavioural or observational methods to capture a fuller picture of child socioemotional functioning.

Furthermore, future studies could directly assess children's interoceptive abilities, which were not examined in the present thesis. Various age-appropriate methods are currently available (see Addabbo & Milani, 2025 for a review), but the dimensions measured and methodologies used differ across developmental stages. For example, in infancy, neurobehavioral and looking-time paradigms have been employed (Imafuku et al., 2023; Maister et al., 2017; Tünte et al., 2024). In pre-school aged children, adapted heartbeat tracking tasks such as the Jumping-Jack Paradigm (Schaan et al., 2019) have been used, whereas for school aged children, some heartbeat tracking tasks and self-reports, such as the MAIA Youth Version (JJP; Jones et al., 2021), are available.

Summary. Taken together, the findings presented in this section suggest that parental interoception has some impact on child socioemotional outcomes. Whereas subjective beliefs about interoceptive caregiving are associated with more adaptive outcomes, heightened objective accuracy may reflect hypervigilance and regulation difficulties that might undermine children's emotional adjustment, suggesting again that the most adaptive or healthiest outcome in this ability might lie somewhere between the extremes. Moreover, future research should incorporate child outcome measures from multiple sources and methods to capture a fuller picture of child socioemotional functioning and directly assess children's interoceptive abilities. For example, studies could combine both parent and teacher reports with child self-reports (when appropriate), use behavioural tasks to assess outcomes such as emotion regulation skills (e.g., frustration or problem-solving tasks), or employ adapted heartbeat tracking tasks, such as the JJP, to evaluate IA.

5.5 General Limitations

Some of the limitations and future directions for research have been addressed in each of the previous sections; however, broader limitations of this thesis will be discussed below including the validity of the measures used, sample characteristics, and conceptual scope.

5.5.1 Validity of Measures

Self-report measures were used in this thesis to assess subjective interoception, psychosocial traits, and child outcomes. These measures provide valuable insights into participants' self-perceptions and beliefs, as individuals are the only ones who can report on private behaviours and intrapsychic experiences, such as their thoughts and feelings. Nevertheless, some inherent limitations of these measures must be acknowledged. One limitation is that participants might respond in ways they perceive as socially desirable or in line with what they believe the researcher expects, rather than answering honestly, an issue often referred to as *social desirability bias*. Another limitation is that individuals may lack the self-awareness necessary to provide accurate reports of their own behaviour or characteristics. However, even if participants are not fully self-aware, their self-perceptions remain valuable, as they can influence how they behave and interact with the world. Additional limitations include memory errors, whereby participants' reports might be biased due to inaccurate recall of past emotions or behaviours; response styles, such as consistently choosing extreme options or showing acquiescence (i.e., a tendency to agree); and context or cultural influences, as reports may vary depending on participants' mood, circumstances, or cultural norms (Paulhus & Vazire, 2007).

Specifically within interoception research, this thesis used primarily the MAIA-2 as a measure of IS, and the newly developed PIQ for subjective parental interoception. Given that both of these questionnaires measure features of attention, regulation, and mentalisation, their use in the current thesis seemed relevant. However, given the divergence between subjective measures of interoception (Desmedt et al., 2022; Murphy et al., 2020), making links or comparing results with studies using different measures will be challenging, as the specific features assessed might differ, for example, with studies using the IAS (Murphy et al., 2020), which is a one-dimensional measure that focuses solely on beliefs about accuracy.

Regarding objective measures of interoception, as outlined in Chapter 1 (Section 1.1.1), assessing IA is inherently challenging given that interoceptive signals cannot be directly assessed or manipulated (Brewer et al., 2021). Research has predominantly focused on the cardiac domain, largely because cardiac signals can be

measured non-invasively and with relative ease compared to other interoceptive modalities. Consequently, most established IA assessments have been developed and validated within this domain, such as the heartbeat counting task (HCT) or two-alternative forced-choice (2AFC) tasks. However, the validity of these tasks has been questioned due to methodological issues, such as the influence of prior beliefs, guessing strategies, or relying on assumptions about heartbeat sensations (Brenner & Ring, 2016; Desmedt et al., 2018; Desmedt, Luminet, Maurage, et al., 2023).

The measure used in this thesis to assess IA was the Heart Rate Discrimination (HRD) task. The HRD task addresses these limitations offering a measure not of accuracy per se but of the bias, called alpha, that is the error between the perceived heart rate versus the ground truth. Nevertheless, the task presents its own limitations, including reliance on working memory and difficulty in the interpretation of linear relationships between alpha and other variables, given that alpha values closest to zero represent the most accurate, while positive values represent overestimation and negative values underestimation of the heart rate. In the case of the CBR task, participants may also rely on strategies such as prior-beliefs or exteroceptive cues; however, because others' interoceptive states are not actually accessible or visible, it is plausible in this case that participants use this information to infer others' cardiac states and it should not be considered as inherent limitation of the assessment, but as possible mechanisms that should be further explored and measured.

5.5.2 Sample Characteristics

Some characteristics of the samples included across studies in the present thesis constitute further limitations. Overall, although participants' ethnic backgrounds were broadly similar to those of the United Kingdom, where around 80% of residents in England and Wales identified their ethnicity as "White" in the 2021 Census (Office for National Statistics, 2025), the overrepresentation of participants from White backgrounds in the parent samples may limit the generalisability of findings to more ethnically diverse groups. Moreover, most parent participants were in stable relationships, highly educated, and in full-time employment, which restricts applicability to families with different socioeconomic backgrounds and varied family structures (Bornstein et al., 2013; Henrich et al., 2010).

Additionally, the parent and non-parent samples differed in age and ethnicity groups, with younger adults of majority Asian background participating in Chapter 3 and older parents of majority White backgrounds in Chapters 2 and 4; such differences might influence psychosocial traits (e.g., Windsor & Anstey, 2010) and complicate comparisons between studies. Gender imbalances were also present in Chapters 3 and 4, where participants were predominantly women, limiting gender difference analyses and potentially biasing results toward dynamics more applicable to women or mothers. In fact, research on parental mentalising has predominantly been conducted with mothers, and studies including fathers have found that they present lower scores (Trepia et al., 2025). Furthermore, sample sizes for Chapters 3 and 4 were relatively small, reducing statistical power and potentially increasing the likelihood of Type II errors.

5.5.3 Conceptual Scope

A further limitation relates to the conceptual scope of the present thesis. While the studies presented addressed relevant aspects of parental interoception, individual interoception, and parental mentalising, they inevitably capture only a subset of the broader constructs under investigation.

Firstly, while interoception is a multidimensional and multimodal construct, the present thesis focused only on interoceptive accuracy (IA) and sensibility (IS), with objective measurement restricted to the cardiac modality. However, other dimensions might also be relevant to investigate, as individual differences in these could influence psychosocial traits, particularly emotion processes and mental health. Khalsa et al. (2018) suggest that atypical interoception in clinical populations may manifest in several ways, including distorted physiological sensitivity, attentional bias (e.g., hypervigilance), cognitive bias (e.g., catastrophizing), abnormal sensibility, and impaired insight. The latter dimension, interoceptive insight, refers to a metacognitive measure of knowledge and confidence in one's own IA (Garfinkel & Critchley, 2013; Khalsa et al., 2018) and is typically operationalised as the correspondence between IA and IS, assessed via questionnaires or confidence ratings (Murphy et al., 2019; Suksasilp & Garfinkel, 2022). While this thesis examined IA, IS, and their associations, it did not include formal metacognitive indices, such as difference scores or signal

detection theory estimates of metacognitive sensitivity and insight (e.g., meta- d' or M-ratio).

Beyond interoceptive dimensions, objective measures in this thesis were limited to the cardiac domain. This mirrors a broader trend in IA research, where cardiac signals are frequently used due to their non-invasive and relative ease in measurement. While this facilitates comparisons with existing research, it also narrows the scope of the findings. Evidence from the individual interoception literature suggests that performance varies across modalities, and psychosocial traits might relate differently to parental interoceptive accuracy in different bodily domains. Moreover, caregiving practices and the parental role in supporting children's homeostasis and self-regulation surely involve a wide range of interoceptive signals and sensations that extend beyond the cardiac domain, including hunger, temperature, energy levels, affective touch, inflammation or illness cues, among others. While the PIQ offers a more multimodal and general appraisal of interoceptive domains at the subjective level, objective assessments of parental interoception would also benefit from incorporating a broader range of bodily axes.

The methodological design also restricted the conceptual scope given that all studies in this thesis were cross-sectional. This limits the ability to test causal relationships and to draw conclusions about developmental trajectories, which is particularly relevant when investigating the development of self-regulation or other abilities that potentially influence well-being. Longitudinal designs would be necessary to determine how parental interoception and related parenting behaviours or traits influence child interoceptive and emotional outcomes over time.

Furthermore, because the focus in this thesis was on parental ability, and child outcomes were assessed only through parental reports, the bidirectionality and reciprocity of parent-child interactions was not captured. No interactive assessments or observations of live parent-child interactions were included, which limits the extent to which the findings reflect the dynamic process of mutual influence between parents and children. Parental interoception is very likely influenced by reciprocal dynamics, indeed, both parental mentalising and synchrony have been described as inherently reciprocal processes. Parental mentalising is a mutually rewarding process, as parents

continuously adapt their behaviour and reflections according to the child's behaviour, (Shai & Belsky, 2017; Sharp & Fonagy, 2008). Similarly, research on physiological synchrony demonstrates that parents and children influence each other's physiological states during interaction, engaging in physiological contagion or co-regulation (Birk et al., 2022; Davis et al., 2018; Leclère et al., 2014).

This omission could be particularly relevant given the findings suggesting that higher parental interoceptive accuracy was not necessarily adaptive and could predict some maladaptive child outcomes. Parental stress and anxiety can influence children's emotion regulation and risk for internalizing behaviours (Zimmer-Gembeck et al., 2022); however, the child's behaviour and temperament can also shape parental responses and influence parental behaviours and symptoms, sometimes eliciting more negative or unsupportive behaviours (Fanti et al., 2013; Neece et al., 2012). By relying exclusively on parental reports and parent-focused assessments, these reciprocal influences could not be captured.

Finally, it has been proposed that the impact of interoception goes beyond homeostatic control to allostatic regulation (Barrett & Simmons, 2015). This is relevant in parent-child dynamics as the parental role involves not only moment-to-moment homeostatic regulation, but anticipatory regulation as well, where parents scaffold children's adaptation to contextual demands (Atzil & Barrett, 2017; Fotopoulou & Tsakiris, 2017; Fotopoulou et al., 2022). However, the methods employed in this thesis did not allow for examination of these broader regulatory dynamics.

5.6 Directions for Future Research

Considering the findings and limitations of this thesis, several directions for future research can be identified. Methodologically, future studies could focus on broadening the range of measures used to assess parental interoception to provide a more comprehensive view of this ability. This could involve incorporating additional interoceptive dimensions such as interoceptive insight, as well as lower-level dimensions, such as signal strength. Extending objective assessments beyond the cardiac domain to include a wider variety of bodily axes would also be valuable. Moreover, using multimethod approaches that combine self-report, behavioural,

physiological, neurobiological, and observational data, alongside more ecologically valid designs, particularly interactive and longitudinal assessments, would strengthen the research in this field.

In turn, these methodological advances could both a) help clarify or confirm theoretical explanations of the current results, and b) enable investigation of concepts and theories that are relevant but laid beyond the scope of this thesis. In particular, future research could examine how bidirectionality and reciprocity operate in parental interoception and children's development of self-regulation. Longitudinal and interactive approaches would also allow the examination of maladaptive cycles of co-regulation and clarify processes of allostatic regulation in parent-child dyads. Research in clinical populations would also be highly valuable, as it could reveal whether non-linear patterns indeed emerge in relation to parental interoception and parent and child outcomes. Greater attention to sample diversity, including fathers, non-traditional families, and participants from diverse ethnic and socioeconomic backgrounds, would also improve the generalisability of findings and help identify other potential moderating factors.

Finally, an additional key question for future research concerns the developmental significance of parental interoception. This central concept for the thesis was introduced given its potential relevance for the development of interoceptive abilities in children. Therefore, a critical question for future research is whether parental interoception not only shapes child socioemotional outcomes, as shown in the present results, but also directly influences the development of interoception itself. This could be explicitly studied using the novel measures presented in this thesis, alongside any further methodological advancements and appropriate child-focused tools (see Addabbo & Milani, 2025 for a review), with longitudinal studies and considering a wider age range for children.

5.7 Concluding Remarks

This thesis aimed to investigate **parental interoception**, a concept introduced to describe parents' ability to notice, attend to, understand, and respond to their children's interoceptive signals and states. Both objective and subjective measures

were developed and employed, demonstrating that this ability can be reliably assessed and that meaningful individual differences exist, linking parental interoception to important psychosocial traits in parents and socioemotional outcomes in children.

The findings support the existence of parental interoception as a complex, multidimensional construct connected to individual interoceptive abilities. Subjective parental interoception was associated with more adaptive outcomes, including better emotion regulation, less avoidant attachment, and higher child prosocial behaviour. In contrast, objective parental interoception showed patterns suggesting that higher accuracy may relate to emotion regulation difficulties, increased stress and anxiety, and more child emotional and behavioural problems. These results raise the possibility that certain biases in parents' inferences about their children's interoceptive states may, in fact, be beneficial.

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Appendices

Appendix A. Chapter 2 – Phase 1 – Measures reviewed for item development.

Measure	Categories included	
	Interoception	Modalities
Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2; Mehling et al., 2018)	• Noticing (4) • Not-distracting (6) • Emotional awareness (5) • Body listening (3) • Attention regulation (7) • Self-regulation (4) • Not-worrying (5) • Trusting (3)	Respiratory Pain Proprioception
Interoception Sensory Questionnaire (ISQ; Fiene, Ireland, & Brownlow, 2018)	• Noticing body signals and sensations (8) • Interpretation of body signals (9) • Self-regulation (3)	Gastrointestinal Thermoregulation Pain Endocrine
Interoceptive Accuracy Scale (IAS; Murphy et al., 2019)	• Perception of interoceptive signals (21)	Cardiac Gastrointestinal Genitourinary Respiratory Thermoregulation Musculoskeletal Pain Endocrine Affective touch

Measure		Categories included
Body Awareness Questionnaire (BAQ; Shields, Mallory, & Simon, 1989)	• Sensitivity to body cycles and rhythms (5) • Detecting bodily change (5) • Predicting bodily reactions (6) • Predicting the onset of illness (2)	Gastrointestinal Vascular Musculoskeletal Endocrine Immune system Thermoregulation
Body Perception Questionnaire (BPQ; Porges, 1993)	• Awareness (45/26/12) • Stress response (10) • Autonomic nervous system reactivity (27/20) • Stress style (12) • Health history inventory (28)	Gastrointestinal Urinary Vestibular Respiratory Proprioception Touch Pain Musculoskeletal Immune system Endocrine Thermoregulation Cardiac Vascular
Body Responsiveness Questionnaire (BRQ; Tihanyi et al., 2017)	• Interoceptive awareness (4) • Perceived disconnection (3)	None
Reflective Functioning		
The Reflective Functioning Questionnaire (RFQ; Fonagy et al., 2016)	• Certainty • Uncertainty • Pre-mentalising	
Parental Reflective Functioning Questionnaire (PRFQ; Luyten et al., 2017)	• Certainty about Mental States • Interest and Curiosity	

Measure	Categories included
	Emotion Regulation
Emotion-Regulation Skills Questionnaire (ERSQ; Grant, Salsman, & Berking, 2018)	• Awareness • Sensation • Clarity • Understanding • Acceptance • Resilience • Compassionate self-support • Readiness to confront • Modification of negative emotions
Difficulties in Emotion Regulation Scale (DERS; Gratz, & Roemer, 2004)	• Non-acceptance of emotional responses • Difficulty engaging in goal-oriented behaviour • Impulse control difficulties • Lack of emotional awareness • Limited access to emotion regulation strategies • Lack of emotional clarity
Negative Mood Regulation Expectancies Scale (NMR Scale; Catanzaro, & Mearns, 1990)	• General • Behavioural (expecting behaviour to alleviate negative mood) • Cognitive (expecting cognition to alleviate negative mood)
Emotion Regulation Questionnaire (ERQ; Gross, & John, 2003)	• Cognitive reappraisal • Expressive suppression

Measure	Categories included
The Cognitive Emotion Regulation Questionnaire (CERQ; Garnefski, & Kraaij, 2007)	• Self-blame • Other-blame • Rumination • Catastrophizing • Putting into perspective • Positive refocusing • Positive reappraisal • Acceptance • Refocus
The Interpersonal Emotion Regulation Questionnaire (IERQ; Hofman et al., 2016)	• Enhancing positive affect • Perspective taking • Soothing • Social modelling
Emotion Regulation of Others and Self (EROS; Niven et al., 2011)	• Intrinsic (efforts to improve and/or worsen their own emotions) • Extrinsic (efforts to improve or worsen the emotions of others)
Difficulties in Interpersonal Regulation of Emotion (DIRE; Dixon-Gordon et al., 2018)	Intrapersonal • Accept • Avoid Interpersonal • Venting • Reassurance-seeking
Regulation of Emotions Questionnaire (REQ; Phillips, & Power, 2007)	• Internal functional • Internal dysfunctional • External functional • External dysfunctional

Measure	Categories included
Parental Assistance with Child Emotion Regulation (PACER) Questionnaire (Cohodes et al., 2020)	• Avoidance • Behavioural disengagement • Problem-solving • Social support search • Distraction • Rumination • Reappraisal • Acceptance • Expressive suppression • Venting
Children's Eating Behaviour Questionnaire (CEBQ; Wardle, 2001)	Feeding • Food responsiveness • Enjoyment of food • Emotional overeating • Desire to drink • Satiety responsiveness • Slowness in eating • Emotional undereating • Fussiness
Child Feeding Questionnaire (CFQ; Birch et al., 2001)	Perception & concerns about obesity risk • Perceived responsibility • Parent perceived weight • Perceived child weight • Parents' concerns about child weight Controlling feeding practices • Monitoring • Restriction • Pressure to eat

Measure	Categories included
Comprehensive Feeding Practices Questionnaire (CFPQ; Musher-Eizenman & Holub, 2007)	• Monitoring • Emotion regulation • Food as a reward • Child control • Modelling • Restriction for weight and restriction for health • Teaching nutrition • Encourage balance/variety • Pressure to eat • Healthy environment • Involvement
Family Mealtime Goals Questionnaire (Snuggs, Houston-Price, & Harvey, 2019)	• Stress/conflict avoidance • Homemade food • Shared family food • Family involvement in mealtimes • Price • Occasional treats • High/low fat regulation
The Pediatric Eating Assessment Tool (PediEAT; Thoyre et al., 2018)	• Physiologic symptoms • Problematic mealtime behaviours • Selective/Restrictive eating • Oral processing
Somatic Symptoms	
The Somatic Symptom Scale-8 (SSS-8; Gierk et al., 2014)	• Gastrointestinal symptoms • Pain • Cardiopulmonary • Fatigue

Measure	Categories included
Scale for Assessment of Somatic Symptoms (SASS; Desai et al., 2015)	• Pain related symptoms • Sensory somatic symptoms • Nonspecific somatic symptoms • Biological function related symptoms
PHQ-15 (Kroenke et al., 2002)	• Gastrointestinal symptoms • Pain • Cardiopulmonary • Fatigue • Menstrual cycle related symptoms
Somatization subscale from the Symptom Checklist 90-R (SCL-90-R; Derogatis, 1992)	• Pain • Fatigue • Gastrointestinal symptoms • Cardiopulmonary • Sensory
Attachment	
The Experiences in Close Relationships, Revised Questionnaire (ECR-R; Fraley et al., 2000)	• Avoidance (18) • Anxiety (18)
Revised Adult Attachment Scale (Collins, 1996)	• Close (comfortable with closeness and intimacy) (6) • Depend (feeling you can depend on others when needed) (6) • Anxiety (worried about being rejected or unloved) (6)

Parent-Child Observation¹ and Interview² Coding Systems

Measure	Categories included
Parental Embodied Mentalising (PEM; Shai, & Belsky, 2017) ¹	• Embodied circles of communication (ECC) initiators • Repetition vs. elaborate interactive sequence • Clarity of infant signaling • Whole body movement vs. only extremities • Ability to follow infant's mental state (kinesthetically manifested) without interrupting • Transition between ECCs • Frequency of extremely low PEM manifestations • Premature termination of ECCs.
The Reflective Functioning coding (Fonagy et al., 1998) ²	• Awareness of the nature of mental states • Explicit effort to tease out mental states underlying behaviour • Recognising developmental aspects of mental states • Mental states in relation to the interviewer
Insightfulness Assessment (Oppenheim, & Koren-Karie, 2013) ²	• Insight into child's motives • Openness/Flexibility of thought • Complexity in description of child • Maintenance of focus on child • Richness of description of child • Coherence of thought • Acceptance/Warmth • Anger • Concern/Worry • Separateness from child
Mind-mindedness coding manual (Meins, & Fernyhough, 2015) ^{1(infants),2} (children & older)	• Appropriate • Non-attuned

Measure	Categories included
Maternal Sensitivity Scale from the Emotional Availability Scales (Biringen et al., 2000) ¹	• Appropriateness • Timing • Flexibility • Quality and appropriateness of affect • Negotiation of conflictual situations

Appendix B. Chapter 2 – Phase 1 – Final version of the PIQ in this phase.

This questionnaire is divided in 2 parts. Each one refers to possible situations where parents may notice, understand, or respond to their baby's bodily sensations and bodily signals. These terms mean very similar things: the term **“bodily sensations”** means things like pain after a fall or due to illness, itching due to fabrics or allergies, pleasant touch by stroking or hugging a soft toy, hunger, thirst, feeling full and content after being fed, feeling fatigued or energised, feeling hot or cold, sweating related to being hot or being anxious, etc. The term **“bodily signals”** means signals related to the inside of the body, such as the beating heart, being out of breath after strenuous exercise or after a fearful experience, signals related to digestion, signals related to needing to go to the toilet, or needing to sleep, red burning cheeks when feeling shy, etc.

Please keep in mind that there are no right or wrong answers, you should choose the option that you think applies most to you generally.

Part 1

This set of questions will ask about your ability to notice, distinguish, and pay attention to your baby's body sensations (comfortable, uncomfortable, and neutral) and biological rhythms.

Please read each statement carefully and indicate if it applies to you generally in daily life. Remember that there are no right or wrong answers.

1	I can notice when my baby feels discomfort in their body (e.g., tummy ache, tiredness, nausea).	I can notice when my child feels discomfort in their body (e.g., tummy ache, tiredness, nausea).
2	I can notice changes in my baby's breathing, such as whether it slows down or speeds up.	I can notice changes in my child's breathing, such as whether it slows down or speeds up.
3	I tend to rely on the time of the day to help me know when my baby needs to eat or sleep.	I tend to rely on the time of the day to help me know when my child needs to eat or sleep.
4	I don't usually notice tension in my baby's body unless other people react to it.	I don't usually notice tension in my child's body unless other people react to it.
5	The only time I notice that my baby is hungry or tired is when they are crying.	The only time I notice that my child is hungry or tired is when they express it explicitly.
6	I notice when my baby is experiencing pleasant sensations in their body (e.g.,	I notice when my child is experiencing pleasant sensations in their body (e.g.,

	they are comfortable or enjoying being stroked).	they are comfortable or enjoying being stroked).
13	I can pay some attention to my baby's bodily sensations (e.g., if they feel comfortable, are feeling hot or cold, are in pain) even when there is a lot going on around me/us.	I can pay some attention to my child's bodily sensations (e.g., if they feel comfortable, are feeling hot or cold, are in pain) even when there is a lot going on around me/us.
14	When I am in conversation with someone, every now and then I switch my attention to my baby's bodily needs to make sure everything is alright.	When I am in conversation with someone, every now and then I switch my attention to my child's bodily needs to make sure everything is alright.
15	I can return my attention to my baby's bodily signals (e.g., heart rate, breathing, red cheeks) if I am distracted.	I can return my attention to my child's bodily signals (e.g., heart rate, breathing, red cheeks) if I am distracted.
16	I can refocus my attention from my own thoughts to sensing my baby's body.	I can refocus my attention from my own thoughts to understanding my child's bodily needs.
17	I can switch my attention between my baby's various bodily sensations (e.g., if they're getting hot while eating).	I can switch my attention between my child's various bodily sensations (e.g., if they're getting hot while eating).
30	I can distinguish between my baby's distress because of hunger and their distress because of lack of sleep.	I can distinguish between my child's distress because of hunger and their distress because of lack of sleep.
31	I can tell from my baby's body when is the "best" time for them to go to sleep at night.	I can tell from my child's body when is the "best" time for them to go to sleep at night.
32	I am aware of different cycles and rhythms in my baby's activity level throughout the day.	I am aware of different cycles and rhythms in my child's activity level throughout the day.
33	I cannot tell from my baby's body signals when is the "best" time for them to eat.	I cannot tell from my child's body signals when is the "best" time for them to eat.

(total # of items: 15)

Part 2

This slightly longer set of questions will ask about your ability to read, understand, and respond to your baby's bodily signals and sensations.

Please read each statement carefully and indicate if it applies to you generally in daily life. Remember that there are no right or wrong answers.

7	When my baby feels any physical pain, I quickly become overwhelmed.	When my child feels any physical pain, I quickly become overwhelmed.
8	I start to worry that something is seriously wrong if my baby feels mild bodily discomfort.	I start to worry that something is seriously wrong if my child feels mild bodily discomfort.

9	When I'm hungry I always think that my baby is hungry too.	When I'm hungry I always think that my child is hungry too.
10	When I am feeling happy, I find it difficult to notice unpleasant body sensations in my baby.	When I am feeling happy, I find it difficult to notice unpleasant body sensations in my child.
11	When my baby has a lot of energy, I always feel energised too.	When my child has a lot of energy, I always feel energised too.
12	I can only feel calm when I notice my baby's body is relaxed.	I can only feel calm when I notice my child's body is relaxed.
18	When something is distressing my baby, I can notice it in how their body reacts/changes.	When something is distressing my child, I can notice it in how their body reacts/changes.
19	I know when my baby is relaxed by noticing how their body changes.	I know when my child is relaxed by noticing how their body changes.
20	When something scares my baby, I can notice it in how their body becomes tense.	When something scares my child, I can notice it in how their body becomes tense.
21	I have difficulty making sense of my baby's emotions unless their body signals are very strong.	I have difficulty making sense of my child's emotions unless their body signals are very strong.
22	When my baby is tired, I can notice it in their body.	When my child is tired, I can notice it in their body.
23	I know when my baby is feeling too hot/cold, by noticing how their body changes.	I know when my child is feeling too hot/cold, by noticing how their body changes.
24	I can notice that my baby's body is less tense after a good feed (i.e., they are satisfied/not hungry anymore).	I can notice that my child's body is less tense after a good meal (i.e., they are satisfied/not hungry anymore).
25	I know when my baby needs to pass a stool by noticing how their body changes.	I know when my child needs to go to the toilet by noticing how their body changes.
26	I know in advance, by observing my baby's body, when they are getting ill.	I know in advance, by observing my child's body, when they are getting ill.
27	I have difficulty making sense of my baby's body signals unless they are very strong.	I have difficulty making sense of my child's body signals unless they are very strong.
28	I have difficulty recognising when my baby is hungry based on their body	I have difficulty recognising when my child is hungry based on their body.
29	Most times, when my baby's body signals a problem, I have difficulty working out what the problem might be (e.g., is hungry, tired, constipated).	Most times, when my child's body signals a problem, I have difficulty working out what the problem might be (e.g., is hungry, tired, constipated).
34	When my baby experiences mild tension in their body, I can use touch to help them reduce it.	When my child experiences mild tension in their body, I can use touch to help them reduce it.
35	When my baby is uncomfortable in their body (e.g., is tense, in pain, has gas), I find it difficult to help them feel better.	When my child is uncomfortable in their body (e.g., is tense, has tummy ache), I find it difficult to help them feel better.
36	I find it difficult to soothe my baby when they are ill.	I find it difficult to soothe my child when they are ill.

37	Most times, I find it difficult to comfort my baby when they are overtired.	Most times, I find it difficult to comfort my child when they are overtired after a long day.
38	When I sense my baby has a fast heartbeat, I can think of different solutions to help them regulate it.	When I sense my child has a fast heartbeat, I can think of different solutions to help them regulate it.
39	When my baby is hungry, I can distract them by singing or playing until I can feed them.	When my child is hungry, I can distract them by chatting or playing until I can offer them food.
40	When my baby's body is relaxed, I know how to slowly caress them to prolong this state.	When my child is relaxing during "downtime", I can stay calm myself to help them prolong their relaxation.
41	When my baby is full of energy, I can enhance this by playfully responding with energy of my own.	When my child is full of energy, I can enhance this by playfully responding with energy of my own.
42	I regularly observe my baby's body signals (e.g., breathing, bodily tension) to obtain information about their emotional state.	I regularly observe my child's body signals (e.g., breathing, bodily tension) to obtain information about their emotional state.
43	I frequently observe my baby's body to inform me about what they need.	I frequently observe my child's body to inform me about what they need.
44	I usually observe my baby's body signals to obtain information about how their body may feel.	I usually observe my child's body signals to obtain information about how their body may feel.
45	Observing my baby's body signals (e.g., heart rate) helps me understand them better.	Observing my child's body signals (e.g., heart rate) helps me understand them better.
46	When I don't know what my baby needs, my first instinct is to observe their body signals.	When I don't know what my child needs, my first instinct is to observe their body signals.
47	I am confident that my baby's body/body signals will communicate important/helpful information.	I am confident that my baby's body/body signals will communicate important/helpful information.
48	I am confident that my baby's body signals will let me know if something is wrong with them.	I am confident that my child's body signals will let me know if something is wrong with them.
49	I am confident that my baby's body will let me know what is good for them.	I am confident that my child's body will let me know what is good for them.

(total # of items: 35)

Note: reversed items are highlighted in orange.

Baby group

Item	<i>M</i>	<i>SD</i>	min	max	skewness	kurtosis
Noticing Bodily Sensations						
1	4.27	0.79	1	5	-1.48	3.26
2	4.18	0.90	1	5	-1.31	1.73
3	3.22	1.23	1	5	-0.28	-1.12
4	4.30	0.80	2	5	-1.08	0.72
5	4.31	0.91	1	5	-1.62	2.54
6	4.55	0.60	1	5	-1.50	4.43
Merger between parental and child states						
7	4.42	0.64	1	5	-1.18	2.92
8	4.57	0.61	2	5	-1.38	2.26
9	4.38	0.68	1	5	-1.30	3.61
10	4.38	0.70	1	5	-1.15	2.00
11	4.08	0.79	1	5	-1.12	2.17
12	4.26	0.80	1	5	-1.13	1.37
Holding Attention to Bodily Sensations						
13	4.19	0.83	1	5	-1.35	2.54
14	4.27	0.76	1	5	-1.32	3.04
15	3.77	1.15	1	5	-0.94	0.04
16	2.87	1.22	1	5	0.15	-1.09
17	2.85	1.19	1	5	0.10	-1.10
Linking Bodily Sensations to Emotions						
18	2.46	1.20	1	5	0.52	-0.85
19	1.83	0.89	1	5	1.15	1.06
20	3.05	1.19	1	5	-0.05	-1.09
21	3.40	1.08	1	5	-0.32	-0.77
Linking Bodily Sensations to Physiological States						
22	4.31	0.64	1	5	-1.08	3.26
23	4.32	0.66	2	5	-0.85	1.25
24	4.39	0.73	2	5	-1.16	1.19
25	3.83	0.92	1	5	-0.79	0.24
26	4.49	0.65	2	5	-1.32	2.28
27	4.02	0.80	1	5	-0.84	1.11
28	4.28	0.85	1	5	-1.34	1.84
29	3.92	1.05	1	5	-0.92	0.07
Noticing Bodily Cycles						
30	3.62	0.99	1	5	-0.54	-0.29
31	3.90	0.97	1	5	-0.81	0.19
32	4.08	0.89	1	5	-1.09	1.04
33	3.70	0.95	1	5	-0.62	-0.22
Regulation of Bodily States						
34	3.84	0.80	1	5	-0.95	1.40

35	3.50	1.08	1	5	-0.53	-0.69
36	3.65	1.12	1	5	-0.59	-0.63
37	3.30	1.24	1	5	-0.20	-1.21
38	3.34	0.99	1	5	-0.34	-0.62
39	3.53	1.08	1	5	-0.64	-0.48
40	3.89	0.89	1	5	-0.57	-0.21
41	4.28	0.82	1	5	-1.54	3.25
Epistemic Attitudes towards Bodily Signals						
42	3.94	0.90	1	5	-1.08	1.40
43	4.06	0.79	1	5	-0.98	1.27
44	4.07	0.73	1	5	-0.82	1.44
45	3.86	0.92	1	5	-0.73	0.22
46	3.94	0.93	1	5	-1.12	1.32
Trust and Self-efficacy						
47	4.23	0.75	1	5	-1.10	1.94
48	4.15	0.73	1	5	-0.82	1.31
49	3.92	0.82	1	5	-0.78	0.78

Child group

Item	<i>M</i>	<i>SD</i>	min	max	skewness	kurtosis
Noticing Bodily Sensations						
1	4.40	0.68	2	5	-1.10	1.46
2	4.12	0.93	1	5	-1.14	1.07
3	3.18	1.20	1	5	-0.38	-1.00
4	4.21	0.87	1	5	-1.14	1.04
5	4.21	0.92	1	5	-1.35	1.76
6	4.39	0.73	1	5	-1.34	2.32
Merger between parental and child states						
7	4.27	0.77	1	5	-1.40	3.28
8	4.26	0.82	1	5	-1.08	0.95
9	4.21	0.77	1	5	-0.97	1.17
10	4.31	0.73	1	5	-1.14	1.96
11	4.11	0.78	1	5	-0.98	1.51
12	4.25	0.78	1	5	-1.10	1.40
Holding Attention to Bodily Sensations						
13	4.14	0.87	1	5	-1.16	1.37
14	4.12	0.86	1	5	-1.16	1.33
15	3.70	1.14	1	5	-0.69	-0.49
16	2.60	1.25	1	5	0.35	-1.08
17	2.70	1.12	1	5	0.25	-0.96
Linking Bodily Sensations to Emotions						
18	2.80	1.20	1	5	0.13	-1.18

19	1.93	0.90	1	5	1.07	1.01
20	2.79	1.11	1	5	0.21	-0.87
21	3.21	1.14	1	5	-0.12	-0.95
Linking Bodily Sensations to Physiological States						
22	4.26	0.71	2	5	-0.97	1.40
23	4.20	0.74	1	5	-1.00	1.60
24	4.40	0.67	2	5	-1.03	1.33
25	3.91	0.94	1	5	-0.90	0.48
26	4.46	0.62	2	5	-1.07	1.80
27	3.96	0.86	1	5	-0.92	0.75
28	3.88	0.87	1	5	-0.83	0.57
29	4.04	0.98	1	5	-1.02	0.39
Noticing Bodily Cycles						
30	3.91	0.93	1	5	-0.96	0.66
31	3.90	0.99	1	5	-0.84	0.09
32	3.91	0.98	1	5	-0.81	-0.11
33	3.72	1.03	1	5	-0.72	-0.16
Regulation of Bodily States						
34	3.80	0.94	1	5	-0.63	-0.14
35	3.73	1.05	1	5	-0.72	-0.21
36	4.09	0.95	1	5	-1.03	0.49
37	3.50	1.18	1	5	-0.36	-1.06
38	3.43	1.00	1	5	-0.44	-0.36
39	3.62	0.94	1	5	-0.79	0.25
40	4.18	0.77	1	5	-0.87	0.90
41	3.91	0.90	1	5	-1.03	1.09
Epistemic Attitudes towards Bodily Signals						
42	3.73	1.03	1	5	-0.77	0.07
43	3.81	0.93	1	5	-0.94	0.83
44	3.87	0.80	1	5	-0.88	1.34
45	3.71	0.95	1	5	-0.80	0.37
46	3.71	0.93	1	5	-0.65	-0.05
Trust and Self-efficacy						
47	4.05	0.77	2	5	-0.63	0.22
48	4.03	0.80	1	5	-0.93	1.27
49	3.70	0.83	1	5	-0.43	0.00

Appendix D. Chapter 2 – Phase 2 – Complete EFA results.

Exploratory factor analyses (EFA) were carried out with polychoric correlations (for ordinal variables) and oblique rotation (allowing correlations between factors). To determine the ideal number of factors eigenvalues above 1 and the point of inflection from the scree plot were considered; however, Horn's Parallel Analysis was used to define this, as it considers the adjusted eigenvalues. Items with low factor loadings (< 0.4), cross-loadings, or low item communality (< 0.3) were deleted and the EFA was repeated until a clear and coherent structure with good factor loadings appeared. The first two rounds are shown below, the third and last EFA is presented in the main text.

Baby Group – First round of EFA

Parallel analysis retained eight factors. Items 45, 20, 40, 35, 15, 16, 30, 25, 47, 26, and 31 were deleted due to low loadings and/or cross-loadings. Factor loadings and communality shown below:

Item #	F1	F2	F3	F4	F5	F6	F7	F8	Communality	Subscale	Item
43	0.803								0.787	Epistemic Attitudes Towards Bodily Signals	I frequently observe my baby's body to inform me about what they need.
42	0.689								0.622	Epistemic Attitudes Towards Bodily Signals	I regularly observe my baby's body signals (e.g., breathing, bodily tension) to obtain information about their emotional state.
44	0.634								0.616	Epistemic Attitudes Towards Bodily Signals	I usually observe my baby's body signals to obtain information about how their body may feel.

46	0.479	0.226	-0.22		0.207	0.421	Epistemic Attitudes Towards Bodily Signals	When I don't know what my baby needs, my first instinct is to observe their body signals.	
45	0.361				0.35	0.205	0.493	Epistemic Attitudes Towards Bodily Signals	Observing my baby's body signals (e.g., heart rate) helps me understand them better.
19		0.608					0.745	Linking Bodily Sensations to Emotions	I know when my baby is relaxed by noticing how their body changes.
6		0.544	0.367				0.716	Noticing Bodily Sensations	I notice when my baby is experiencing pleasant sensations in their body (e.g., they are comfortable or enjoying being stroked).
41		0.532					0.434	Regulation of Bodily States	When my baby is full of energy, I can enhance this by playfully responding with energy of my own.
18		0.432		0.257			0.57	Linking Bodily Sensations to Emotions	When something is distressing my baby, I can notice it in how their body reacts/changes.
24		0.411				0.223	0.467	Linking Bodily Sensations to Physiological States	I can notice that my baby's body is less tense after a good feed (i.e., they are satisfied/not hungry anymore).
22	0.204	0.401	0.208			-0.21	0.573	Linking Bodily Sensations to Physiological States	When my baby is tired, I can notice it in their body.
20	0.211	0.356					0.43	Linking Bodily Sensations to Emotions	When something scares my baby, I can notice it in how their body becomes tense.
40		0.348			0.317		0.365	Regulation of Bodily States	When my baby's body is relaxed, I know how to slowly caress them to prolong this state.
37r			0.664		0.283		0.558	Regulation of Bodily States	Most times, I find it difficult to comfort my baby when they are overtired.
21r		0.583		0.339			0.682	Linking Bodily Sensations to Emotions	I have difficulty making sense of my baby's emotions unless their body signals are very strong.

5r	0.201	0.514			-0.28	0.509	Noticing Bodily Sensations	The only time I notice that my baby is hungry or tired is when they are crying.
29r		0.507			0.231	0.51	Linking Bodily Sensations to Physiological States	Most times, when my baby's body signals a problem, I have difficulty working out what the problem might be (e.g., is hungry, tired, constipated).
10		-0.44			0.261	0.614	Merger Between Parental and Child States	When I am feeling happy, I find it difficult to notice unpleasant body sensations in my baby.
28r		0.44	0.23	0.282		0.541	Linking Bodily Sensations to Physiological States	I have difficulty recognising when my baby is hungry based on their body
4r	0.261	0.402			0.297	0.485	Noticing Bodily Sensations	I don't usually notice tension in my baby's body unless other people react to it.
35r		0.366	0.206			0.392	Regulation of Bodily States	When my baby is uncomfortable in their body (e.g., is tense, in pain, has gas), I find it difficult to help them feel better.
17			0.603			0.709	Holding Attention to Bodily Sensations	I can switch my attention between my baby's various bodily sensations (e.g., if they're getting hot while eating).
32	0.258	0.475			0.208	0.598	Noticing Bodily Cycles	I am aware of different cycles and rhythms in my baby's activity level throughout the day.
1		0.45				0.402	Noticing Bodily Sensations	I can notice when my baby feels discomfort in their body (e.g., tummy ache, tiredness, nausea).
15		0.389			0.202	0.522	Holding Attention to Bodily Sensations	I can return my attention to my baby's bodily signals (e.g., heart rate, breathing, red cheeks) if I am distracted.
16	0.298	0.345				0.68	Holding Attention to Bodily Sensations	I can refocus my attention from my own thoughts to sensing my baby's body.
30		0.305	0.267	0.293		0.52	Noticing Bodily Cycles	I can distinguish between my baby's distress because of hunger and their distress because of lack of sleep.

25		0.219				0.276	Linking Bodily Sensations to Physiological States	I know when my baby needs to pass a stool by noticing how their body changes.
48			0.842			0.786	Trust and Self-Efficacy	I am confident that my baby's body signals will let me know if something is wrong with them.
49			0.555	0.284		0.505	Trust and Self-Efficacy	I am confident that my baby's body will let me know what is good for them.
47	0.352	0.21		0.38		0.593	Trust and Self-Efficacy	I am confident that my baby's body/body signals will communicate important/helpful information.
26			0.243	0.339		0.389	Linking Bodily Sensations to Physiological States	I know in advance, by observing my baby's body, when they are getting ill.
31			0.255	0.283	0.234	0.46	Noticing Bodily Cycles	I can tell from my baby's body when is the "best" time for them to go to sleep at night.
27r				0.942		0.995	Linking Bodily Sensations to Physiological States	I have difficulty making sense of my baby's body signals unless they are very strong.
34			0.223		0.569	0.593	Regulation of Bodily States	When my baby experiences mild tension in their body, I can use touch to help them reduce it.
38					0.556	0.5	Regulation of Bodily States	When I sense my baby has a fast heartbeat, I can think of different solutions to help them regulate it.
23					0.3	0.431	Linking Bodily Sensations to Physiological States	I know when my baby is feeling too hot/cold, by noticing how their body changes.
13			0.274	0.349		0.488	Holding Attention to Bodily Sensations	I can pay some attention to my baby's bodily sensations (e.g., if they feel comfortable, are feeling hot or cold, are in pain) even when there is a lot going on around me/us.
2					0.437	0.494	Noticing Bodily Sensations	I can notice changes in my baby's breathing, such as whether it slows down or speeds up.

Baby Group – Second round of EFA

Parallel analysis retained six factors. Items 18, 41, 1, 24, 38, 13, and 2 were deleted due to low loadings. Factor loadings and communality shown below:

Item #	F1	F2	F3	F4	F5	F6	Communality	Subscale	Item
21r	0.844						0.685	Linking Bodily Sensations to Emotions	I have difficulty making sense of my baby's emotions unless their body signals are very strong.
28r	0.708						0.553	Linking Bodily Sensations to Physiological States	I have difficulty recognising when my baby is hungry based on their body
29r	0.707						0.523	Linking Bodily Sensations to Physiological States	Most times, when my baby's body signals a problem, I have difficulty working out what the problem might be (e.g., is hungry, tired, constipated).
27r	0.673						0.636	Linking Bodily Sensations to Physiological States	I have difficulty making sense of my baby's body signals unless they are very strong.
37r	0.581						0.39	Regulation of Bodily States	Most times, I find it difficult to comfort my baby when they are overtired.
10	-0.55	-0.21				0.359	0.634	Merger Between Parental and Child States	When I am feeling happy, I find it difficult to notice unpleasant body sensations in my baby.
4r	0.548						0.416	Noticing Bodily Sensations	I don't usually notice tension in my baby's body unless other people react to it.
5r	0.495		0.208	-0.21			0.433	Noticing Bodily Sensations	The only time I notice that my baby is hungry or tired is when they are crying.
43		0.807					0.744	Epistemic Attitudes Towards Bodily Signals	I frequently observe my baby's body to inform me about what they need.
44		0.731					0.633	Epistemic Attitudes Towards Bodily Signals	I usually observe my baby's body signals to obtain information about how their body may feel.
42		0.665			0.258		0.589	Epistemic Attitudes Towards Bodily Signals	I regularly observe my baby's body signals (e.g., breathing, bodily tension) to obtain information about their emotional state.

46	0.565			0.37	Epistemic Attitudes Towards Bodily Signals	When I don't know what my baby needs, my first instinct is to observe their body signals.		
18	0.241	0.226		0.453	Linking Bodily Sensations to Emotions	When something is distressing my baby, I can notice it in how their body reacts/changes.		
6		0.976		0.995	Noticing Bodily Sensations	I notice when my baby is experiencing pleasant sensations in their body (e.g., they are comfortable or enjoying being stroked).		
19	0.274	0.423		0.66	Linking Bodily Sensations to Emotions	I know when my baby is relaxed by noticing how their body changes.		
22	0.225	0.399	0.205	0.547	Linking Bodily Sensations to Physiological States	When my baby is tired, I can notice it in their body.		
41		0.356		0.307	Regulation of Bodily States	When my baby is full of energy, I can enhance this by playfully responding with energy of my own.		
1		0.315	0.235	0.341	Noticing Bodily Sensations	I can notice when my baby feels discomfort in their body (e.g., tummy ache, tiredness, nausea).		
49			0.753	0.593	Trust and Self-Efficacy	I am confident that my baby's body will let me know what is good for them.		
48			0.525	0.529	Trust and Self-Efficacy	I am confident that my baby's body signals will let me know if something is wrong with them.		
34			0.516	0.26	Regulation of Bodily States	When my baby experiences mild tension in their body, I can use touch to help them reduce it.		
24		0.294	0.384	0.442	Linking Bodily Sensations to Physiological States	I can notice that my baby's body is less tense after a good feed (i.e., they are satisfied/not hungry anymore).		
38			0.222	0.218	Regulation of Bodily States	When I sense my baby has a fast heartbeat, I can think of different solutions to help them regulate it.		
17				0.806	0.849	Holding Attention to Bodily Sensations	I can switch my attention between my baby's various bodily sensations (e.g., if they're getting hot while eating).	
32				0.475	0.211	0.582	Noticing Bodily Cycles	I am aware of different cycles and rhythms in my baby's activity level throughout the day.
13			0.332	0.281	-0.48	0.76	Holding Attention to Bodily Sensations	I can pay some attention to my baby's bodily sensations (e.g., if they feel comfortable, are feeling hot or cold, are in pain) even when there is a lot going on around me/us.

2	0.222	-0.24	0.386	Noticing Bodily Sensations	I can notice changes in my baby's breathing, such as whether it slows down or speeds up.
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Child Group – First round of EFA

Parallel analysis retained six factors. Items 32, 1, 2, 19, 46, 26, 25, 31, 30, 24, 29, 5, 33, 10 and 40 were deleted due to low loadings or cross-loadings. Factor loadings and communality shown below:

Item #	F1	F2	F3	F4	F5	F6	Communality	Subscale	Item
17	0.701			0.201			0.702	Holding Attention to Bodily Sensations	I can switch my attention between my child's various bodily sensations (e.g., if they're getting hot while eating).
15	0.667						0.622	Holding Attention to Bodily Sensations	I can return my attention to my child's bodily signals (e.g., heart rate, breathing, red cheeks) if I am distracted.
16	0.62						0.6	Holding Attention to Bodily Sensations	I can refocus my attention from my own thoughts to understanding my child's bodily needs.
6	0.562					0.248	0.574	Noticing Bodily Sensations	I notice when my child is experiencing pleasant sensations in their body (e.g., they are comfortable or enjoying being stroked).
4	0.477	0.389		-0.2	0.266		0.668	Holding Attention to Bodily Sensations	When I am in conversation with someone, every now and then I switch my attention to my child's bodily needs to make sure everything is alright.
13	0.419	0.244			0.221		0.525	Holding Attention to Bodily Sensations	I can pay some attention to my child's bodily sensations (e.g., if they feel comfortable, are feeling hot or cold, are in pain) even when there is a lot going on around me/us.
4r	0.411			0.335			0.539	Noticing Bodily Sensations	I don't usually notice tension in my child's body unless other people react to it.

32	0.375			0.385	Noticing Bodily Cycles	I am aware of different cycles and rhythms in my child's activity level throughout the day.		
1	0.362		0.27	0.397	Noticing Bodily Sensations	I can notice when my child feels discomfort in their body (e.g., tummy ache, tiredness, nausea).		
43		0.779		0.748	Epistemic Attitudes Towards Bodily Signals	I frequently observe my child's body to inform me about what they need.		
45		0.757		0.624	Epistemic Attitudes Towards Bodily Signals	Observing my child's body signals (e.g., heart rate) helps me understand them better.		
42		0.636		0.215	0.605	Epistemic Attitudes Towards Bodily Signals	I regularly observe my child's body signals (e.g., breathing, bodily tension) to obtain information about their emotional state.	
44		0.484	0.263		0.608	Epistemic Attitudes Towards Bodily Signals	I usually observe my child's body signals to obtain information about how their body may feel.	
38		0.465			0.364	Regulation of Bodily States	When I sense my child has a fast heartbeat, I can think of different solutions to help them regulate it.	
2	0.33	0.374			0.515	Noticing Bodily Sensations	I can notice changes in my child's breathing, such as whether it slows down or speeds up.	
19		0.373		0.29	0.617	Linking Bodily Sensations to Emotions	I know when my child is relaxed by noticing how their body changes.	
46		0.37	0.297		0.425	Epistemic Attitudes Towards Bodily Signals	When I don't know what my child needs, my first instinct is to observe their body signals.	
49			0.644		0.476	Trust and Self-Efficacy	I am confident that my child's body will let me know what is good for them.	
48	0.206		0.539		0.51	Trust and Self-Efficacy	I am confident that my child's body signals will let me know if something is wrong with them.	
47			0.422		0.245	0.504	Trust and Self-Efficacy	I am confident that my baby's body/body signals will communicate important/helpful information.
23			0.414			0.528	Linking Bodily Sensations to Physiological States	I know when my child is feeling too hot/cold, by noticing how their body changes.

26		0.377		0.209	0.384	Linking Bodily Sensations to Physiological States	I know in advance, by observing my child's body, when they are getting ill.
25		0.346		0.286	0.348	Linking Bodily Sensations to Physiological States	I know when my child needs to go to the toilet by noticing how their body changes.
31	0.262	0.343			0.337	Noticing Bodily Cycles	I can tell from my child's body when is the "best" time for them to go to sleep at night.
30	0.29	0.309		0.218	0.433	Noticing Bodily Cycles	I can distinguish between my child's distress because of hunger and their distress because of lack of sleep.
24		0.279	0.287		0.384	Linking Bodily Sensations to Physiological States	I can notice that my child's body is less tense after a good meal (i.e., they are satisfied/not hungry anymore).
28r		0.302	0.618		0.68	Linking Bodily Sensations to Physiological States	I have difficulty recognising when my child is hungry based on their body.
21r			0.575	0.205	0.687	Linking Bodily Sensations to Emotions	I have difficulty making sense of my child's emotions unless their body signals are very strong.
27r		0.213	0.532	0.311	0.716	Linking Bodily Sensations to Physiological States	I have difficulty making sense of my child's body signals unless they are very strong.
29r			0.377	0.311	0.434	Linking Bodily Sensations to Physiological States	Most times, when my child's body signals a problem, I have difficulty working out what the problem might be (e.g., is hungry, tired, constipated).
5r	0.252		0.35		0.453	Noticing Bodily Sensations	The only time I notice that my child is hungry or tired is when they express it explicitly.
33r	0.202		0.336		0.26	Noticing Bodily Cycles	I cannot tell from my child's body signals when is the "best" time for them to eat.
10	-0.23			-0.29	0.449	Merger Between Parental and Child States	When I am feeling happy, I find it difficult to notice unpleasant body sensations in my child.
36r			0.774		0.674	Regulation of Bodily States	I find it difficult to soothe my child when they are ill.
35r			0.751		0.604	Regulation of Bodily States	When my child is uncomfortable in their body (e.g., is tense, has tummy ache), I find it difficult to help them feel better.

40	0.235	0.229	0.276	Regulation of Bodily States	When my child is relaxing during “downtime”, I can stay calm myself to help them prolong their relaxation.
18		0.473	0.578	Linking Bodily Sensations to Emotions	When something is distressing my child, I can notice it in how their body reacts/changes.
34		0.47	0.425	Regulation of Bodily States	When my child experiences mild tension in their body, I can use touch to help them reduce it.

Child Group – Second round of EFA

Parallel analysis retained six factors. Items 23, 18, and 34 were deleted due to low loadings. Factor loadings and communality shown below:

Item #	F1	F2	F3	F4	F5	F6	Communality	Subscale	Item
17	0.788						0.728	Holding Attention to Bodily Sensations	I can switch my attention between my child's various bodily sensations (e.g., if they're getting hot while eating).
15	0.721						0.609	Holding Attention to Bodily Sensations	I can return my attention to my child's bodily signals (e.g., heart rate, breathing, red cheeks) if I am distracted.
16	0.667						0.595	Holding Attention to Bodily Sensations	I can refocus my attention from my own thoughts to understanding my child's bodily needs.
6	0.575					0.205	0.56	Noticing Bodily Sensations	I notice when my child is experiencing pleasant sensations in their body (e.g., they are comfortable or enjoying being stroked).
14	0.553	0.292		0.233	-0.24	-0.22	0.722	Holding Attention to Bodily Sensations	When I am in conversation with someone, every now and then I switch my attention to my child's bodily needs to make sure everything is alright.

13	0.461	0.222		0.222		0.536	Holding Attention to Bodily Sensations	I can pay some attention to my child's bodily sensations (e.g., if they feel comfortable, are feeling hot or cold, are in pain) even when there is a lot going on around me/us.
4r	0.429				0.26	0.514	Noticing Bodily Sensations	I don't usually notice tension in my child's body unless other people react to it.
43		0.793				0.758	Epistemic Attitudes Towards Bodily Signals	I frequently observe my child's body to inform me about what they need.
45		0.736				0.608	Epistemic Attitudes Towards Bodily Signals	Observing my child's body signals (e.g., heart rate) helps me understand them better.
42		0.71			0.224	0.648	Epistemic Attitudes Towards Bodily Signals	I regularly observe my child's body signals (e.g., breathing, bodily tension) to obtain information about their emotional state.
38		0.555				0.388	Regulation of Bodily States	When I sense my child has a fast heartbeat, I can think of different solutions to help them regulate it.
44		0.519	0.272			0.608	Epistemic Attitudes Towards Bodily Signals	I usually observe my child's body signals to obtain information about how their body may feel.
49			0.713			0.517	Trust and Self-Efficacy	I am confident that my child's body will let me know what is good for them.
47			0.652			0.601	Trust and Self-Efficacy	I am confident that my baby's body/body signals will communicate important/helpful information.
48			0.638			0.559	Trust and Self-Efficacy	I am confident that my child's body signals will let me know if something is wrong with them.
23	0.2	0.207	0.33			0.468	Linking Bodily Sensations to Physiological States	I know when my child is feeling too hot/cold, by noticing how their body changes.
36r				0.794		0.673	Regulation of Bodily States	I find it difficult to soothe my child when they are ill.
35r				0.72		0.563	Regulation of Bodily States	When my child is uncomfortable in their body (e.g., is tense, has tummy ache), I find it difficult to help them feel better.
27r		0.211		0.362	0.518	0.753	Linking Bodily Sensations to Physiological States	I have difficulty making sense of my child's body signals unless they are very strong.
28r			0.243	0.221	0.513	0.609	Linking Bodily Sensations to Physiological States	I have difficulty recognising when my child is hungry based on their body.

21r	0.208	0.225	0.497	0.662	Linking Bodily Sensations to Emotions	I have difficulty making sense of my child's emotions unless their body signals are very strong.
18	0.265		0.377	0.565	Linking Bodily Sensations to Emotions	When something is distressing my child, I can notice it in how their body reacts/changes.
34		0.259	0.336	0.396	Regulation of Bodily States	When my child experiences mild tension in their body, I can use touch to help them reduce it.

Note: Results from the third and final rounds for both groups are shown in the main paper.

Parental Interoception Questionnaire (PIQ) 2025

Preprint:

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- Appropriate citation is provided
- Any modifications by the users are clearly identified

If you modify the questionnaire for your research (including translations) please let us know for our records.

PIQ Scoring Instructions

1. Reverse-code items marked with (R): items 7, 15, 16, 20, 21, and 22.
1 = 5 2 = 4 3 = 3 4 = 2 5 = 1
2. Obtain mean scores for each subscale.
 - a. Attention: items 1, 2, 3, 4, 5, 6, and 7(R)
 - b. Epistemic Attitudes (EA): items 8, 9, 10, and 11
 - c. Trust and Self-Efficacy (Trust): items 12, 13, and 14
 - d. Regulation: items 15(R), 16(R), 17, 18, and 19
 - e. Linking: items 20(R), 21(R), 22(R), 23, and 24
3. Obtain the overall mean score (all items).

Parental Interoception Questionnaire (PIQ) Child version (3- to 10-year-olds)

In this questionnaire, each question refers to possible situations where parents may notice, understand, or respond to their child's bodily sensations and bodily signals. These terms mean very similar things: the term **“bodily sensations”** means things like pain after a fall or due to illness, itching due to fabrics or allergies, pleasant touch by stroking or hugging a soft toy, hunger, thirst, feeling full and content after being fed, feeling fatigued or energised, feeling hot or cold, sweating related to being hot or being anxious, etc. The term **“bodily signals”** means signals related to the inside of the body, such as the beating heart, being out of breath after strenuous exercise or after a fearful experience, signals related to digestion, signals related to needing to go to the toilet, or needing to sleep, red burning cheeks when feeling shy, etc.

Please read each statement carefully and indicate how much you agree or disagree that it applies to you generally in daily life. Remember that there are no right or wrong answers.

	1	2	3	4	5
	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
1. I can return my attention to my child's bodily signals (e.g., heart rate, breathing, red cheeks) if I am distracted.	1	2	3	4	5
2. I can refocus my attention from my own thoughts to understanding my child's bodily needs.	1	2	3	4	5
3. I can switch my attention between my child's various bodily sensations (e.g., if they're getting hot while eating).	1	2	3	4	5
4. I notice when my child is experiencing pleasant sensations in their body (e.g., they are comfortable or enjoying being stroked).	1	2	3	4	5
5. I can pay some attention to my child's bodily sensations (e.g., if they feel comfortable, are feeling hot or cold, are in pain) even when there is a lot going on around me/us.	1	2	3	4	5
6. When I am in conversation with someone, every now and then I switch my attention to my child's bodily needs to make sure everything is alright.	1	2	3	4	5
7. I don't usually notice tension in my child's body unless other people react to it.	1	2	3	4	5
8. I frequently observe my child's body to inform me about what they need.	1	2	3	4	5
9. Observing my child's body signals (e.g., heart rate) helps me understand them better.	1	2	3	4	5
10. I regularly observe my child's body signals (e.g., breathing, bodily tension) to obtain information about their emotional state.	1	2	3	4	5
11. I usually observe my child's body signals to obtain information about how their body may feel.	1	2	3	4	5

Please read each statement carefully and indicate how much you agree or disagree that it applies to you generally in daily life. Remember that there are no right or wrong answers.

1	2	3	4	5	
Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree	
12. I am confident that my child's body will let me know what is good for them.	1	2	3	4	5
13. I am confident that my child’s body signals will let me know if something is wrong with them.	1	2	3	4	5
14. I am confident that my child’s body/body signals will communicate important/helpful information.	1	2	3	4	5
15. I find it difficult to soothe my child when they are ill.	1	2	3	4	5
16. When my child is uncomfortable in their body (e.g., is tense, has tummy ache), I find it difficult to help them feel better.	1	2	3	4	5
17. I find it easy to soothe my child when they’re upset.	1	2	3	4	5
18. When my child is not feeling well in their body, I find it easy to soothe them.	1	2	3	4	5
19. When I sense my child has a fast heartbeat, I can think of different solutions to help them regulate it.	1	2	3	4	5
20. I have difficulty making sense of my child’s emotions unless their body signals are very strong.	1	2	3	4	5
21. I have difficulty making sense of my child's body signals unless they are very strong.	1	2	3	4	5
22. I have difficulty recognising when my child is hungry based on their body.	1	2	3	4	5
23. I find it easy making sense of my child’s emotions even if their body signals are not very intense.	1	2	3	4	5
24. I find it easy recognising when my child needs to go to the toilet based on their body.	1	2	3	4	5

Parental Interoception Questionnaire (PIQ) Baby version (0- to 3-year-olds)

In this questionnaire, each question refers to possible situations where parents may notice, understand, or respond to their child's bodily sensations and bodily signals. These terms mean very similar things: the term **“bodily sensations”** means things like pain after a fall or due to illness, itching due to fabrics or allergies, pleasant touch by stroking or hugging a soft toy, hunger, thirst, feeling full and content after being fed, feeling fatigued or energised, feeling hot or cold, sweating related to being hot or being anxious, etc. The term **“bodily signals”** means signals related to the inside of the body, such as the beating heart, being out of breath after strenuous exercise or after a fearful experience, signals related to digestion, signals related to needing to go to the toilet, or needing to sleep, red burning cheeks when feeling shy, etc.

Please read each statement carefully and indicate how much you agree or disagree that it applies to you generally in daily life. Remember that there are no right or wrong answers.

	1	2	3	4	5
	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
1. I can return my attention to my baby's bodily signals (e.g., heart rate, breathing, red cheeks) if I am distracted.	1	2	3	4	5
2. I can refocus my attention from my own thoughts to sensing my baby's body.	1	2	3	4	5
3. I can switch my attention between my baby's various bodily sensations (e.g., if they're getting hot while eating).	1	2	3	4	5
4. I notice when my baby is experiencing pleasant sensations in their body (e.g., they are comfortable or enjoying being stroked).	1	2	3	4	5
5. I can pay some attention to my baby's bodily sensations (e.g., if they feel comfortable, are feeling hot or cold, are in pain) even when there is a lot going on around me/us.	1	2	3	4	5
6. When I am in conversation with someone, every now and then I switch my attention to my baby's bodily needs to make sure everything is alright.	1	2	3	4	5
7. I don't usually notice tension in my baby's body unless other people react to it.	1	2	3	4	5
8. I frequently observe my baby's body to inform me about what they need.	1	2	3	4	5
9. Observing my baby's body signals (e.g., heart rate) helps me understand them better.	1	2	3	4	5
10. I regularly observe my baby's body signals (e.g., breathing, bodily tension) to obtain information about their emotional state.	1	2	3	4	5
11. I usually observe my baby's body signals to obtain information about how their body may feel.	1	2	3	4	5

Please read each statement carefully and indicate how much you agree or disagree that it applies to you generally in daily life. Remember that there are no right or wrong answers.

	1	2	3	4	5
	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
12. I am confident that my baby's body will let me know what is good for them.	1	2	3	4	5
13. I am confident that my baby's body signals will let me know if something is wrong with them.	1	2	3	4	5
14. I am confident that my baby's body/body signals will communicate important/helpful information.	1	2	3	4	5
15. I find it difficult to soothe my baby when they are ill.	1	2	3	4	5
16. When my baby is uncomfortable in their body (e.g., is tense, in pain, has gas), I find it difficult to help them feel better.	1	2	3	4	5
17. I find it easy to soothe my baby by stroking them when they're upset.	1	2	3	4	5
18. When my baby is not feeling well in their body, I find it easy to soothe them.	1	2	3	4	5
19. When I sense my baby has a fast heartbeat, I can think of different solutions to help them regulate it.	1	2	3	4	5
20. I have difficulty making sense of my baby's emotions unless their body signals are very strong.	1	2	3	4	5
21. I have difficulty making sense of my baby's body signals unless they are very strong.	1	2	3	4	5
22. I have difficulty recognising when my baby is hungry based on their body.	1	2	3	4	5
23. I find it easy making sense of my baby's emotions even if their body signals are not very intense.	1	2	3	4	5
24. I find it easy recognising when my baby needs to pass a stool based on their body.	1	2	3	4	5

Sensitivity analyses for stimuli check

Given that the stimuli used in the CBR task for Chapter 3 were newly created, a check was conducted to determine whether any of the children depicted in the stimuli influenced participant's performance.

One outlier was found, whose videos had a higher overall performance score ($M = 0.79$, $SD = 0.41$) than those of the other children. Additionally, a technical issue occurred during one of the recordings, resulting in the ECG signal and video being synchronised only to the second rather than the millisecond, as with the rest. Sensitivity analyses for the main task analyses excluding trials that included these two children are presented below.

1. Effect of difficulty level

A simple linear regression examining the relationship between each participant's average difficulty level and their average performance found no significant effect ($\beta = 0.04$, 95% CI [-0.03, 0.10], $p = .313$, Adj. $R^2 = .001$).

2. Performance against chance level

Participants average performance was significantly above chance level, as shown by a one-sample t -test against 0.5 ($t(63) = 7.68$, $p < .001$, $d = 0.96$). The significant result remained even after controlling for the effects of gender, child sex, response bias (c), and difficulty level with a linear regression model ($F(4, 54) = 2.48$, $p = .054$, Adj. $R^2 = .093$), which showed that, overall, participants performed significantly above chance ($\beta = .55$, 95% CI [.51, .59], $p < .001$), men performed marginally better than women ($\beta = .04$, 95% CI [-.01, .10], $p = .096$), and average performance was significantly higher when the stimuli depicted boys versus girls ($\beta = .07$, 95% CI [.01, .12], $p = .012$).

3. Effect of stress.

Participant's performance in the CBR task did not differ between the neutral ($M = .60$, $SD = .12$) and stress ($M = .60$, $SD = .11$) conditions, as shown by a paired t -test ($t(61) = 0.33$, $p = .739$).

4. Relationships With Interoceptive Accuracy and Sensibility

The predictive value of interoceptive accuracy (alpha) for CBR task performance was examined using linear regression analysis. The initial model, with only alpha as a predictor, revealed a weak but statistically significant negative association ($F(1,55) = 4.52$, $p = .038$, Adj. $R^2 = .059$). Specifically, greater overestimation of the heart rate (higher alpha values) was associated with lower CBR performance ($\beta = -0.002$, 95% CI $[-0.004, -0.0002]$, $p = .038$). When gender and child sex were added as covariates, model fit improved ($F(3,53) = 3.98$, $p = .012$, Adj. $R^2 = .138$); however, the predictive effect of interoceptive accuracy was attenuated ($\beta = -0.002$, 95% CI $[-0.002, -0.001]$, $p = .102$).

Regarding interoceptive sensibility, no significant association was found between CBR task performance and the MAIA overall score ($r = -.11$, $p = .373$).

Note: results presented here did not meaningfully differ from results including the complete sample, therefore, the analyses presented in the main thesis text include the full children sample.