Mothers' interoceptive knowledge predicts children's emotion regulation and social skills in middle childhood

Jennifer K. MacCormack[1], Vanessa L. Castro[2], Amy G. Halberstadt[2], & Megan L. Rogers[3]

[1]Department of Psychology and Neuroscience
University of North Carolina at Chapel Hill

[2]Department of Psychology
North Carolina State University

[3]Department of Psychology
Florida State University

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Social Development

Address correspondence to:
Jennifer MacCormack, Department of Psychology and Neuroscience, University of North Carolina, Chapel Hill, NC 27599 jkmaccor@unc.edu

Abstract

Interoception, often defined as the perception of internal physiological changes, is implicated in many adult social affective processes, but its effects remain understudied in the context of parental socialization of children's emotions. We hypothesized that what parents know about the interoceptive concomitants of emotions, or *interoceptive knowledge* (e.g., "my heart races when excited"), may be especially relevant in emotion socialization and in supporting children's working models of emotions and the social world. We developed a measure of mothers' interoceptive knowledge about their own emotions and examined its relation to children's social affective outcomes relative to other socialization factors, including self-reported parental behaviors, emotion beliefs, and knowledge of emotion-relevant situations and nonverbal expressions. To assess these, mothers (*N*=201) completed structured interviews and questionnaires. A few months later, third-grade teachers rated children's social skills and emotion regulation observed in the classroom. Results indicated that mothers' interoceptive knowledge about their own emotions was associated with children's social affective skills (emotion regulation, social initiative, cooperation, self-control), even after controlling for child gender and ethnicity, family income, maternal stress, and the above maternal socialization factors. Overall, findings suggest that mothers' interoceptive knowledge may provide an additional, unique pathway by which children acquire social affective competence.

The reactions, conversations, and experiences that caregivers explicitly create and even curate can shape children's internal working models of themselves and the wider world; these in turn support children's development of effective emotion regulation and social skills (Eisenberg, Cumberland, & Spinrad, 1998; Morris et al., 2007; Rothenberg et al., 2017). Yet *internal* factors, such as what parents know and believe about emotions can also impact children's development (Castro, Halberstadt, Lozada, & Craig, 2015; Gottman, Katz, & Hooven, 1996). Further, given the primacy of the body in early development (Adolph, Berger, & Leo, 2011; Kermoian & Campos, 1988), parents' perceptions and articulation of emotion's physiological concomitants could be an important, as yet underappreciated factor impacting how children learn to identify, interpret, and manage their feelings and social lives. In the present study, we developed a measure of parental *interoceptive knowledge,* i.e., what parents know about how the body feels during different subjective states including emotions. We examined how parental interoceptive knowledge relates to other established socialization factors while also testing its ability to predict emotion regulation and social skills in middle childhood.

Why interoceptive knowledge?

Interoception is defined as the perception of internal physiological changes—especially as related to the viscera, such as sensing one's heartbeat and gastrointestinal sensations (Craig, 2003; Sherrington, 1906). Interoception is implicated in many adult social affective processes, including emotional experience and regulation, empathy, and intuitive decision-making (Critchley & Garfinkel, 2017; Dunn et al., 2010; Ernst et al., 2013; Füstös, Gramann, Herbert, & Pollatos, 2013). Despite its demonstrated importance in adulthood, interoception remains understudied in the context of early life (Murphy, Brewer, Catmur, & Bird, 2017).

Sensitivity to interoceptive cues likely emerges in infancy (Maister, Tang, & Tsakiris, 2017). Certainly, by middle childhood, children can detect their heartbeats with some accuracy (Koch & Pollatos, 2014), with some interoceptive-related advantages such as engaging in greater physical activity (Georgiou et al., 2015), but also potential disadvantages, such as being prone to anxiety and somatic symptoms (Eley et al., 2004). Fotopoulou and Tsakiris (2017) argue that children must learn to make

inferences about the meaning of their own interoceptive signals before they can learn to make inferences about others' states. Such mentalizations likely emerge from both lived experience and learning acquired from others such as parents (Vigliocco, Meteyard, Andrews, & Kousta, 2009). As such, parents' knowledge linking interoceptive sensations with emotions and other states could provide one avenue by which children learn to navigate their own bodies, feelings, and the minds of others (Atzil, Gao, Fradkin, & Barrett, 2018).

Although to our knowledge no work yet examines the role of interoceptive knowledge in the processes by which parents socialize the understanding, experience, and expression of children's emotion, there are good reasons to do so. One goal of emotion socialization is for children to develop more precise labels for and understanding of their own and others' internal, first-person states—yet internal states and sensations, be it feeling sad, tired, or thirsty, cannot be directly experienced by outside observers. This limited access to others' internal states poses not only a developmental puzzle for children to solve (e.g., developing theory of mind, learning to accurately predict what others are thinking and feeling), but also can pose a barrier for parents, especially in early development when a child is preverbal or when the child can speak but does not yet have a full vocabulary to articulate their needs, thoughts, and experiences (Gebauer, 2012; Gergely & Watson, 1996; Holodynski & Seeger, 2019). Interoceptive knowledge may help parents overcome this barrier, providing a broader repertoire of possible sensations and experiences so that parents can better mentalize and talk to children about the internal, first-person experience of emotions and other states.

Indeed, across development, bodily sensations become increasingly salient to children when indexing emotion categories (Hietanen, Glerean, Hari, & Nummenmaa, 2016). As such, these sensations may serve as concrete internal cues that children can use to identify their feelings, linking together, as Fogel (2009, 2011) has discussed, embodied self-awareness with conceptual self-awareness. Knowing that anger is associated with feeling hot, whereas fear with chills, are tangible insights that a child can experience directly as they learn to attach meaning to sensations. Similarly, recognizing how the body feels during different emotions could guide children's selection of emotion regulation strategies, such as

learning to breathe deeply when angry. In order to help guide children through this process of linking the felt body with specific emotional meanings and management strategies, parents need to have knowledge and awareness of their own and other people's experiences (including interoceptive sensations) and be able to effectively communicate that information to the child. For example, parents with more interoceptive knowledge may be more likely to mention interoceptive sensations both in child-directed emotion discussions and adult-directed conversations that the child overhears, providing further reinforcement that interoceptive sensations are important and can be linked to emotions. Finally, interoceptive knowledge could support more sensitive parenting and mind-mindedness. For example, knowing more about interoceptive sensations and those sensations' possible meanings may lead parents to value children's interoceptive experiences as meaningful indicators of different mental states—e.g., knowing that one's child eating less than usual could mean that s/he is feeling unwell but also perhaps anxious (Atzil et al., 2018; Fogel, 2011; Meins, 2013).

In sum, parental interoceptive knowledge may support greater parental awareness of how their child might be feeling, while also helping the parent (1) select more effective socialization strategies, (2) transmit more varied and concrete information about the experience and management of emotion, and (3) emphasize the relevance of interoceptive sensations and skills. However, given what is already known about emotion socialization, it is important to compare and contextualize interoceptive knowledge against other forms of parental behaviors, beliefs, and knowledge which are known to influence children's social affective abilities (see **Figure** for a conceptual model). Below, we briefly summarize what is known about parental behaviors, emotion beliefs, and emotion knowledge in shaping children's social affective development.

Parental socialization behaviors, beliefs, and knowledge in children's social affective development

Emotion socialization behaviors. Parent socialization efforts manifest in many ways, including how adults react to others' behaviors and feelings, and how emotions are discussed and modeled both intentionally and unintentionally around the child (Eisenberg et al., 1998). One widely-used framework organizes parental reactions around supportive and non-supportive behaviors (Fabes, Eisenberg, &

Bernzweig, 1990). Supportive behaviors include actively engaging with children's emotions, accepting children's feelings, and incorporating such feelings into growth-oriented discussions. Young children of emotion-supportive parents better grasp the causes and consequences of emotions and exhibit better scholastic success, peer relationships, and self-control (Denham & Kochanoff, 2002; Eisenberg et al., 1995; Miller-Slough et al., 2018; Spinrad et al., 2006), although in middle and later childhood, supportive parenting is sometimes negatively associated with certain social skills (Castro, Halberstadt, & Garrett-Peters, 2018; Mirabile, Oertwig, & Halberstadt, 2018).

Nonsupportive behaviors include minimizing, ignoring, denying, shaming, or punishing a child's emotional experiences and expressions. These behaviors may emerge in part because nonsupportive parents tend to experience greater distress in reaction to their children's emotions or report that their children's emotions are extreme or intense, and thus may find children's emotions difficult to constructively manage (Fabes, Leonard, Kupanoff, & Martin, 2001). In general, children with nonsupportive parents exhibit impoverished emotion understanding and greater anxiety, with adverse effects on scholastic achievement, self-control, and social skills (Eisenberg et al., 1995; Hurrell, Hudson, & Schniering, 2015; Klein et al., 2018; Spinrad et al., 2006).

Emotion beliefs. Presumably, socialization behaviors are in part guided by parents' beliefs about the nature and value of emotion, further infusing the broader familial "climate" around emotions (Garrett-Peters, Castro, & Halberstadt, 2017; Lozada et al., 2016; Meyer et al., 2014). Of particular interest are parents' *beliefs that children's emotions are valuable or dangerous* (Dunsmore, Her, Halberstadt, & Perez-Rivera, 2009). When parents believe children's emotions are valuable, they are more supportive and growth-minded, and their children exhibit better social skills and emotion regulation from preschool into early adolescence (Katz, Maliken, & Stettler, 2012; Stettler & Katz, 2014; Wong, McElwain, & Halberstadt, 2009). However, when parents view children's emotions as dangerous, they are more likely to minimize or punish certain emotions (e.g., Gottman et al., 1996) and more likely to mask their feelings in front of children, potentially creating an impoverished affective home environment (Dunsmore et al., 2009; Halberstadt, Thompson, Parker, & Dunsmore, 2008). Thus, parents' emotion beliefs shape their

reactions to children's emotion and ultimately impact children's opportunities to master social affective skills (Katz et al., 2012).

Emotion knowledge. Although emotion beliefs likely guide *how* parents seek to socialize their children's emotions, emotion knowledge is thought to represent *what* parents are trying to instill via socialization—the rich cache of information about the contexts and concomitants associated with different emotion categories (Castro, Cheng, Halberstadt, & Grühn, 2016; Lindquist, MacCormack, & Shablack, 2015; Wilson-Mendenhall, Barrett, & Barsalou, 2015). *Situational knowledge* refers to knowing which emotions are likely to be experienced in a given situation. This knowledge includes social scripts (e.g., people tend to feel sad about a personal loss), as well as more idiographic information (e.g., my mom gets excited when her favorite sports team wins; Castro et al., 2016). *Nonverbal knowledge* refers to knowing what behaviors are most likely to be emitted by the face, vocal tone, or body for different emotions (Hall & Bernieri, 2001; Hall, Murphy, & Mast, 2007). Prior work already highlights the value of situational or nonverbal components of parental emotion knowledge (e.g., Castro, Halberstadt, Lozada, & Craig, 2015), but no work yet examines parental interoceptive knowledge.

Interoceptive knowledge is a novel construct (**Table 1**) thought to encompass both explicit and implicit descriptive knowledge about the nature, value, and regulation of interoceptive sensations and how these sensations may relate to different physical, emotional, and cognitive states. As operationalized here, we focused on mothers' propositional knowledge about the nature of their own interoceptive sensations in relation to emotions. For example, the concept of "anxiety" may invoke embodied images of sweaty palms, heart palpitations, and an upset stomach. Because children's association of bodily sensations with emotions becomes increasingly complex and differentiated from early life into adolescence (Hietanen et al., 2016), it may be that interoceptive knowledge helps parents facilitate children's growing ability to link the body to emotions, ultimately supporting children's social affective competence.

Children's social affective competence in middle childhood

Children's social affective competence broadly encompasses the key social affective skills that children must master to achieve self-insight, successful relationships, and resilience in the face of stressors (Camras & Halberstadt, 2017; Eisenberg et al., 1998; Saarni, 1999). In middle childhood, teachers and peers expect children to become proficient at managing their feelings. Additionally, as children spend more time with social cohorts and encounter more strangers, they must better predict how others feel, especially as emotion expressions become more fragmented, successfully masked, and diverse with age (Castro, Camras, Halberstadt, & Shuster, 2018). We measured social affective competence in the classroom because children continue to develop their interpersonal strategies in school and because social affective competence supports effective classroom learning, predicting long-term social and academic outcomes (Durlak et al., 2011; Eisenberg, Sadovsky, & Spinrad, 2005). Additionally, teacher reports of children's competence provided a more stringent test of our hypotheses in a context that is largely independent of the home.

The Present Study

Parents' emotion-related behaviors, beliefs, and knowledge are recognized pathways by which children acquire social affective competence. We extended this work by creating a measure of maternal *interoceptive knowledge* and examining this construct's unique contribution to children's social affective competence relative to other common constructs of parental emotion socialization. We operationalized children's social affective competence as emotion-related *skills* (emotion regulation; social skills such as social initiative, cooperation, and self-control) vs. *difficulties* (emotional lability; problem behaviors such as externalizing, internalizing, and hyperactivity), as rated by the children's third-grade teachers. We sought out a racially and socioeconomically diverse sample of mother-child dyads and controlled for the effects of child age, gender, ethnicity, and family income. We also included maternal stress in our models as an index of the broader familial affective context, given that parental stress is a potent predictor of socialization behaviors and children's outcomes (e.g., Crnic, Gaze, & Hoffman, 2005).

Method

Participants

Participants were 201 mother-child dyads who were part of and supplemental to a sample recruited from birth (reference omitted for blind review). See **Table 2** for demographics.

Procedure

Following maternal consent and child assent, mothers completed questionnaires assessing their emotion beliefs, parenting behaviors, recent maternal stress, and demographics and then were interviewed to assess their situational, nonverbal, and interoceptive knowledge of emotions. All data collection, entry, and coding were conducted by mixed-ethnicity, mixed-gender teams. Approximately 3.5 months following the laboratory visit, teachers completed questionnaires assessing children's social affective competence in school, with questionnaires returned for 165 children.

Measures

Maternal parenting behaviors. Mothers completed the Coping with Children's Negative Emotions Scale (CCNES; Fabes et al., 1990; adapted by Stelter & Halberstadt, 2010). Mothers responded to 16 hypothetical situations in which their child exhibited anger or sadness, rating their use of six different reactions on 7-point scales from 1 (*very unlikely*) to 7 (*very likely*). Supportive reactions included problem-focused, emotion-focused, and expressive encouragement subscales (α=.75; *I would tell my child that it is okay to have strong feelings when you don't get something you want*). Nonsupportive reactions included the minimizing and punitive subscales (α=.86; *I would tell my child that he/she is being immature and that the toy is silly*). The CCNES and its adaptations demonstrate reasonable internal consistency, reliability over time, and construct validity (Baker, Fenning, & Crnic, 2011; Fabes et al., 2001; Rogers et al., 2016). See Supplemental Materials for adapted questionnaire.

Maternal emotion beliefs. Mothers completed the Parents' Beliefs about Children's Emotions Questionnaire (PBACE; Halberstadt, Dunsmore, et al., 2008), using 6-point scales, ranging from 1 (*strongly disagree*) to 6 (*strongly agree*). The 22-item *Emotions are Valuable* subscale represents the degree to which parents believe that children's emotions are important or valuable (α=.86; *It is good for*

children to feel angry at times). The 16-item *Emotions are Dangerous* subscale represents the degree to

which parents believe that children's emotions can be problematic or even harmful (α=.90; *Children who*

feel emotions strongly are likely to face a lot of trouble in life). Responses were averaged across items to

create a mean score of that subscale. Construct validity is provided by previous studies in middle

childhood (Castro et al., 2015; Lozada et al., 2016).

Maternal emotion knowledge. Mothers listened to three vignettes designed to elicit mildly

negative or mixed emotions (adapted for this study from Bajgar, Ciarrochi, Lane, & Deane, 2005;

Cunningham, Kliewer, & Garner, 2009; Lane, Quinlan, Schwartz, Walker, & Zeitlin, 1990). In Vignette

1, the mother imagined sitting with her child in a restaurant when she notices smoke billowing from the

kitchen. In Vignette 2, someone who is usually critical of the mother unexpectedly pays her a

compliment. In Vignette 3, the mother and a friend apply for the same position, but the friend gets the job

and the mother does not. After each vignette, mothers answered: "What emotions would you be feeling in

that situation?" and "How would you know you were feeling that way?" and could generate as many free

responses as they wished. Mothers' responses to *how would you know* were independently coded for the

three types of emotion knowledge (situational, nonverbal, and interoceptive) by two research assistants

(M_{kappa}=.88 across the three types of knowledge) with disagreements resolved by a third expert coder.

Mothers' use of contextual cues was coded as *situational knowledge,* including both assessments

of events happening in the vignette (e.g., "I'd know I was feeling afraid because I'd be scanning the

restaurant for more clues of a fire") as well as mothers' reliance on prior similar situations (e.g., "I'd

know because this has actually happened to me before"). Mothers' use of their own facial expressions,

non-linguistic vocal expressions, and behavioral action-tendencies was coded as *nonverbal knowledge*

(e.g., "I'd know I was angry because of the harshness in my voice"). Mothers' use of their interoceptive

cues was coded as *interoceptive knowledge* (e.g., "I'd know I was worried because of the knots in my

stomach")*.* We coded only for absence or presence within each vignette for two reasons: (1) to avoid

confounding knowledge with verbosity, as some mothers were more talkative than others, and (2) to first

assess whether these types of knowledge mattered at all, before attempting to assess complexity in

different knowledge types (a goal now for future studies). Coding for absence vs. presence provides evidence that knowledge of situational, nonverbal, and interoceptive features of emotions exists, without researchers having to infer much about the granularity of that knowledge.

The most common emotions for Vignette 1 (seeing smoke in a restaurant with your child) were *fear*, *concern*, *worry*, *panic*, *surprise*, and *anxiety*. The predominant interoceptive sensation reported was a change in heart rate (e.g., heart racing, pounding), but mothers also said that they might feel more bodily tension, feel an adrenaline rush, experience gastric changes (e.g., stomach tightening), become hot or flushed, breathe heavier or faster, or feel their body shake/tremble. These sensations are consistent with the high arousal emotions that mothers said they would feel in this vignette (e.g., fear). For Vignette 2 (receiving a compliment from someone who is usually critical), the most common emotions were *surprise*, *happy*, *shock*, *suspicion*, *skepticism*, and *gratitude*. In Vignette 2, the predominant interoceptive sensations were feeling the body relax vs. tense up in response to the compliment (depending on whether mothers thought the person was well-meaning vs. had an ulterior motive), alongside other sensations such as breathing more easily or the body/chest becoming warmer. In Vignette 3 (friend gets the job), the most common emotions were *happy*, *disappointed*, *sadness*, *jealousy*, *excitement*, and *anger*. Here, mothers reported that they would feel predominantly gastric changes ("sinking feeling in my stomach"), cardiac changes, feelings like tears welling up in eyes and a lump in one's throat, or the body feeling drained vs. relaxed. These sensations are again consistent with whether the mother said she would feel happy or excited for her friend's success or whether she focused on the disappointment or sadness of not getting the job herself. Overall, emotions and their associated interoceptive sensations appeared consistent with typical responses in English-speaking samples (e.g., Shields, 1984), as did the situational and nonverbal features provided. Across all three vignettes, 80.67% of responses included situational knowledge, 40.49% included nonverbal knowledge, 36.50% included interoceptive knowledge, and 4.91% were vignettes where mothers could not produce a codable answer (e.g., "I don't know" as a response). Percentages add up to more than 100% because mothers frequently provided more than one type of knowledge in a vignette. See Supplemental Materials for the coding manual and full frequencies.

Maternal stress. Mothers completed the Daily Inventory of Stressful Experiences (Almeida, Wethington, & Kessler, 2002), indicating whether they had experienced seven different types of stressors in the past 24-hrs (e.g., work, home, health, or home stressors). Each type of stressor counted as 0 (*did not experience*) or 1 (*did experience*), and the sum represented the amount of recent daily life stress. This measure has been validated in previous literature on stress in daily life (Almeida, Stawski, & Cichy, 2011).

Children's social affective competence. Teachers completed the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997), using 4-point scales ranging from 1 (*rarely/never*) to 4 (*almost always*). The 8-item *Emotion Regulation* scale assesses adaptive regulation, including abilities like flexibility, equanimity, and contextual appropriateness (α=.82). The 15-item *Lability* scale assesses reactivity, mood swings, and emotional intensity (α=.92). Evidence of reliability and construct validity is substantial (Kim & Cicchetti, 2010). Teachers also completed the Social Skills Rating System-Teacher's Version (SSRS-T; Gresham & Elliott, 1990), using 3-point scales with 0 (*never*), 1 (*sometimes*), or 2 (*very often*). The 30-item *Social Skills* scale measures children's assertion (showing social initiative), cooperation (being helpful), and self-control (turn-taking). The 24-item *Problem Behaviors* scale measures children's externalizing (e.g., outbursts of anger), internalizing (e.g., anxiety), and hyperactivity (e.g., impulsivity). Teacher ratings were averaged within scales (αs=.93, .92). There is substantial evidence for SSRS reliability and construct validity (Gresham, Elliott, Vance, & Cook, 2011).

Results

Analytic Approach

We first examined descriptive statistics and bivariate correlations for maternal and child variables (**Tables 2, 3**). All variables except family income were normally distributed and met general linear model assumptions. We used a natural log transformation to improve the family income distribution. All variables were then standardized as z-scores. We used hierarchical linear regression to assess the additive and unique effects of supportive vs. non-supportive parenting behaviors and value vs. danger beliefs (Step 1), situational, nonverbal, and interoceptive knowledge (Step 2), and demographic factors (child age,

gender, and ethnicity; family income; maternal stress; Step 3), when predicting children's social affective skills (**Table 4**) and difficulties (**Table 5**). In these tables, standardized betas are also reported, serving as effect size estimates. This study's data are currently available upon request from the corresponding author but are not yet publicly available as other work is still ongoing with this dataset.

Preliminary Analyses

Children's emotion regulation and social skills ("skills") were highly correlated, $r=.76$, $p<.0001$; as were children's emotional lability and problem behaviors ("difficulties"), $r=.86$, $p<.0001$; thus, these pairs of highly-related constructs were averaged to create more stable scores. Maternal supportive and nonsupportive behaviors were negatively correlated with each other, $r=-.22$, $p=.003$, as were value and danger beliefs, $r=-.25$, $p<.0001$. Maternal situational, nonverbal, and interoceptive knowledge appear to be independent measures of emotion knowledge, $rs= -.10-.09$, $ps>.10$. Demographic correlations with child outcome measures and parental factors supported the decision to control for them in further analyses (**Table 3**).

Associations with Maternal Interoceptive Knowledge

Given the novelty of interoceptive knowledge in emotion socialization, we first examined correlations with other socialization constructs, child outcomes, and demographics (**Table 3**). Interoceptive knowledge did not correlate with parenting behaviors, but mothers with greater interoceptive knowledge were more likely to endorse value beliefs and less likely to endorse danger beliefs about children's emotions. Maternal interoceptive knowledge was also associated with children's greater social affective skills and fewer difficulties. Interoceptive knowledge was unrelated to child age and gender but was positively associated with child ethnicity (higher for European Americans), family income, and greater maternal stress.

Predicting Child Social Affective Skills

The first model step (**Table 4**), predicting children's *social affective skills*, included maternal socialization behaviors and emotion beliefs; this step was significant. Collectively, mothers' reactions to and beliefs about children's emotions explained 9.5% of the variance in children's social affective skills.

Consistent with prior findings in different samples (Dunsmore et al., 2009; Mirabile et al., 2018; Nelson & Boyer, 2018) and as reported elsewhere with this sample (Castro, Halberstadt, et al., 2018; Rogers, Halberstadt, Castro, MacCormack, & Garrett-Peters, 2016), children of more supportive mothers had fewer social affective skills[1]. Of note, mothers' unsupportive behaviors were not significant and remained so in all subsequent steps. Additionally, mothers' value beliefs about children's emotions were positively associated with social affective skills, whereas mothers' danger beliefs were inversely associated.

The addition of mothers' types of emotion knowledge in the second model step resulted in a significant change, $\Delta R^2=.06$, $p=.030$. Maternal situational and nonverbal knowledge were nonsignificant and remained so in the final step. Interoceptive knowledge however was significant. Mothers' supportive behaviors and value beliefs also remained significant, but danger beliefs dropped from significance. In the final model step, the inclusion of demographics resulted in a significant model change, $\Delta R^2=.22$, $p<.0001$. Child gender and family income were significant predictors: girls and wealthier children had greater social affective skills than boys and poorer children. Maternal supportive behaviors dropped from significance in Step 3, suggesting that demographic factors share variance with maternal supportive behaviors in explaining children's skills. Mothers' value beliefs remained significant however. Finally, maternal interoceptive knowledge remained significant, highlighting that this type of emotion knowledge continues to predict children's skills, even when controlling for maternal socialization behaviors and emotion beliefs, other forms of emotion knowledge, and demographics.

Predicting Child Social Affective Difficulties

The first model step (**Table 5**), predicting children's *social affective difficulties,* included maternal socialization behaviors and emotion beliefs; this step was significant. Collectively, mothers' reactions to and beliefs about children's emotions explained 10.7% of the variance in children's social

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[1] This counter-intuitive finding, found here and in separate samples, is discussed more fully in the papers referenced, but two competing explanations for these cross-sectional effects are worth exploring. It may be that children evidencing poorer social affective skills at this age elicit more sensitive, supportive behaviors by parents who are trying to help their children "catch up" to their peers' skills. Alternatively, supportive parenting in middle childhood may take on different forms, and some types of scaffolding at this age may be less effective and akin to "helicopter parenting," infringing upon the child's maturing social affective autonomy.

affective difficulties. As above with social affective skills, mothers' supportive reactions were associated with greater social affective difficulties, whereas maternal value beliefs predicted lower teacher-rated social affective difficulties. Nonsupportive behaviors and danger beliefs were nonsignificant and remained so in all subsequent model steps.

The addition of mothers' emotion knowledge in the second model step did not result in a significant ΔR^2 (p=.312). Mothers' supportive reactions and value beliefs remained significant. In the final model step, including demographics resulted in a significant model change, ΔR^2=.26, p<.0001. Child gender and family income were both significant predictors: boys and children from poorer households had greater social affective difficulties than girls and children from wealthier households. Maternal supportive reactions and value beliefs remained significant in Step 3.

Discussion

The present findings provide initial evidence for the importance of maternal interoceptive knowledge. Even when accounting for many parental and child factors, mothers' own interoceptive knowledge remained a significant predictor of third-grade children's greater social affective skills (i.e., emotion regulation, social initiative, cooperation, and self-control) a few months later. These findings are consistent with work in adults demonstrating that interoception relates to greater emotion regulation, empathy, and social sensitivity (reviews in Tsakiris & De Preester, 2018). The effects of maternal interoceptive knowledge on children's emotional lability and problem behaviors were weaker compared to effects on children's social affective skills. It may be that maternal interoceptive knowledge helps children learn to identify and enact appropriate affective responses but is less helpful with children's inhibition of ineffective or inappropriate responses, at least at this age. Similarly, children's difficulties might reflect an over-awareness of bodily cues on the one hand and an absence of regulatory skill on the other. Children who are predisposed to arousal (e.g., more labile) or who are over-distracted by internal or external cues (e.g., hyperactive or attention deficit) may require greater caregiver support (Carpenter et al., 2018) than was captured here.

Interoceptive knowledge was also associated with greater value and lower danger beliefs about children's emotions, suggesting that interoceptive knowledge coincides with a more accepting view of children's emotions as valuable sources of insight rather than problems. Although we cannot speak to directionality, believing emotions are valuable rather than dangerous could make it easier for both parents and children to engage with emotions and the physiological sensations and arousal that accompany emotions, thus providing greater opportunities for social affective development. This hypothesis is grounded in adult studies showing that greater interoceptive awareness is linked to greater emotional acceptance rather than distress (Mehling et al., 2012), but should be further tested in the context of emotion socialization.

One potential point of debate is whether interoceptive knowledge as a construct differs from interoceptive awareness (Fogel, 2011). Awareness can be more precisely defined as in-the-moment access to interoceptive cues during an emotional experience or other state. In contrast, interoceptive knowledge likely draws on prior awareness of interoceptive cues but could also include cultural scripts and schemas unrelated to mothers' own interoceptive awareness or ability. Within the context of emotion socialization, interoceptive knowledge may be more useful than interoceptive awareness, given that knowledge (as we measured it) is declarative and something that can be articulated by parents when teaching children. For example, mothers with greater interoceptive knowledge may be better able to assist children with identifying and managing emotions. Interoceptive knowledge may also support other skills not measured in this study, such as parents' ability to mentalize about their children's internal states or parental modeling of effective emotion regulation and social skills, as suggested by literature connecting interoception with empathy, emotion regulation, and prosociality (Durlik, Brown, & Tsakiris, 2014; Ernst et al., 2013; Ferri, Ardizzi, Ambrosecchia, & Gallese, 2013). Future work should examine how interoceptive knowledge may facilitate parental inferences about children's internal states, such as work on affect mirroring and attunement, social biofeedback theory, and mind-mindedness (Gergely & Watson, 1996; Holodynski & Seeger, 2019; Meins, Fernyhough, Johnson, & Lidstone, 2006).

Finally, it was somewhat surprising that, of the three kinds of parental emotion knowledge measured, only interoceptive knowledge mattered for children's social affective competence. As noted earlier, work on emotion socialization has previously emphasized the importance of situational and nonverbal features of emotion. Both situational and nonverbal cues are external and observable to others, making it easier for parents and children to express, model, and communicate about these cues and their emotional meanings. Interoceptive cues on the other hand are internal and unobservable. Without much interoceptive knowledge, parents may struggle to teach children how to become more aware of and effectively manage these important bodily cues when experiencing emotion and mentalizing about others' internal experiences and intentions. Another possibility is that situational and nonverbal cues are easier for parents to teach children in early life, again because these are external and observable. However, because interoceptive cues are limited to first-person direct experience, they may be more difficult to teach or may take longer to socialize. As such, parents' situational and nonverbal knowledge may matter less by middle childhood compared to interoceptive knowledge which may remain relevant. Future studies could examine parental emotion knowledge at different stages of children's development (i.e., infancy, early vs. middle vs. late childhood) and identify how different facets of parental knowledge might play changing vs. consistent roles in children's social affective development.

Strengths & Limitations

The correlational and primarily cross-sectional nature of these data limit causal inferences. Furthermore, our measure of interoceptive knowledge is new and not yet validated against other measures and dimensions of interoception. Besides future psychometric development of our measure, we hope this study inspires a deeper exploration of interoceptive knowledge as a construct. As a first step, we measured the absence vs. presence of interoceptive knowledge in each emotion vignette, which implies frequency and breadth of use, such that mothers received higher scores when they reported interoceptive knowledge across the varied emotion-related contexts (vignettes). Developing more vignettes would help test whether some individuals have more knowledge about one interoceptive modality vs. another (e.g., cardiac vs. gastric). Future vignettes could also include both ambiguous vs. prototypical emotion

scenarios: interoceptive knowledge may be most relevant in ambiguous situations wherein interoceptive cues can serve as valuable sources of insight. During coding, we saw that mothers demonstrated clear signs of understanding the vignettes and had the ability to produce reasonable emotions, situational inferences, nonverbal behaviors, and interoceptive sensations that make sense within U.S. culture. Thus, we did not code for appropriateness in this particular dataset, but future work could examine appropriateness in relation to parental and child social affective difficulties.

We assessed what we considered the most relevant forms of maternal knowledge as well as other socialization factors but may have inadvertently omitted other relevant knowledge types. Although we found clear evidence of unique associations for mothers' interoceptive knowledge and value beliefs with children's social affective competence, we still do not know exactly how these maternal psychological factors translate into parenting behaviors. We suspect that interoceptive knowledge coupled with valuing emotions provides mothers with the ability to be aware of and comfortable with their own feelings, to focus on what their children are feeling and need, and to be able to guide children's emotion-related knowledge. This may then manifest in several ways—from how mothers talk about emotions and bodily sensations in daily life to the types of regulation strategies that mothers model and teach. These pathways are only theorized at this point, but the present findings are promising.

We also would have preferred to include fathers for generalizability and ethical reasons (i.e., parents should not be excluded on the basis of gender); however, we recruited from an already-existing sample of mother-child dyads. Similarly, our findings may not generalize to parents of non-typically developing children, as the importance of interoceptive vs. other types of parental emotion knowledge (e.g., situational knowledge) may differ depending on the unique needs of the child. Finally, we did not address children's own situational, nonverbal, and interoceptive knowledge, but doing so, particularly in longitudinal studies, would help clarify the exact mechanisms by which parental knowledge translates to children's downstream social affective functioning. Longitudinal designs might also capture "sleeper" effects whereby parents' earlier socialization messages may impact children's skills at later periods in development.

This study also demonstrates several strengths. First, we included multiple respondents (mothers, teachers) which helped us avoid measurement errors due to mono-reporting. Second, assessing emotion knowledge via coded open-ended vignettes rather than closed questionnaires helped us more broadly observe mothers' production of various situational, nonverbal, and interoceptive cues, rather than assessing cue recognition or forcing mothers to rate their experiences on a small number of predefined features. We further assessed multiple domains of maternal socialization (behaviors, beliefs, knowledge) so as to more fully understand which domains serve as "workhorses" in socialization, and captured children's competence in a different developmental context (the classroom). Our sample was also diverse with regard to child ethnicity, maternal education, and family income, increasing the generalizability of findings. We focused on third-grade children, an older and potentially more skilled but frequently understudied age group in social affective development. Finally, we introduced a novel construct— parental interoceptive knowledge—to the field of developmental science, as a first step in identifying how parental interoceptive processes may contribute to children's social affective development.

Conclusion

Maternal interoceptive knowledge was associated with children's social affective skills in middle childhood. However, many questions remain. Future investigations should consider the role of interoceptive knowledge across different developmental stages. For example, with preverbal children, parents may need to rely *more* on interoceptive knowledge to infer children's physiological state and what that physiology means (e.g., "Is my infant upset, hungry, or both?"). Similarly, parents with greater interoceptive knowledge may emphasize emotional arousal, thus teaching children interoceptive cues that could help them differentiate emotions from other feelings such as hunger or fatigue and effectively regulate those feelings.

Although more work is needed to further validate the construct of interoceptive knowledge, it may have tangible value in intervention contexts. For example, when children suffering from abdominal pain learn to focus on, interpret, and accept interoceptive sensations, they can reduce both pain and pain distress (Zucker et al., 2017). Parental interoceptive knowledge could similarly help support children who

are suffering from pain and acute or chronic illnesses. Other work shows that mindfulness interventions can improve different facets of interoception (Fischer, Messner, & Pollatos, 2017); future studies could examine whether mindfulness interventions boost parent/child interoceptive knowledge and downstream health and wellbeing. Programs that focus on developing emotional competence, such as the RULER program (Nathanson, Rivers, Flynn, & Brackett, 2016), could also test how teaching the interoceptive features of emotion experience and regulation supports children's growing emotional expertise.

Finally, future work should more explicitly connect parent and child interoception. This study was a first step, but it is critical that future work more fully address interoceptive development in children, including interoceptive knowledge. Given the neurophysiological basis of interoception, it is likely that some aspects of interoception, such as sensitivity to afferent physiological cues, are partially inherited (Murphy et al., 2019), perhaps predisposing children to certain social affective tendencies (e.g., over- or under-sensitivity to arousal and somatic experiences). Future work with twin and adoption studies could help clarify the extent to which different facets of interoception are inherited vs. socialized. Of course, likely all facets of interoception develop as an interaction between genes and environment. Interoceptive knowledge may be one facet that is more malleable to socialization and thus could serve as a primary vehicle by which socialization shapes other more heritable facets of interoception and emotion. More generally, we posit that parental socialization of children's interoceptive sensations likely follows similar mechanisms to emotion socialization. Just as children can learn about emotions from their parents' nonverbal behaviors, emotion discussions, and reactions to emotions, so too children may learn about interoceptive sensations via visible behaviors (e.g., parent placing a hand over the heart, visibly taking deeper breaths, etc.), through conversations, and through parents' supportive vs. punitive reactions to the child's verbalized or inferred sensations. We envision a rich body of future work at the intersection of affective, interoceptive, and developmental sciences, uncovering how interoception intertwines with social affective development across the lifespan.

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Table 1. Key facets of interoception with definitions.

Interoceptive Facet	Definition
Ability	Objective (measurable) sensitivity or accuracy in monitoring and distinguishing changes in visceral signals, e.g., heartbeat.
Sensibility	Subjective self-assessment about how typically "in touch" with the body or interoceptively able individuals believe themselves to be.
Awareness	Sometimes defined as the correspondence between ability and sensibility. Other times defined as the interoceptive sensations that are accessible to conscious self-reporting during momentary experience.
Knowledge	Accumulated implicit and explicit understanding about the nature, value, and regulation of interoceptive sensations in relation to physical, emotional, and cognitive states. This knowledge is likely reliant upon other facets of an individual's own interoceptive processes (e.g., greater interoceptive ability may create more opportunities to learn how visceral sensations link with different emotions), but it also may incorporate culturally-based scripts that are broader than personal experience. We suggest this construct encompasses knowledge about one's own idiosyncratic experiences (e.g., "My heart pounds when I speak in public"), knowledge about familiar others (e.g., "My friend loses his appetite when upset"), and general knowledge (e.g., "People get sweaty palms when nervous").

Note: The first three represent commonly examined facets of interoception (Khalsa et al., 2018). Knowledge is introduced here as a new facet.

Table 2. Means, standard deviations, and ranges for maternal socialization predictors, demographics, and children's outcomes.

Variables	Mean	SD	Min-Max
Maternal behaviors (CCNES)			
Supportive	5.29	.781	2.53-6.87
Nonsupportive	2.57	.721	1.36-5.27
Maternal beliefs (PBACE)			
Value beliefs	5.06	.473	3.71-6.00
Danger beliefs	2.56	.914	1.00-5.56
Maternal knowledge (Interview)			
Situational	.68	.606	0.00-3.00
Nonverbal	.26	.344	0.00-2.00
Interoceptive	.62	.728	0.00-3.00
Demographics			
Child age (yrs)	8.75	.340	7.92-9.73
Family income ($)	84,228	63,298	800-420,000
Maternal stress (DISE)	2.45	1.75	0.00-7.00
Child skills (ERC, SSRS)			
Emotion regulation	3.20	.516	1.50-4.00
Social skills	1.45	.411	.22-2.00
Child difficulties (ERC, SSRS)			
Emotion lability	1.57	.510	1.00-3.40
Problem behaviors	.44	.395	0.00-2.00

Note: Regarding gender, 98 daughters (48.8%) and 103 sons (51.2%) participated. Regarding ethnicity, 116 African-American (57.7%), 81 European-American (40.3%), and 4 biracial (2.0%) children participated. For maternal education, 31 mothers had a high school degree or less (15.5%), 107 mothers had one year of college or an associate degree (53.2%), and 55 mothers had four years of college or more (27.4%). Eight mothers omitted educational status (3.9%).

Table 3. Bivariate correlations between maternal socialization factors, demographics, and child social affective outcomes.

Variables	Maternal Behaviors		Maternal Beliefs		Maternal Knowledge			Demographics					Child Outcomes	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Maternal behaviors														
1. Supportive	-	**-.22^b**	**.21^b**	**-.16^a**	.04	-.03	-.02	**-.17^a**	-.04	.01	-.01	.04	-.10	**.19^a**
2. Nonsupportive			**-.19^b**	**.44^c**	.10	-.04	-.06	.10	.10	-.12	**-.23^b**	**.17^a**	-.11	.06
Maternal beliefs														
3. Value				**-.25^c**	.05	.04	**.16^a**	-.03	-.05	.05	.09	.04	**.25^c**	**-.24^b**
4. Danger					**.17^a**	-.02	**-.16^a**	**.14^a**	-.01	**-.24^b**	**-.42^c**	-.01	**-.17^a**	.14
Maternal knowledge														
5. Situational						-.05	-.10	.03	-.07	-.05	-.12	-.01	-.05	.01
6. Nonverbal							.09	-.04	-.06	**-.16^a**	.05	.08	-.09	.03
7. Interoceptive								.04	.07	**.26^c**	**.18^a**	**.18^a**	**.26^c**	**-.20^b**
Demographics														
8. Child age									.02	**.16^a**	.09	.12	.01	-.04
9. Child gender										.12	-.06	.02	**-.30^c**	**.25^b**
10. Child ethnicity											**.45^c**	.10	**.30^c**	**-.24^b**
11. Family income												.01	**.45^c**	**-.50^c**
12. Maternal stress													-.09	.12
Child outcomes														
13. Skills														**-.71^c**
14. Difficulties														-

Note: Bolded correlations are significant, with lettered superscripts indicating level of significance as ^{a} *p*<.05, ^{b} *p*<.01, ^{c} *p*<.001. Gender was coded as 0=girls, 1=boys; ethnicity coded as 0=African American, 1=European American.

Table 4. Regression model of maternal socialization behaviors, emotion beliefs, and emotion knowledge, with demographics predicting children's social affective skills.

Predictors	R^2	b	SE	β	p	Lower 95% CI	Upper 95% CI
Step 1: $F(4, 139)= 4.77$***	.095***						
Supportive reactions		**-.190**	**.084**	**-.190**	**.024**	**-.356**	**-.025**
Nonsupportive reactions		-.016	.097	-.015	.868	-.207	.175
Value emotion beliefs		**.275**	**.087**	**.259**	**.002**	**.103**	**.447**
Danger emotion beliefs		**-.192**	**.092**	**-.190**	**.039**	**-.373**	**-.010**
Step 2: $F(7, 136)= 4.17$***	.134*						
Supportive reactions		**-.177**	**.082**	**-.177**	**.033**	**-.340**	**-.015**
Nonsupportive reactions		-.037	.095	-.035	.695	-.225	.151
Value emotion beliefs		**.247**	**.086**	**.233**	**.005**	**.076**	**.418**
Danger emotion beliefs		-.147	.091	-.146	.109	-.328	.033
Situational knowledge		-.053	.078	-.053	.501	-.206	.101
Nonverbal knowledge		-.111	.075	-.116	.141	-.260	.037
Interoceptive knowledge		**.196**	**.074**	**.211**	**.009**	**.049**	**.343**
Step 3: $F(12, 131)= 7.22$***	.343***						
Supportive reactions		-.118	.076	-.117	.124	-.268	.032
Nonsupportive reactions		.025	.085	.023	.770	-.144	.194
Value emotion beliefs		**.184**	**.076**	**.174**	**.017**	**.034**	**.335**
Danger emotion beliefs		.024	.087	.024	.784	-.148	.196
Situational knowledge		-.031	.069	-.032	.651	-.167	.105
Nonverbal knowledge		-.116	.068	-.122	.091	-.252	.019
Interoceptive knowledge		**.173**	**.069**	**.186**	**.013**	**.037**	**.309**
Child age		-.034	.078	-.033	.660	-.188	.120
Child gender		**-.280**	**.069**	**-.282**	**.0001**	**-.417**	**-.142**
Child ethnicity		.093	.083	.095	.262	-.071	.257
Family income		**.377**	**.088**	**.364**	**.0001**	**.203**	**.551**
Maternal stress		-.111	.073	-.113	.128	-.255	.032

Note: Adjusted R^2 is reported. Significance reported for R^2 represents whether there was a significant ΔR^2. Bolded lines indicate significant effects. All variables are z-scored. Confidence intervals are for the unstandardized betas. *$p<.05$, ***$p<.0001$

Table 5. Regression model of maternal socialization behaviors, emotion beliefs, and emotion knowledge, with demographics predicting children's social affective difficulties.

Predictors	R^2	b	SE	β	p	Lower 95% CI	Upper 95% CI
Step 1: $F(4, 139)= 5.30$*	.107***						
Supportive reactions		**.258**	**.082**	**.260**	**.002**	**.095**	**.421**
Nonsupportive reactions		.026	.095	.024	.787	-.162	.214
Value emotion beliefs		**-.292**	**.086**	**-.278**	**.001**	**-.462**	**-.123**
Danger emotion beliefs		.137	.090	.137	.131	-.042	.315
Step 2: $F(7, 136)= 3.56$**	.111						
Supportive reactions		**.248**	**.082**	**.250**	**.003**	**.085**	**.411**
Nonsupportive reactions		.039	.095	.037	.684	-.150	.227
Value emotion beliefs		**-.271**	**.087**	**-.258**	**.002**	**-.442**	**-.100**
Danger emotion beliefs		.111	.091	.111	.227	-.070	.292
Situational knowledge		.010	.078	.010	.899	-.144	.164
Nonverbal knowledge		.047	.075	.049	.537	-.102	.196
Interoceptive knowledge		-.136	.074	-.148	.070	-.283	.011
Step 3: $F(12, 131)= 7.58$*	.356***						
Supportive reactions		**.172**	**.074**	**.173**	**.023**	**.024**	**.319**
Nonsupportive reactions		-.034	.084	-.032	.688	-.199	.132
Value emotion beliefs		**-.220**	**.075**	**-.209**	**.004**	**-.368**	**-.072**
Danger emotion beliefs		-.083	.085	-.084	.329	-.252	.085
Situational knowledge		-.024	.067	-.024	.726	-.157	.109
Nonverbal knowledge		.065	.067	.069	.334	-.068	.198
Interoceptive knowledge		-.123	.067	-.134	.071	-.256	.011
Child age		.024	.076	.023	.757	-.127	.175
Child gender		**.205**	**.068**	**.209**	**.003**	**.071**	**.340**
Child ethnicity		-.002	.081	-.002	.985	-.162	.159
Family income		**-.501**	**.086**	**-.488**	**.0001**	**-.672**	**-.331**
Maternal stress		.123	.071	.126	.085	-.017	.264

Note: Adjusted R^2 is reported. Significance reported for R^2 represents whether there was a significant ΔR^2. Bolded lines indicate significant effects. All variables are z-scored. Confidence intervals are for the unstandardized betas. ** $p<.01$, ***$p<.0001$

Figure. A theoretical model of key factors measured in this study that are implicated in children's emerging social affective competence.