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Infant emotional responses to challenge predict empathic behavior in toddlerhood

Malou M. P. G. Noten[1,2] | Kristiaan B. van der Heijden[1,2] | Stephan C. J. Huijbregts[1,2] | Stephanie H. M. van Goozen[1,3] | Hanna Swaab[1,2]

[1]Department of Clinical Neurodevelopmental Sciences, Leiden University, Leiden, The Netherlands

[2]Leiden Institute for Brain and Cognition, Leiden University, Leiden, The Netherlands

[3]School of Psychology, Cardiff University, Cardiff, United Kingdom

Correspondence
Kristiaan B. van der Heijden, Department of Clinical Neurodevelopmental Sciences, Leiden University, Wassenaarseweg 52, Box 9555, 2300 RB Leiden, The Netherlands, Room 4A15.
Email: KBHeijden@fsw.leidenuniv.nl

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Abstract

Although emotional responses are theorized to be important in the development of empathy, findings regarding the prediction of early empathic behavior by infant behavioral and physiological responses are mixed. This study examined whether behavioral and physiological responses to mild emotional challenge (still face paradigm and car seat task) in 118 infants at age 6 months predicted empathic distress and empathic concern in response to an empathy-evoking task (i.e, experimenter's distress simulation) at age 20 months. Correlation analyses, corrected for sex and baseline levels of physiological arousal, showed that stronger physiological and behavioral responses to emotional challenge at age 6 months were positively related to observed empathic distress, but not empathic concern, at age 20 months. Linear regression analyses indicated that physiological and behavioral responses to challenge at 6 months independently predicted empathic distress at 20 months, which suggests an important role for both physiological and behavioral emotional responses in empathy development. In addition, curvilinear regression analyses showed quadratic associations between behavioral responses at 6 months, and empathic distress and empathic concern at 20 months, which indicates that moderate levels of behavioral responsivity predict the highest levels of empathic distress and empathic concern.

KEYWORDS
autonomic nervous system, empathy, infant, pre-ejection period, respiratory sinus arrhythmia

1 | INTRODUCTION

Empathy is a fundamental component of social competence that involves the ability to share and understand the feelings of others. Precursors of empathy may already be present at a very early age, as newborns and infants become distressed in response to other infants' crying, but not to recordings of their own crying (Dondi, Simion, & Caltran, 1999; Geangu, Benga, Stahl, & Striano, 2010). Research suggests that physiological and behavioral responses to emotional challenge predict empathic behavior in children and adults, which supports neurodevelopmental theories indicating that emotional responsivity is a predictor of empathy (Decety, 2010; Eisenberg, 2010; Preston & De Waal, 2002). Emotional responses are determined by emotional reactivity and emotion regulation. Emotional reactivity refers to the way in which input from the external or internal world is perceived, valued, and triggers action, and is generally associated with activity in subcortical emotional processing systems (Etkin, Buchel, & Gross, 2015; Gross, 2015; McRae et al., 2012). Emotion regulation refers to the implementation of conscious or non-conscious goals to start, stop, or otherwise modulate the trajectory of an emotion, and is associated with activity in prefrontal systems. Emotional reactivity is a core aspect of temperament and individuals who are reactive themselves, in particular to negative emotions, have been shown to be more sensitive to the distress of others and therefore become more empathic (Eisenberg, 2000; Rothbart & Bates, 2006; Spinrad & Stifter, 2006). In addition to (negative) emotional reactivity, subsequent emotion regulation has been shown to be important in order to prevent oneself from becoming overwhelmed by vicariously induced feelings of others (Eisenberg, 2000). In childhood, most studies indicate that emotional responses to challenge are positively associated with empathy (Eisenberg, 2000, 2010). However, in infants and toddlers, both positive and negative associations between negative emotional responses to challenge and empathy have been found (Eisenberg, 2000, 2010; Hastings & Miller, 2014). Possibly, this is due to the fact that the autonomic nervous system, which plays an important role in emotional responses, matures rapidly during this period and becomes stable around age 5 (Alkon, Boyce, Davis, & Eskenazi, 2011; Quigley & Moore, 2018). Therefore, the association between emotional responses to challenge and empathic behavior is not clear at this developmental stage.

1.1 | Empathy in infancy and toddlerhood

Sharing the feelings of others (empathy) can result in empathic concern for the other, which is an other-oriented response, and in empathic distress, which is a self-oriented response (Eisenberg, 2010). In infancy, empathy-eliciting situations are often emotionally challenging and result in over-arousal (Eisenberg, 2010; Hoffman, 2000). Over-arousal can manifest as personal distress and seeking comfort, because vicarious emotional responses cannot be regulated and become aversive (Liew et al., 2011; McDonald & Messinger, 2011). Empathy does not always lead to empathic distress in infancy, because the infant's responses to empathy depend on the nature of the stressor and the capacity of the infant to regulate emotions (Davidov, Zahn-Waxler, Roth-Hanania, & Knafo, 2013; Roth-Hanania, Davidov, & Zahn-Waxler, 2011).

In addition to empathic distress, other-oriented empathic concern also occurs in infancy and toddlerhood, which includes concern for the wellbeing of others and trying to understand the cause of the feelings of the other, and motivates attempts to reduce the other person's distress (Davidov et al., 2013; Eisenberg, Eggum, & Di Giunta, 2010; McDonald & Messinger, 2011). As a result of development in emotion regulation, self-other differentiation and perspective taking during the second and third year of life, toddlers increasingly focus on the other's distress instead of focusing exclusively on their own distress, which results in higher levels of empathic concern. In turn, empathic concern can motivate prosocial behavior (Eisenberg et al., 2010; Eisenberg, Spinrad, & Knafo, 2015; Hoffman, 2000; Williams, O'Driscoll, & Moore, 2014). At the age of 3, over 50% of the children have been shown to perform some act of prosocial behavior in response to their mother's distress, although less than 20% of the children do so in response to a distressed stranger, which confirms the suggestion that empathic behavior increases with familiarity and similarity to the victim (Knafo, Zahn-Waxler, Van Hulle, Robinson, & Rhee, 2008; McDonald & Messinger, 2011; Preston & De Waal, 2002). Prosocial behavior can be motivated by empathic distress instead of empathic concern, in particular in adults, when prosocial behavior is aimed at comforting oneself (Batson, Fultz, & Schoenrade, 1987; Cialdini, 1991; Cialdini et al., 1987). In children, however, positive associations between prosocial behavior and empathic concern have been found, whereas prosocial behavior and personal distress were unrelated or negatively related (Knafo et al., 2008; Liew et al., 2011; Lin & Grisham, 2017; Vaish, Carpenter, & Tomasello, 2009; Williams et al., 2014).

Although empathic distress may not lead to helping as empathic concern does, it may still be considered an important aspect of empathy, since it reflects the extent to which an individual is affected by the suffering of another person (Batson et al., 1987; Eisenberg et al., 2010; Singer & Klimecki, 2014). In addition, empathic distress has been suggested to be a precursor of empathic concern (Hoffman, 2000; McDonald & Messinger, 2011; de Waal, 2008; Zahn-Waxler & Radke-Yarrow, 1990). However, empathic distress and empathic concern both result from empathy and can occur simultaneously throughout development (Gill & Calkins, 2003; Israelashvili & Karniol, 2018; Liew et al., 2011; Lin & Grisham, 2017; Young, Fox, & Zahn-Waxler, 1999). In line with Hoffman's stages of empathy, which indicate that empathic concern starts to co-occur with empathic distress as soon as self-other distinction is present, neuroimaging research in children indicates that brain regions associated with empathic distress develop earlier than brain regions associated with empathic concern, and behavioral research indicates that empathic distress is stable over time, whereas empathic concern increases during the first years of life (Decety, 2010; Decety & Michalska, 2010; Geangu et al., 2010; Hoffman, 2000; Roth-Hanania et al., 2011). It remains unclear whether the association of emotional responses with empathic behavior differs for distressed and concerned responses to empathic situations.

1.2 | Emotional responses

In infancy, emotional responses have been examined by behavioral observations and physiological measurement of changes in the autonomic nervous system. The autonomic nervous system consists of the sympathetic nervous system and parasympathetic nervous system, and both branches of the autonomic nervous system independently influence cardiac autonomic balance (Cacioppo, Uchino, & Berntson, 1994; Quigley & Moore, 2018). Reciprocal activation (ie, the increase in the sympathetic and decrease in the parasympathetic nervous system) is considered optimal in response to arousing situations, but coactivation and coinhibition also occur and these responses have been related to relatively poor adaptation, including aggressive behavior and impaired emotion regulation (Berntson, Cacioppo, & Quigley, 1991; Stifter, Dollar, & Cipriano, 2011; Suurland, van der Heijden, Huijbregts, van Goozen, & Swaab, 2017a, 2017b). Therefore, it is important to measure indicators of both parasympathetic (RSA) and sympathetic (pre-ejection period) activation when examining autonomic nervous system responses (Hastings, Miller, Kahle, & Zahn-Waxler, 2014). Parasympathetic activity can be measured using RSA, which is the variability of heart rate during the respiratory cycle. More RSA suppression in response to challenge has been associated with better emotion regulation (Calkins & Dedmon, 2000; Calkins, Dedmon, Gill, Lomax, & Johnson, 2002). Sympathetic activity can be measured by pre-ejection period, which represents the time between the depolarization of the left ventricle (onset of the heartbeat) and the onset of the left ventricular ejection of blood into the aorta. Although measurement of sympathetic activity by skin conductance level is more common, pre-ejection period is considered a more direct indicator of cardiac sympathetic activity that can reliably be used in infancy (Alkon et al., 2006; Cacioppo et al., 1994; Suurland et al., 2016). Increased sympathetic activity in response to emotional challenge, which is reflected by shortening of the pre-ejection period, has been associated with fewer behavioral problems (Boyce et al., 2001; Stifter et al., 2011).

The importance of both the sympathetic and parasympathetic nervous system for emotional responses has been explained by the polyvagal theory, which indicates that suppression of the parasympathetic nervous system suffices to cope with stress in mild emotional situations, whereas activation of the metabolically demanding sympathetic nervous system is adaptive in more stressful situations that cannot be regulated by the parasympathetic nervous system alone (Hastings & Miller, 2014; Porges, 2007; Porges & Furman, 2011). According to the polyvagal theory, both positive and negative associations between autonomic arousal and empathic behavior could be adaptive (Porges, 2007; Porges & Furman, 2011). On the one hand, a decrease in autonomic arousal (ie, an increase in parasympathetic activity and/or decrease in sympathetic activity) might contribute to a calm bodily state and engagement in social behavior, which could comprise high levels of empathic concern and low levels of empathic distress (Hastings & Miller, 2014; Hastings et al., 2014). On the other hand, an increase in autonomic arousal contributes to mobilization of resources, which might not only be necessary for empathic distress, but also to act concerned and prosocial. The two opposing mechanisms, both in accordance with the polyvagal theory, might explain the contradictory results that have been found for the association between physiological responses and empathy (Hastings & Miller, 2014). Another explanation for these contradictory results could be that the association between physiological responses and empathy is quadratic rather than linear. Possibly, children need sufficient physiological response to become empathic, but excessive responses could reflect over-arousal. This indicates that under-arousal would predict low empathic concern and low empathic distress, whereas over-arousal would predict low empathic concern and high empathic distress (Miller, Kahle, & Hastings, 2017; Tully, Donohue, & Garcia, 2015).

1.3 | Emotional responses and empathy in toddlerhood

Several studies have investigated the association of physiological or behavioral emotional responses with different types of empathic behaviors in toddlers. A study in 30-month-old children examined suppression of RSA in response to hearing a recording of a crying infant (Gill & Calkins, 2003). More RSA suppression was associated with less empathic concern and less behaviorally observed arousal (ie, distress). Similarly, more RSA suppression in response to recordings of a crying infant was also associated with less personal distress in 3-year-olds (Schuetze, Eiden, Molnar, & Colder, 2014). However, another study found that, at age 18 months, more RSA suppression in response to simulated distress was associated with more comfort seeking and personal distress (which are behavioral components of empathic distress), whereas the association was in the opposite direction at age 30 months (Liew et al., 2011).

Sympathetic responses, as indicated by pre-ejection period, have been investigated in relation to empathic behavior in one study, which showed that empathy, as indicated by sad facial expressions in response to a sad empathy-eliciting video in primary school aged children, was associated with reduced sympathetic (lengthened cardiac pre-ejection period) and increased parasympathetic (RSA augmentation) activity during the video (Marsh, Beauchaine, & Williams, 2008). In addition, pre-ejection period has been investigated in relation to constructs that are closely related to empathy. One study in 5-year-olds indicated that more pre-ejection period shortening and more RSA suppression were associated with reduced teacher reported prosocial behavior, which is an indicator of empathic concern (Kalvin, Bierman, & Gatzke-Kopp, 2016), whereas another study indicated that only RSA suppression (and not pre-ejection period shortening) was associated with helping others during an altruism task at age 4 (Miller, Kahle, & Hastings, 2015). Furthermore, one study using skin conductance in response to emotional video clips as a measure of the sympathetic nervous system at age 5, did not show an association with empathic behavior in response to distress simulation (Zahn-Waxler, Cole, Welsh, & Fox, 1995).

Four studies used a longitudinal design to examine whether infant emotional responses predicted empathic behavior. In these studies, positive associations between emotional responses and empathy were observed. At age 4 months, more situational emotional responses, as indicated by self-soothing strategies in response to a distress-eliciting situation, predicted more personal distress in an empathy-eliciting situation at 12 months (Ungerer et al., 1990). Another study indicated that less situational emotional responsivity, as indicated by behavioral responses to arousing stimuli at 4 months of age, predicted less personal distress and less empathic concern and caring behavior during an empathy-eliciting task at age 2 years (Young et al., 1999). Furthermore, positive associations have also been reported between dispositional emotional responses, as indicated by parent reports of negative emotionality in response to fear at age 10 months, and both empathic concern and empathic distress in response to distress simulation at age 18 months (Spinrad & Stifter, 2006). Recently, it has been shown that greater RSA suppression at 18 months predicted more helping, an indicator of empathic concern, at 30 months of age (Liew et al., 2011).

In sum, emotional responses have been linked to empathy in children and adults, but the association remains unclear in infancy and toddlerhood. In infancy and toddlerhood, both positive and negative associations have been found between physiological responses as indicated by withdrawal of the parasympathetic nervous system (RSA suppression) and empathic behavior (Gill & Calkins, 2003; Kalvin et al., 2016; Liew et al., 2011; Miller et al., 2015; Schuetze et al., 2014). However, the associations were positive in the youngest children (age 18 months; Liew et al., 2003). Research on the association between physiological response as indicated by activation of the sympathetic nervous system (shortened PEP or increased skin conductance) and empathy is scarce and contradictory as well, and has only included children above age 4 (Kahle, Miller, Lopez, & Hastings, 2016; Marsh et al., 2008; Miller et al., 2015; Zahn-Waxler et al., 1995). Finally, longitudinal studies showed that situational and dispositional measures of emotional responses were positively associated with empathic behavior at a later age (Spinrad & Stifter, 2006; Ungerer et al., 1990; Young et al., 1999).

1.4 | The present study

Clearly, more research on infant emotional responses as a predictor of later empathy is necessary. This study investigated whether empathic distress, as indicated by self-distress and comfort seeking, and empathic concern, as indicated by concerned expressions, hypothesis testing and prosocial behavior, at age 20 months could be predicted from physiological and behavioral responses to mild emotional challenges in infants at age 6 months. In addition, we examined whether these associations were linear or quadratic.

Our aim was to predict empathy from emotional responses in early infancy. Although emotional responses are present from birth, they were examined at age 6 months because previous studies indicated that physiological measurements can only be considered reliable from age 6 months (Alkon et al., 2006; Cacioppo et al., 1994; Suurland et al., 2016). As discussed above, empathic distress (ie, personal distress and comfort seeking) is clearly present early in development, but becomes relatively less important in early childhood. In contrast, empathic concern (ie, concerned expressions, hypothesis testing, and prosocial behavior) starts to develop during the second and third year of life and becomes more important in childhood. In toddlerhood, around age 20 months, expressions of both empathic distress and empathic concern are expected to occur in response to empathy eliciting stimuli. We hypothesized, in line with the polyvagal theory and based on previous studies in children up to age 2 years, a positive association between emotional responses at age 6 months and empathic distress at age 20 months. As for empathic concern, we did not have specific hypotheses about the direction of the association with emotional responses, given the inconsistency in previous findings and the suggestion that, based on the polyvagal theory, both positive and negative associations could be adaptive.

In order to gain better insight into the associations between emotional responses and empathy, quadratic associations were examined in addition to linear associations. Possibly, both high and low emotional responses predict low empathic distress and concern, whereas moderate responses represent an optimum and predict high empathic distress and concern. This study adds to the previous literature by investigating empathic behavior in relation to physiological as well as behavioral responses to emotional challenge, using two different emotional challenge tasks: the still face paradigm and car seat task, which represent a mild social challenge and a mild frustration challenge, respectively. In addition, physiological responses were examined using parasympathetic (RSA) as well as sympathetic (pre-ejection period) cardiac measures of the autonomic nervous system. Finally, both linear and quadratic models were tested.

2 | METHODS

2.1 | Participants

This study is part of the Mother-Infant Neurodevelopment Study in Leiden, The Netherlands (MINDS – Leiden). MINDS – Leiden is an ongoing longitudinal study into neurobiological and neurocognitive predictors of early behavior problems. The study was approved by the ethics committee of the Department of Education and Child Studies at the Faculty of Social and Behavioral Sciences, Leiden University (ECPW-2011/025), and by the Medical Research Ethics Committee at Leiden University Medical Centre (NL39303.058.12). All participating women provided written informed consent. Dutch speaking primiparous women between 17 and 25 years old (M = 23.28, SD = 2.21) with uncomplicated pregnancies were eligible to participate and 134 women were recruited during pregnancy via midwifery clinics, hospitals, prenatal classes, and pregnancy fairs. Women from high-risk backgrounds were oversampled in this study and screened for the following risk factors during pregnancy: positive screening on psychiatric disorder, substance use (alcohol, tobacco, drugs) during pregnancy, single status, unemployment, financial problems, no secondary education, limited social support network, and teenage pregnancy (see Smaling et al., 2015 for a detailed description of the procedures). The current sample consisted of 45.5% women that screened positively on one or more risk factors. Oversampling women from high risk backgrounds may increase variability in infant behavior and would compensate for a bias caused by possibly higher levels of dropout in the high-risk population. For this study, data from home visits at 6 months and 20 months post-partum were used. Dropout (N = 9 at 6 months and N = 16 at 20 months) was primarily due to unreachability of the mother, was not related to age or ethnicity, but was related to lower education level ($F(1, 132) = 7.56$, $p = 0.007$) and the presence of at least one risk factor ($F(1, 132) = 5.05$, $p = 0.026$).

2.2 | Procedures

Mothers were included in the study during pregnancy, when a first home visit took place in order to obtain background information and informed consent (N = 134). At age 6 months, a second home visit was scheduled at a time of day when the mother expected the infant to be most alert (N = 125). After some time to familiarize with the presence of the experimenters, the cardiac monitoring equipment was attached to the infant. Subsequently, the two mild emotional challenges were administered in a fixed order. To limit carryover effects, there was a break of approximately 30 min after the first challenge, which included the execution of some non-emotional tasks, and the second challenge was administered when the infant was calm. At age 20 months, a third home visit was scheduled, again at a time of day when the mother expected the child to be most alert (*N* = 118, including one participant who did not participate in the 6 month home visit). Empathy was examined after approximately 15 min of mother-child interaction. All home visits were carried out by two trained female experimenters, of whom at least one was familiar with the mother (for the second and third home visits). At the end of each appointment, the child was rewarded with a gift and the mother received a reimbursement for her time.

2.3 | Instruments

2.3.1 | Infant physiological and behavioral responses to emotional challenge

In order to measure behavioral and physiological responses to mildly stressful emotional challenges we used the still face procedure and the car seat task (Goldsmith & Rothbart, 1999; Tronick, Als, Adamson, Wise, & Brazelton, 1979). The still face paradigm is a validated mild social challenge during which mothers are instructed to play with their child for 2 min (play episode) (Mesman, van Ijzendoorn, & Bakermans-Kranenburg, 2009; Tronick et al., 1979). Subsequently, the interaction is interrupted by 2 min during which the mother is instructed to keep a neutral face and refrain from interacting with the child (still face episode). Finally, play with the child is resumed (reunion episode). Autonomic arousal was assessed during the play episode (baseline) and the still-face episode (challenge). The car seat task was drawn from the pre-locomotor version of the Laboratory Temperament Assessment Battery (Lab-TAB) and was designed to elicit mild frustration in infants (Goldsmith & Rothbart, 1999). First, the infant watched a 2-min relaxing movie on their mother's lap in order to measure baseline state. Subsequently, the child was buckled in a car seat. For 1 min, the mother stood behind the child without interacting with the infant, but she was still visible if the child turned its head. Previous studies found behavioral and physiological distress in response to this task at 6 months of age (Kim & Kochanska, 2012; Kochanska, Aksan, & Carlson, 2005; Suurland, Heijden, Huijbregts, Goozen, & Swaab, 2017a, 2017b). Autonomic arousal was measured during the baseline and the frustration episode.

All episodes of the still face paradigm and car seat task were video recorded and behavioral displays of emotional responses to the emotional challenges were coded afterwards by trained experimenters, allocating global scores from 0 to 3 (higher scores indicate more behavior) for distress vocalizations (intensity of whining, fussing, or crying), struggle (squirming in the seat or arching his/her back), and self-soothing behavior (using a body part or object for self-stimulation; Goldsmith & Rothbart, 1999; Miller, McDonough, Rosenblum, & Sameroff, 2002; Shapiro, Fagen, Prigot, Carroll, & Shalan, 1998). One average score was created from global ratings for the first and second half of the challenge episode. The coding training consisted of one instruction meeting, 10 clips that were coded independently and a second meeting to discuss these clips with the trainer. Subsequently, another set of ten clips was coded and compared to a standard that was created by experienced coders in order to establish sufficient reliability (ICC > 0.80) to move to the formal coding phase. Inter-rater reliability for 20% of the video clips that were double coded (intra-class correlation of absolute agreement, ICC) was 0.96 for distress vocalizations, 0.85 for struggle and 0.93 self-soothing behavior during the still face paradigm, and 0.94 for distress vocalizations, 0.75 for struggle and 0.90 for self-soothing behavior during the car seat task. This is comparable to previous studies (Kim & Kochanska, 2012; Kochanska et al., 2005; Miller et al., 2002). Behavioral data on the car seat task were missing for three children due to technical recording problems.

Autonomic nervous system parameters were assessed during the challenge tasks with the Vrije Universiteit Ambulatory Monitoring System (VU-AMS; De Geus & Van Doornen, 1996; de Geus, Willemsen, Klaver, & van Doornen, 1995; Willemsen, DeGeus, Klaver, VanDoornen, & Carrofl, 1996). Seven disposable pre-gelled Ag/AgCl electrodes (ConMed Huggable 1620-001) were attached to the trunk of the infant after removing oil with alcohol wipes. Electrocardiogram and impedance cardiogram were continuously measured. The electrocardiogram electrodes were placed slightly below the right collar bone 4 cm to the left of the sternum, at the apex of the heart on the left lateral margin of the chest approximately at the level of the processus xiphodius and the ground electrode was placed on the right side, between the lower two ribs. Thoracic impedance was assessed against a constant current of 50 KHz, 350 microamperes. Two electrodes on the back were used for sending this high-frequency signal through the subject's body, with two measuring electrodes on the chest picking up the voltage drop over the thorax. These measuring electrodes were placed at the suprasternal notch above the top of the sternum and at the processus xiphodius at the bottom of the sternum. The sending electrodes were placed at the back on the spine, at least 3 cm above the electrode at the top of the sternum and 3 cm below the electrode at the bottom of the sternum. Impedance cardiogram measures consisted of thorax impedance ($Z0$), impedance change (dZ) and the first derivative of impedance change (dZ/dt). The electrocardiogram and dZ/dt signal were sampled at 1,000 Hz, and the $Z0$ signal was sampled at 10 Hz. The VU-AMS calculates Large Scale Ensemble Averages across the entire baseline and challenge periods for the impedance electrocardiogram instead of 1 min ensemble averaging (see Riese et al., 2003 for the rationale). Mean values of pre-ejection period and RSA across the entire baseline and challenge episodes were automatically calculated using VU-DAMS software suite version 2.0, then visually checked by a trained experimenter and adjusted manually if necessary. The peak-trough method was used to compute RSA (de Geus et al., 1995; Grossman, Beek, & Wientjes, 1990), in which the respiration signal and the inter beat intervals are combined to compute the shortest inter beat interval during inspiration (when heart rate accelerates) and the longest inter beat interval during expiration (when heart rate decelerates). Pre-ejection period was obtained by calculating the difference between the Q-wave onset on the electrocardiogram (onset of the ventricular depolarization) and the B-point on the dZ/dt signal of the impedance cardiogram (onset of left ventricular ejection; Willemsen et al., 1996). Shorter pre-ejection periods reflect more sympathetic activation. Two trained raters independently performed the manual scoring of the data (ICC was 0.84 for the B-point and 0.86 for the Q-point) to make sure the location of the B-point and Q-point were correct and morphologically consistent across the entire recording. One consensus score for analysis was created in case of differences between the raters' scores. Two infants' autonomic nervous system data were excluded due to technical problems. Two mothers were unwilling to comply with the procedures due to resistance of the infant during the still face paradigm, and four mothers during the car seat task. In addition, movement artefacts caused missing data for RSA (6.9%) and pre-ejection period (18.2%) measurements. Missing values were unrelated to other relevant variables in the study (e.g. maternal age, ethnicity and educational level). Pre-ejection period shortening could be calculated for 101 infants in response to the still face paradigm and for 98 infants in response to the car seat task. RSA suppression could be calculated for 116 infants in response to the still face paradigm and 107 infants in response to the car seat task.

2.3.2 | Behavioral responses to an empathy-eliciting event

Empathic distress and empathic concern were assessed at 20 months post-partum using a distress simulation procedure adapted from Zahn-Waxler, Radke-Yarrow, Wagner, and Chapman (1992). Before the start of the study, the experimenter asked the mother to fill out some questionnaires, not to respond to the upcoming event and to refrain from interacting with the child during the task. Subsequently, the experimenter pretended to bump her toe into a piece of furniture. She pretended to be in pain for 30 s and to slowly recover from the pain during another 30 s. During this simulation, the experimenter sat down on the floor to rub her foot, she expressed pain vocally (eg, saying: "ouch, that hurts!") and did not make eye contact with the child. Behavioral responses of the child were videotaped by a second experimenter and coded for two subscales of Empathic distress: *Comfort seeking* (0–4), (0); does not seek comfort with self or mother; (1) mild self-comforting behavior or seeking proximity to mother; (2) moderate comfort seeking with self or mother, or combining mild comfort seeking with self and mother; (3) moderate comfort seeking by climbing onto mothers lap combined with self-comforting behavior or high levels of comfort seeking with the self or mother; (4) self-comforting behavior for nearly the whole task and high levels of proximity to mother by "flying" onto the mother's neck, and *Personal distress* (0–3), (0) no distress; (1) mild distress; (2) moderate distress, as indicated by eyes wide and mouth open; (3) severe distress by whimpering, whining, or crying; Liew et al., 2011; Lin & Grisham, 2017; Zahn-Waxler, Radke-Yarrow, et al., 1992). Furthermore, three subscales of empathic concern were coded: *Concerned expressions* (0–3), (0) no concern; (1) slight or some concern as indicated by brow furrowing for less than 3 s; (2) moderate concern expressed in face (brow furrowing 3–8 s) or voice such as saying "ouch"; (3) strong facial concern as indicated by brow furrowing for at least 8 s, *Hypothesis testing* (0–4), (0) no hypothesis testing; (1) simple nonverbal gestures such as looking back and forward to the victim's face and foot or simple verbal inquires such as "hurt?"; (2) a combination of gestures and verbal inquires; (3) at least two distinct combined attempts to understand; (4) four or more combined attempts to understand, and *Prosocial behavior* (0–3), (0) no prosocial behavior; (1) assisting for less than 3 s by comforting the experimenter or sharing toys; (2) assisting for 3–5 s; (3) assisting more than 5 s (Liew et al., 2011; Lin & Grisham, 2017; Young et al., 1999; Zahn-Waxler, Robinson, Robinson, & Emde, 1992). All videos were coded by two reliable coders that created one consensus score in case of differences between them (ICC of absolute agreement: hypothesis testing = 0.85; prosocial behavior = 0.81; concerned expressions = 0.69; self-distress = 0.87; comfort seeking = 0.78). This is comparable to previous studies (Gill & Calkins, 2003; Zahn-Waxler, Robinson, et al., 1992). Due to failure of the video equipment, the score for comfort seeking could not be determined for one participant and all empathy data were missing for another participant.

2.4 | Data analysis

All variables were checked for outliers and violations of assumptions. Due to a lack of variance on the subscales hypothesis testing and prosocial behavior (only 16.1% of the children showed prosocial behavior and only 14.4% of the children scored higher than 1 on hypothesis testing), dichotomous variables were created for these subscales before entering them in point-biserial correlation analyses (ie, correlation between one continuous variable and one dichotomous variable). Values that were three standard deviations above or below the average were removed (one value for PEP during the still face procedure, one value for lnRSA during the still face procedure, and two values for lnRSA during the car seat baseline). The natural logarithm of RSA (lnRSA) was used because RSA was positively skewed at all time-points. In order to test autonomic nervous system changes from baseline to challenge on the still face paradigm and car seat task, paired sample t tests were conducted. For autonomic nervous system variables on the still face paradigm and the car seat task, change scores were calculated for responses to challenge in a manner that positive difference scores indicated increased arousal resulting from activation of the sympathetic nervous system as indicated by shortened pre-ejection period and suppression of the parasympathetic nervous system as indicated by suppression of lnRSA. Missing data on emotional responses and empathy were imputed according to a multiple imputation approach resulting in 126 cases to be used in the analyses (Graham, 2009; Horton & Lipsitz, 2001). In addition to emotional responses and empathy variables, baseline autonomic arousal and control variables that were significant in preliminary analyses were included in the imputation model. A total of 10 imputed datasets were generated and relative efficiency estimates exceeded 95% for each parameter (Dong & Peng, 2013).

The correlation and regression analyses were performed using the pooled estimates across imputed datasets. The quadratic terms R^2 and X^2 for the multiple regression analyses and the data points for Figure 1 were obtained from the complete case data because pooled estimates were not available for these terms.

Associations between behavioral and physiological responses to the challenge tasks and empathy scores were examined with bivariate correlations and partial correlations, controlled for baseline autonomic arousal and variables that appeared significant in preliminary analyses, in order to provide insight into the influence of control variables on the associations between emotional responses and empathy. Multiple regression analyses were performed in order to test the independent contribution of behavioral and physiological responses to empathic behavior. Logistic regressions were used for dichotomous variables. Curvilinear (logistic) regression analyses were conducted to determine non-linear associations between behavioral and physiological responses to the challenge tasks and empathic behavior. The predictors were centered on the mean before entering them in the curvilinear regression analyses. In each curvilinear regression a linear predictor (mean centered variable) and quadratic predictor (mean centered and squared variable) was entered. Negative quadratic betas indicate that the quadratic pattern can be described as an inverted U-curve and significant linear betas indicate that the top of the curve lies somewhat to the right of the average score for empathic behavior. Separate analyses were performed for the still face paradigm and car seat task in order to explore possible task effects. All analyses were done using the Statistical Package for Social Sciences (SPSS for windows, version 23, SPSS Inc.) and statistical significance was set at $p < .05$ a priori.

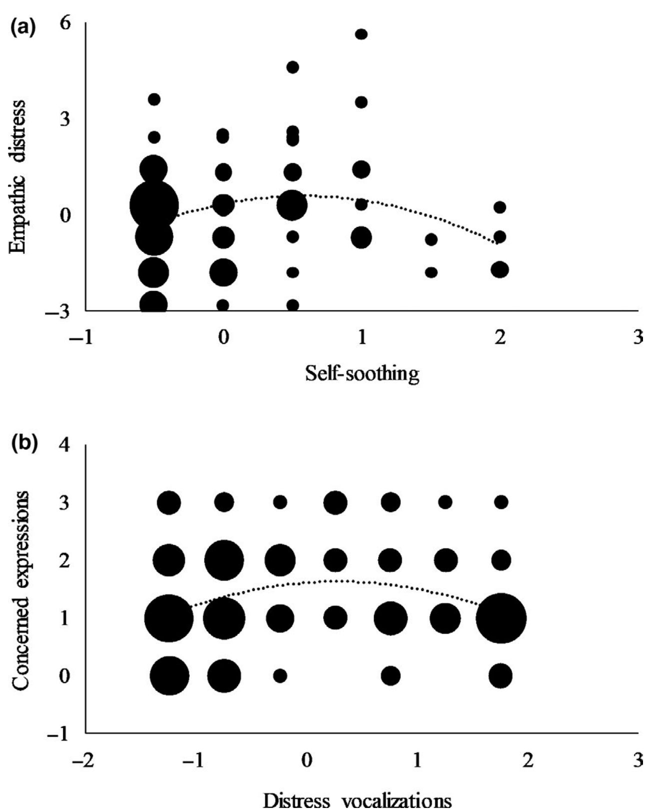

FIGURE 1 (a) The quadratic association between self-soothing during the car seat task (6 months) and empathic distress (20 months). (b) The quadratic association between distress vocalizations during the car seat task (6 months) and concerned expressions (20 months). Note: The size of the dots indicate the amount of participants at each data point based on complete case data

3 | RESULTS

3.1 | Descriptives

Sample characteristics and descriptive statistics are displayed in Table 1. The sample included nine children with low birthweight (<2,500 g) and 12 children were born preterm (<37 weeks). These children did not differ from the other children in the sample on any of the relevant variables in the study. No differences were found between mothers from high- and low-risk background on any of the measures examined in this study. However, individual risk factors were associated with some of the variables used. If the mother had no secondary education (more risk), the child showed less concerned expressions ($r(118) = −0.19$, $p = .038$). In addition, mothers with substance use during pregnancy had children with less lnRSA suppression in response to the still face procedure ($r(116) = −19$, $p = .039$), more pre-ejection period shortening in response to the car seat task ($r(98) = 0.22$, $p = .034$), less vocal distress in response to the car seat task ($r(120) = −0.24$, $p = .010$), and less struggle during the still face procedure ($r(123) = −0.21$, $p = .023$) at age 6 months. Mothers with limited social support networks had children with less lnRSA suppression in response to the car seat task ($r(107) = −0.25$, $p = .009$). Correlational analyses including these subscales were controlled for the specific risk factors that were associated with each specific subscale. During the distress simulation at age 20 months, girls showed more concerned expressions ($t(116) = −2.19$, $p = .030$, $d = 0.41$) and personal distress ($t(116) = −2.25$, $p = .026$, $d = 0.42$) than boys. Therefore, correlational analyses including these subscales were controlled for sex. In addition, correlational analyses including physiological responses were controlled for baseline physiological state. Paired sample *t* tests showed shortened pre-ejection period (still face paradigm: $t(100) = 2.26$, $p = .026$, $d = 0.23$; car seat task: $t(97) = 3.46$, $p = .001$, $d = 0.35$); and lnRSA suppression (still face paradigm: $t(115) = 4.79$, $p < .001$, $d = 0.44$) from baseline to challenge, except for lnRSA during the car seat task. Related samples Wilcoxon Signed Rank tests, indicated no difference between levels of vocal distress and struggle during the still face procedure and car seat task at age 6 months, but infants showed more self-soothing during the still face procedure ($M = 0.90$, $SD = 1.00$, $Mdn = 0.5$) than during the car seat task ($M = 0.50$, $SD = 0.68$, $Mdn = 0.0$), ($Z (116) = 3.56$, $p < .001$).

Based on interrelations, the behavioral scores for personal distress and comfort seeking at age 20 months were transformed into standardized scores and averaged to form one composite scores for empathic distress (Liew et al., 2011; Lin & Grisham, 2017). Hypothesis testing, concerned expressions and prosocial behavior are indicators of empathic concern at age 20 months,

TABLE 1 Sample characteristics

Variable	*N*	M	*SD*	Range
Caucasian ethnicity	126	85.8%		
Highest education completed (mother)	126			
Primary education		3.0%		
Secondary education		21.6%		
Tertiary education		46.3%		
Bachelor degree or higher		29.1%		
Infant sex (male)	126	54.8%		
Infant gestational age at birth (weeks)	125	39.33	2.04	31.43–42.00
Infant birth weight (g)	126	3,345	541	1,700–4,530
Infant APGAR score (5-min)	76	9.49	0.96	4–10
Infant age at 6 month measurement	126	6.43	0.46	5.72–8.90
Infant age at 20 month measurement	118	20.43	0.70	18.73–24.05
Empathic concern (20 months)				
Prosocial behavior	118	0.30	0.77	0–3
Hypothesis testing	118	1.30	0.83	0–4
Hypothesis testing/prosocial behavior	118	0.25	0.44	0–1
Concerned expressions	118	1.31	0.90	0–3
Empathic distress (20 months)	117	0.00	0.79	−1.40–2.82
Personal distress	118	0.95	0.81	0–3
Comfort seeking	117	1.70	0.98	0–4
Still face paradigm (6 months)				
Baseline PEP	106	62.53	6.55	44.13–76.89
Baseline lnRSA	117	3.39	0.38	2.39–4.36
Challenge PEP	110	61.39	7.40	37.90–76.89
Challenge lnRSA	116	3.22	0.42	2.29–4.18
Distress vocalizations	123	1.04	1.06	0–3
Struggle	123	1.06	0.96	0–3
Self-soothing	123	0.90	1.00	0–3
Car seat task (6 months)				
Baseline PEP	113	63.23	6.28	45.06–76.89
Baseline lnRSA	113	3.30	0.40	2.28–4.56
Challenge PEP	101	61.52	6.84	45.00–76.00
Challenge lnRSA	111	3.30	0.55	1.92–4.86
Distress vocalizations	120	1.24	1.08	0–3
Struggle	119	1.05	0.44	0–2
Self-soothing	117	0.50	0.68	0–2.5

Note: Maternal background variables were obtained during pregnancy, infant birth characteristics were obtained 6 months post-partum; Pre-ejection period (PEP); natural log of respiratory sinus arrhythmia (lnRSA).

but only hypothesis testing and prosocial behavior were positively associated. Results from a nonlinear principal component analysis indicated that the data were best described by two factors. One factor (eigenvalue 1.220 which accounted for 40.66% of the variance) that included hypothesis testing (unrotated component loading 0.807) and prosocial behavior (unrotated component loading 0.731), and another factor including concerned expressions (eigenvalue 1.052; accounting for 35.06% of the variance; unrotated component loading 0.915). One composite variable was created for hypothesis testing/prosocial behavior which indicated whether no hypothesis testing/prosocial behavior was observed (value 0) or some hypothesis/testing prosocial behavior was observed (value 1). The concerned expressions variable was retained.

3.2 | Predicting empathic distress and concern from behavioral and physiological responses

Table 2 shows bivariate (below the diagonal) and partial correlations, controlled for baseline, maternal risk factors, and sex (above the diagonal), between physiological and behavioral responses to challenge at age 6 months and behavioral responses to the distress simulation task at age 20 months. The effect of controlling for baseline, maternal risk factors, and sex on the correlation coefficients and significance levels was marginal, except for a positive association between lnRSA suppression to the still face procedure and lnRSA suppression to the car seat task in the controlled correlations, which was not present in the uncontrolled correlations. The controlled correlations (above the diagonal) will be discussed further in the results and discussion sections. Correlations of baseline lnRSA and pre-ejection period with the main variables in the study are shown in Table 2. Regarding responses on the still face paradigm, pre-ejection period shortening from baseline to challenge was associated with less comfort seeking and empathic distress (composite), and more struggle was associated with more empathic distress (composite) and more concerned expressions. The results on the car seat task indicated that shortened pre-ejection period and lnRSA suppression from baseline to challenge were related to more empathic distress (composite). Shortened pre-ejection period was also associated with more personal distress and comfort seeking. In addition, more struggle was related to more empathic distress (composite) and comfort seeking.

Multiple linear regressions were performed to examine if behavioral and physiological responses to challenge at age 6 months contributed independently to empathic distress at age 20 months. Behavioral responses to challenge and physiological responses to challenge were included as predictors. Empathic distress (composite), concerned expressions, and hypothesis testing/prosocial behavior were used as dependent variables. Empathic distress was included as covariate in the prediction of concerned expression and hypothesis testing/prosocial behavior, and concerned expressions and hypothesis testing were included as covariates in the prediction of empathic distress. Logistic linear regressions were used for the dichotomous dependent variable hypothesis testing/ prosocial behavior. The results, reported in Tables 3 and 4, show that struggle and shortened pre-ejection period in

TABLE 2 Correlation analyses of the main variables in the study

	1	1a	1b	2a	2b	2bi	2bii	3	4	5	6	7	8	9	10	11	12
Empathic distress (20 months)																	
1. Empathic distress	—	0.78**	0.79**	0.35**	−0.09	−0.06	−0.08	−0.20*	0.11	0.16	0.19*	−0.10	0.25**	0.19*	0.10	0.29**	0.01
1a. Personal distress	0.79**	—	0.24*	0.52**	−0.00	−0.04	−0.07	−0.05	0.03	0.10	0.16	−0.10	0.19*	0.13	0.16	0.16	−0.03
1b. Comfort seeking	0.79**	0.24*	—	0.03	−0.15	−0.16	−0.07	−0.26**	0.14	0.16	0.17	−0.05	0.22*	0.17	0.00	0.29**	0.02
Empathic concern (20 months)																	
2a. Concerned expressions	0.36**	0.52**	0.4	—	−0.00	0.05	−0.08	0.05	0.00	−0.03	0.20*	−0.03	0.00	−0.10	0.02	0.09	0.00
2b Hypothesis testing/prosocial behavior	−0.09	0.01	−0.15	−0.01	—	0.69**	0.77**	−0.06	−0.01	−0.01	0.05	−0.09	−0.08	0.05	0.07	−0.01	−0.02
2bi. Hypothesis testing	−0.06	0.06	−0.16	0.04	0.69**	—	0.24*	−0.02	0.07	0.09	0.02	−0.08	−0.11	0.01	0.08	0.07	−0.06
2bii. Prosocial behavior	−0.08	−0.06	−0.07	−0.09	0.77**	0.24*	—	−0.08	−0.06	−0.10	0.04	−0.07	−0.05	−0.01	−0.06	−0.05	−0.07
Still face procedure (6 months)																	
3. PEP shortening	−0.21	−0.06	−0.28*	0.04	−0.08	−0.03	−0.09	—	0.01	0.16	0.17	0.03	0.13	−0.09	0.05	−0.11	−0.17
4. lnRSA suppression	0.18	0.09	0.19*	0.02	−0.02	0.06	−0.08	−0.05	—	0.33**	0.13	−0.01	−0.06	0.19*	0.00	0.04	−0.10
5. Distress vocalizations	0.16	0.10	0.16	−0.03	−0.01	0.09	−0.10	0.14	0.32**	—	0.33**	−0.22*	0.20*	0.04	0.17	0.01	0.00
6. Struggle	0.20*	0.14	0.18*	0.17	0.02	−0.02	0.01	0.14	0.18*	0.34**	—	−0.16*	0.10	−0.06	0.01	0.09	0.02
7. Self-soothing	−0.10	−0.11	−0.05	−0.04	−0.09	−0.08	−0.07	0.03	−0.00	−0.22*	−0.14	—	−0.17	0.08	−0.12	−0.05	−0.16
Car seat task (6 months)																	
8. PEP shortening	0.21*	0.15	0.19	0.01	−0.07	−0.08	−0.04	0.07	−0.09	0.17	0.04	−0.18	—	0.01	0.07	0.06	−0.16
9. lnRSA suppression	0.22*	0.16	0.18	−0.05	0.08	−0.00	0.04	−0.08	0.04	0.03	−0.10	0.10	0.04	—	0.28**	0.14	0.01
10. Distress vocalizations	0.12	0.17	0.02	0.02	0.03	0.04	−0.08	0.06	0.05	0.18	0.06	−0.10	0.02	0.24*	—	−0.04	−0.05
11. Struggle	0.29**	0.17	0.29**	0.12	−0.01	0.07	−0.06	−0.12	0.05	0.01	0.12	−0.05	0.03	0.12	0.00	—	−0.23*
12. Self-soothing	0.01	−0.00	0.02	0.03	−0.02	−0.05	−0.07	−0.17	−0.09	0.00	0.04	0.22*	−0.16	0.02	−0.02	−0.23*	-

*$p \le .05$, **$p \le .01$; pre-ejection period (PEP); natural log of respiratory sinus arrhythmia (lnRSA); PEP/lnRSA scores indicate difference scores between baseline and challenge; scores above the diagonal were controlled for maternal risk factors, sex, and baseline effects whenever necessary and scores below the diagonal were not.

response to the car seat task independently contributed to empathic distress. Linear regression analyses with behavioral and physiological responses to the still face procedure as predictors, or with concerned expressions or hypothesis testing/prosocial behavior as outcome measure yielded no significant results.

Curvilinear regression analyses on the association between emotional responses at age 6 months and empathy at age 20 months indicated that a quadratic association was present between self-soothing behavior during the car seat task and the empathic distress composite, and between distress vocalizations during the car seat task and concerned expressions (Table 5 and Figure 1). Curvilinear regression analyses with physiological responses or struggle to emotional challenge as predictors, or with hypothesis testing/prosocial behavior as outcome measure yielded no significant results.

4 | DISCUSSION

The main goal of this study was to examine the predictive value of physiological and behavioral responses to mild emotional challenge at age 6 months to empathic distress and empathic concern in response to simulated distress by a stranger at age 20 months. We expected a positive association between emotional responses and empathic distress, but we did not have specific hypotheses about the direction of the association between emotional responses and empathic concern. In addition, we examined whether these associations were linear or quadratic.

4.1 | Empathic distress

The results indicated that empathic distress was predicted by behavioral and physiological responses to challenge. Shortened pre-ejection period and lnRSA suppression in response to the car seat task were positively associated with the empathic distress composite. In addition, struggle during the car seat task and still face paradigm was positively associated with the empathic distress composite. These results indicate that infants who are more emotionally responsive themselves, are also more sensitive to the distress of others and confirm previous findings indicating that behavioral and physiological responses to challenge are positively related to empathic distress until age two

TABLE 3 Linear and logistic regression analyses of the effect of behavioral and physiological responses to the car seat task at age 6 months on empathic behavior at age 20 months

Linear regression	**B**	***SE***	**R^2**	***p***
Model 1: empathic distress			.43	**<.001**
Concerned expressions	0.29	.23		**.003**
Hypothesis testing/prosocial behavior	−0.16	.19		.41
Distress vocalizations	0.05	.05		.82
Struggle	0.44	15		**.004**
Self-soothing	0.10	.10		.32
PEP shortening	0.03	.02		**.032**
lnRSA suppression	0.26	.14		.06
Model 2: concerned expressions			.21	**<.01**
Empathic distress	0.46	.15		<**.004**
Distress vocalizations	0.01	.08		.94
Struggle	0.05	.20		.82
Self-soothing	0.03	.14		.22
PEP shortening	−0.01	.02		.54
lnRSA suppression	−0.22	.16		.18
Logistic regression	**B**	***SE***	**χ^2**	***p***
Model 3: hypothesis testing/prosocial behavior			16.20	**<.001**
Empathic distress	−0.33	.43		.45
Distress vocalizations	0.05	.21		.82
Struggle	0.03	.55		.96
Self-soothing	−0.09	.35		.81
PEP shortening	−0.03	.05		.64
lnRSA suppression	0.42	.45		.36

Note: Pre-ejection period (PEP); natural log of respiratory sinus arrhythmia (lnRSA); scores were not standardized before entering them in the regression analyses.
Bold values indicate statistical significance.

TABLE 4 Linear and logistic regression analyses of the effect of behavioral and physiological responses to the still face procedure at age 6 months on empathic behavior at age 20 months

Linear regression	B	*SE*	R^2	*p*
Model 1: empathic distress			.28	**<.001**
Concerned expressions	0.30	0.09		**.001**
Hypothesis testing/prosocial behavior	−0.21	0.19		.28
Distress vocalizations	0.10	0.08		.22
Struggle	0.10	0.08		.19
Self-soothing	−0.04	0.07		.56
PEP shortening	−0.05	0.02		**.009**
lnRSA suppression	0.16	0.20		.41
Model 2: concerned expressions			.24	**<.001**
Empathic distress	0.45	0.13		**.001**
Distress vocalizations	−0.13	0.09		.17
Struggle	0.12	0.09		.21
Self-soothing	−0.02	0.08		.84
PEP shortening	0.03	0.02		.25
lnRSA suppression	−0.02	0.24		.94

Logistic regression	B	SE	χ^2	*p*
Model 3: hypothesis testing/prosocial behavior			21.45	**<.001**
Empathic distress	−0.41	0.37		.27
Distress vocalizations	−0.03	0.24		.91
Struggle	0.14	0.25		.57
Self-soothing	−0.23	0.23		.32
PEP shortening	−0.06	0.06		.36
lnRSA suppression	−0.05	0.63		.94

Note: Pre-ejection period (PEP); natural log of respiratory sinus arrhythmia (lnRSA); scores were not standardized before entering them in the regression analyses.
Bold values indicate statistical significance.

(Liew et al., 2011; Ungerer et al., 1990; Young et al., 1999). In contrast, a negative association between pre-ejection period shortening to the still face paradigm and empathic distress (composite) was present, which will be discussed in more detail further on (see section Task effects4.1). Behavioral (ie, struggle) and physiological responses (ie, shortened pre-ejection period) to the car seat task were, independently of each other, significant predictors of empathic distress. These results stress the importance of both behavioral and physiological responses for the development of empathy.

In addition to the linear associations, quadratic associations were found between self-soothing behavior during the car seat task and empathic distress (composite). The findings suggest that low and high levels of self-soothing behavior result in low empathic distress, whereas moderate levels of self-soothing behavior are associated with more empathic distress. An explanation for the association between high levels of self-soothing behavior and low levels of empathic distress might be that high arousal levels as reflected by strong self-soothing behavior could be related to "over-arousal" and freezing behavior during the empathy task, which is reflected behaviorally as a low level of empathic distress (Gill & Calkins, 2003; Porges, 2007).

4.2 | Empathic concern

As for empathic concern, the three indicators of empathic concern (ie, concerned expressions, hypothesis testing, and prosocial behavior) could not be represented as a single factor, whereas these indicators were positively associated in previous studies at this age (Knafo et al., 2008; Liew et al., 2011). However, hypothesis testing and prosocial behavior could be combined into one factor. Possibly, concerned expressions was a separate factor because it refers to a feeling, which is difficult to inhibit, whereas hypothesis testing and prosocial behavior refer to actions, which increase with familiarity with the victim (Knafo et al., 2008; McDonald & Messinger, 2011; Preston & De Waal, 2002). Therefore, the concerned expressions variable may have represented the extent to which the children felt concern for the experimenter and the hypothesis testing/prosocial behavior composite represented whether children were able to act upon these feelings in an empathy-evoking situation with a stranger. With regard to the association between indices of empathic concern and emotional responses, a positive association was found between struggle during the still face paradigm and concerned expressions. This is in line with a longitudinal study suggesting that

TABLE 5 Curvilinear (logistic) regression analyses of the effect of behavioral and physiological responses to challenge at age 6 months on empathic behavior at age 20 months

	Empathic distress		Concerned expressions		Hypothesis testing/ prosocial behavior	
	B (*SE*)	*p*	B (*SE*)	*p*	B (*SE*)	*p*
Still face procedure						
Linear: PEP shortening	−0.04 (0.08)	.05	0.00 (0.02)	.86	−0.04 (0.06)	.52
Quadratic: PEP shortening	0.00 (0.00)	.35	0.00 (0.00)	.23	−0.01 (0.01)	.38
Linear: lnRSA suppression	0.32 (0.19)	.09	0.06 (0.24)	.23	−0.13 (0.58)	.83
Quadratic: lnRSA suppression	0.23 (0.32)	.46	0.08 (0.41)	.20	−0.15 (1.01)	.89
Linear: distress vocalizations	0.08 (0.09)	.34	−0.03 (0.10)	.79	−0.02 (0.25)	.94
Quadratic: distress vocalizations	0.05 (0.08)	.64	0.01 (0.10)	.96	−0.01 (0.23)	.95
Linear: struggle	0.14 (0.08)	.10	0.11 (0.10)	.24	0.03 (0.24)	.89
Quadratic: struggle	0.08 (0.09)	.35	0.13 (0.11)	.23	0.04 (0.26)	.88
Linear: self-soothing	0.01 (0.10)	.96	0.08 (0.12)	.67	−0.10 (0.30)	.75
Quadratic: self-soothing	−0.11 (0.09)	.24	−0.14 (0.10)	.18	−0.15 (0.28)	.58
Car seat task						
Linear: PEP shortening	0.04 (0.02)	**.03**	0.01 (0.02)	.82	−0.03 (0.06)	.63
Quadratic: PEP shortening	−0.00 (0.00)	.67	−0.00 (0.00)	.69	−0.01 (0.10)	.38
Linear: lnRSA suppression	0.29 (0.15)	.6	−0.08 (0.17)	.63	0.31 (0.43)	.48
Quadratic: lnRSA suppression	0.08 (0.18)	.68	0.04 (0.20)	.20	0.01 (0.45)	.99
Linear: distress vocalizations	0.14 (0.08)	.06	0.12 (0.09)	.20	0.14 (0.23)	.53
Quadratic: distress vocalizations	−0.12 (0.08)	.14	−0.23 (0.11)	**.04**	−0.17 (0.26)	.52
Linear: struggle	0.53 (0.16)	**<.01**	0.22 (0.20)	.28	0.02 (0.51)	.97
Quadratic: struggle	−0.04 (0.31)	.89	0.26 (0.36)	.46	−1.08 (1.05)	.31
Linear: self-soothing	0.29 (0.17)	.09	0.13 (0.19)	.50	0.33 (0.49)	.50
Quadratic: self-soothing	−0.32 (0.14)	**.02**	−0.10 (0.17)	.54	−0.53 (0.49)	.28

Bold values indicate statistical significance.

lower behavioral responses to challenge (under-arousal) predicted less empathic concern in toddlers (Young et al., 1999). In addition, a quadratic association was found between distress vocalizations during the car seat task and concerned expressions. This indicates that both high levels (over-arousal) and low levels (under-arousal) of behavioral responses to challenge (ie, distress vocalizations) predicted low levels of empathic concern (ie, concerned expressions), whereas moderate levels of behavioral responses to challenge represented optimal levels of arousal that predict the highest levels of empathic concern in response to empathy.

Remarkably, no quadratic associations of physiological responses with empathic concern or empathic distress were found. In addition, linear as well as quadratic associations were found between behavioral responses and empathic behavior. The co-occurrence of linear and quadratic associations could indicate that only the increasing part of the curve was present in the data yielding linear associations (struggle, pre-ejection period, and lnRSA), whereas the whole curve was reflected by distress vocalizations and self-soothing behavior, which yielded quadratic associations. This study used mild emotional challenges that may not elicit high levels of physiological arousal and more severe stressors, such as longer challenges (eg, an extended still face period) or physical challenges (eg, examining stress in responses to vaccination), might be necessary to be able to examine the whole curve (Bosquet Enlow et al., 2014; Jansen, Beijers, Riksen-Walraven, & de Weerth, 2010).

In addition to the co-occurrence of linear and quadratic associations, it stands out that there was a smaller number of significant findings regarding empathic concern (ie, hypothesis testing, concerned expressions and prosocial behavior) compared to empathic distress (ie, personal distress and comfort seeking). We propose several explanations for this difference. First, behavioral and physiological responses might have a stronger influence on empathic distress than on empathic concern because empathic concern develops under the influence of other factors such as socialization and perspective taking (Farrant, Devine, Maybery, & Fletcher, 2012; Vaish et al., 2009). Second, according to the polyvagal theory, positive associations are expected between physiological responses and empathic distress, whereas both activation and withdrawal of the parasympathetic nervous system could facilitate empathic concern (Hastings & Miller, 2014). In line with this suggestion, previous studies indicated stronger associations between physiological responses and empathic distress than between physiological responses and empathic concern (Hastings & Miller, 2014; Liew et al., 2011; Schuetze et al., 2014). Third, we chose for a distress simulation task performed by a trained experimenter instead of the child's mother in order to reduce the bias caused by differences in the credibility and intensity of the distress simulation. Distress as a result of stranger fear might have influenced the measure of empathic distress. Higher levels of empathic distress have been shown in relatively fearful toddlers (Liew et al., 2011). Although we used an introductory period of at least 15 min for the child to become familiar with and comfortable in the presence of the experimenter, we cannot exclude the possibility that stranger fear might have been present in a part of the sample. Fourth, while we used difference scores between baseline and challenge episodes for analyses regarding emotional responses, more advanced techniques, such as dynamic RSA trajectories, have previously been shown to yield associations between physiological responses and empathic concern in children from age 4 (Miller, Nuselovici, & Hastings, 2016). Fifth, 74.6% of the children did not show prosocial behavior or hypothesis testing and the large number of zero's may have led to false negative findings. However, logistic regression analyses applied in this study are considered robust to zero-inflation and strategies to correct for class imbalance (ie, zero inflation for dichotomous variables) are generally only recommended in case of extremely rare events, for example, 99.9% zero's (King & Zeng, 2001; Sun, Wong, & Kamel, 2009); see (Perumean-Chaney, Morgan, McDowall, & Aban, 2013; Wagh & Kamalja, 2017) for extensive discussion on advanced techniques to correct for possible bias).

4.3 | Task effects

There was a discrepancy in physiological responses between the still face paradigm and car seat task. For the car seat task, RSA suppression and shortened pre-ejection period positively predicted empathic distress (composite), whereas shortened pre-ejection period in response to the still face paradigm was a negative predictor of empathic distress (composite). This suggests that these paradigms might be qualitatively different, resulting in different physiological responses. Although we did not have hypotheses regarding task differences, the discrepancy between findings on the car seat task and still face paradigm is contradictory to a meta-analysis demonstrating that the link between RSA suppression and children's adaptive functioning outcomes did not vary as a function of type of challenge (ie, frustration, cognitive, social, positive, or sensory oriented tasks; Graziano & Derefinko, 2013). In addition, our results are also contradictory to previous findings that behavioral responses to a social interaction task (still face paradigm) were more pronounced than responses to a non-social task in which a mobile, which had previously moved in response to the infants' kicking, could no longer be moved by the infant (Shapiro et al., 1998).

Several explanations are possible. First, children were possibly more tired during the car seat task because this task always was the last task of the home visit, while the still face paradigm was performed approximately 30 min earlier. Tiredness has been suggested to reduce RSA suppression to distress, which is in line with our finding that RSA did not significantly decrease in response to the car seat task (Keltikangas-Järvinen & Heponiemi, 2004). It is surprising that RSA suppression in response to the car seat task predicted empathic distress, whereas on average RSA did not change from baseline to the car seat phase. Previous studies indicated that RSA suppression in response to challenge is not stable yet at age 6 months, as some infants show RSA suppression and others show RSA augmentation, which results in no net RSA suppression for the entire sample (Alkon et al., 2011; Quigley & Moore, 2018). In line with those previous findings, in the current study both RSA suppression (45.8%) and RSA augmentation (54.2%) were found in response to the car seat task. The correlation analyses showed that more RSA suppression was associated with more empathic distress. Similarly, Liew et al. (2011) did not find overall RSA suppression at 18 months, but RSA suppression at age 18 months did predict empathic behavior at age 30 months.

A second explanation for the task effects is the presence of a carryover effect. Although there was sufficient time to recover between tasks, infants could have remembered that being in the car seat was not pleasant the first time (still face paradigm). This may have caused them to become distressed faster when they were put in the car seat for the second time (car seat task). Previous studies on the still face paradigm indicate that a second still face phase was more distressing than the first one, although it should be noted that the recovery time between the challenges was much shorter in these studies (Bosquet Enlow et al., 2014; Haley & Stansbury, 2003). Therefore, the lack of counterbalancing of the challenge tasks is a limitation of this study and should be taken into account in further research. Third, the contrast in the direction of the results might be explained by the principals of the polyvagal theory, which suggests that activation of the metabolically demanding sympathetic nervous system is only adaptive in more stressful situations, whereas suppression of the parasympathetic nervous system suffices to regulate stress in less threatening situations (Porges, 2007). If the car seat task was somewhat more stressful for infants than the still face paradigm, sympathetic nervous system responses would be positively related to comfort seeking, because activation of the sympathetic nervous system is adaptive in this situation, whereas this relation would be reversed during a milder stressor (still face paradigm), because in such events activation of the sympathetic nervous system is not adaptive. Although this suggestion is in line with previous research showing that pre-ejection period responses depends on task characteristics (Maier, Waldstein, & Synowski, 2003; Quigley & Stifter, 2006), we did not find any indications that the car seat task was more stressful, as there was no significant difference in pre-ejection period shortening between the still face procedure and car seat task.

4.4 | Limitations

In addition to the limitations that already have been discussed, there are some general limitations concerning the design of the study. This study investigated empathy at an important point in development, because empathy, in particular responses to empathy-evoking events that include empathic concern, rapidly develop during the second year of life and by age three the majority of children show prosocial behavior in response to empathy eliciting situations performed by both caregivers and strangers (Knafo et al., 2008; McDonald & Messinger, 2011; Zahn-Waxler, Radke-Yarrow, et al., 1992). Therefore, studies using the distress simulation task have particularly focused on the second year of life (Mark, Ijzendoorn, & Bakermans-Kranenburg, 2002; Spinrad & Stifter, 2006; Young et al., 1999). However, it would be valuable to keep track of the prediction of empathic behavior by behavioral and physiological responses to challenge over a longer period of time, until empathy has fully developed. With such a design, it is possible to examine the effect of behavioral and physiological responses to challenge on the developmental course of empathic distress and empathic concern.

Furthermore, because internal arousal related to empathy is sometimes hard to observe from behavior, measurement of physiological responses to objectively examine empathy during the distress simulation task would have provided better insight into empathy at age 20 months. Physiological measurements during empathy eliciting tasks have been shown to result in reliable measures of empathy and have been found to be associated with behavioral measures of empathy in toddlerhood (Gill & Calkins, 2003; Liew et al., 2011; Schuetze et al., 2014). In addition, the physiological and the different behavioral outcome measures of empathy could be considered simultaneously using structural equation models.

Finally, RSA suppression and shortened pre-ejection period in response to challenge have been suggested to be indicators of emotion regulation (Calkins & Dedmon, 2000; Porges & Furman, 2011; Stifter et al., 2011; Suurland et al., 2016). Therefore, this study supports previous suggestions that emotion regulation is an important component of empathy (Eisenberg, 2010; Hoffman, 2000). Future studies could benefit from examining emotion regulation in depth by taking both physiological reactivity (from baseline to challenge) and physiological recovery (from the challenge to subsequent recovery phase) into account (Cole, Martin, & Dennis, 2004; Suurland et al., 2016).

5 | CONCLUSION

We extended the current literature by examining the predictive value of behavioral and physiological responses to two emotional challenges to later empathic behavior. Furthermore, this study is the first to simultaneously examine behavioral responses and responses of both branches of the autonomic nervous system in order to predict observed empathic behavior. The results of the study revealed a clear linear association between early physiological and behavioral responses to mild emotional challenge and later empathic distress, but the correlations were relatively small, which limits the impact of our findings. Furthermore, the linear association between emotional responses and indicators of empathic concern was less clear. In addition, quadratic associations were found between behavioral responses to challenge and empathic distress and empathic concern, which indicates that moderate levels of behavioral responses represent optimal levels of arousal that predict the highest levels of empathic distress and empathic concern. Overall, our results indicate that stronger physiological and behavioral responses to emotional challenge at age 6 months predict more empathic distress at age 20 months. In turn, empathic distress in response to others' distress during infancy is a precursor of later empathic concern (McDonald & Messinger, 2011; Zahn-Waxler & Radke-Yarrow, 1990). Behavioral and physiological responses to emotional challenge independently predicted empathic distress, which emphasizes the importance of research on the interplay between behavioral and physiological responses to challenge as predictors of empathy development. Identifying processes that shape emotional responses early in life may be key to understanding how impairments in empathy develop. Therefore, identification of these processes facilitates the identification of infants at risk for impairments in empathy, which could be included in preventive interventions that aim to improve empathy (Feshbach & Feshbach, 2009).

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Malou M. P. G. Noten https://orcid.org/0000-0002-5963-5057

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