The effects of maternal behavior on the emotional reactivity and emotion regulation of 6- and 12-month-old infants

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Abstract

Problems with emotion regulation in childhood are related to negative child outcomes later in life, such as behavior problems. Because parents play an essential role by assisting their infant to develop the ability to regulate their emotions, the purpose of this study was to gain deeper understanding of the relation between maternal behavior and infants' behavioral and physiological emotional reactivity and emotion regulation. 66 mother-infant dyads participated in two stress paradigms: the still-face paradigm was conducted at 6 months of age and the child was exposed to the robot paradigm at 12 months of age. During the stress paradigms infants' behavioral reactivity, self-soothing behavior, heart rate and respiratory sinus arrhythmia (RSA) were examined. Maternal sensitivity and maternal intrusiveness were observed during a free play task at the 6-month appointment. Overall, the infants showed behavioral and physiological arousal and regulation during stress. Although no effect of maternal intrusiveness was found, the 6-month-old infants of mothers judged as more sensitive showed more emotional reactivity, indicated by a greater increase in negative affect and heart rate than infants of less sensitive mothers. These infants also showed more physiological regulation, indicated by a greater decrease in RSA during stress than infants of less sensitive mothers. The stability of emotional reactivity and emotion regulation between 6 and 12 months was low: only the difference in RSA from stress to recovery was modestly stable. It is concluded that maternal behavior has an effect on the development of infants' emotional reactivity and emotion regulation Future studies should further investigate the environmental characteristics influencing the development of emotion regulation in children using longitudinal designs.

The effects of maternal behavior on the emotional reactivity and emotion regulation of 6- and 12-month-old infants

According to the functionalist perspective, emotions are important for different processes: emotions improve memory, influence decision making processes and cause essential behavioral reactions (Gross & Thompson, 2007). Although expressing intense negative emotions can be adaptive in threatening situations, emotional reactivity becomes dysfunctional when it is situationally inappropriate (Cicchetti, Ackerman & Izard, 1995). Problems with emotion regulation in infancy can have enduring negative effects on the development of the child (Eisenberg, Spinrad & Eggum, 2010). Emotion dysregulation is an important risk factor for externalizing behavior (Hill, Degnan, Calkins & Keane, 2006; Roll, Koglin & Petermann, 2012). For example, Crockenberg, Leerkes and Barríg Jó (2008) found that problems in regulating emotions in infancy are related to aggressive behavior when children are 2.5 years old. Emotional dysregulation in preschool children also predicts cognitive, social and behavioral problems at kindergarten age (NICHD Early Child Care Research Network, 2004). Emotion regulation is related to academic success as well: in kindergarten it was positively related to math and literacy scores and productivity during the lessons (Graziano, Reavis, Keane & Calkins, 2007).

The ability to regulate emotions continues to develop until adulthood, but most progress in the development of emotion regulation is achieved in the first years of life (Halligan et al., 2013). Studies regarding the stability of emotion regulation over time found mixed results, suggesting that environmental factors possibly could influence the development of emotion regulation (Propper & Moore, 2006). Because parents play an essential role by assisting their infant to develop the ability to regulate their emotions (Calkins & Hill, 2007), it is important to gain deeper understanding of the relation between parenting and infants' emotional reactivity and emotion regulation. This knowledge could be relevant for intervention programs to prevent negative child outcomes, such as externalizing behavior and academic failure.

Emotional reactivity and emotion regulation

According to the modal model, emotions are whole body phenomena related to changes in the behavioral and physiological systems of the individual, which occur when someone experiences a psychologically relevant situation (Gross & Thompson, 2007). While focusing the attention on the situation, the individual evaluates and interprets it, which could provoke an emotional response. Emotions have to compete with other behavioral and cognitive processes in the situation: sometimes, for example in a very threatening environment, emotions can take full control (Frijda, 1986 as cited in Suri, Sheppes & Gross, 2013), but often emotions are adjusted to the situation, because other processes have priority (Gross & Thompson, 2007). In this paper a commonly accepted definition of emotion regulation is applied: 'Emotion regulation consists of the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and temporal features, to accomplish one's goals' (Thompson, 1994, pp. 27-28).

Infant behavior during stress

In the first year of life, children show several behavioral responses during stressful situations (Ekas, Lickenbrock & Braungart-Rieker, 2013). A commonly used approach to examine infants' emotional reactivity and emotion regulation is to expose children to a stress paradigm, for example the still-face procedure (Tronick, Als, Adamson, Wise & Brazelton, 1978). The still-face paradigm consists of three episodes: first the baseline episode in which the mother interacts and plays with her child as usual, second the still-face episode in which the mother becomes unresponsive with a neutral facial expression and third the reunion episode, in which the mother resumes the interaction with her child. With regard to stress reactivity, several studies found the still-face effect in infants during the still-face paradigm: from the baseline episode to the still-face episode, 3- to 6-month-old infants showed decreased positive affect and increased negative affect (Bazhenova, Plonskaia & Porges, 2001; Bigelow & Walden, 2009; Haley & Stansburry, 2003; Mesman, Linting, Joosen, Bakermans-Kranenburg & Van IJzendoorn, 2013; Moore et al., 2009; Moore & Calkins, 2004). During the reunion episode, the still-face effect decreased, although the level of positive affect remained lower and the level of negative effect remained higher compared to the baseline episode (Conradt & Ablow, 2010; Moore & Calkins, 2004). In addition, infants showed a decrease in the amount of smiling (Bigelow & Walden, 2009; Jean & Stack, 2012; Mattson et al., 2013) and an increase in the amount of cry faces from the baseline to the still-face episode (Mattson et al., 2013). A meta-analysis confirmed the still-face effect in infants during the still-face paradigm: children showed a decrease in gaze and positive affect, and an increase in neutral and negative affect from baseline to the stressful still-face period (Mesman, Van IJzendoorn & Bakermans-Kranenburg, 2009). From the still-face episode to the reunion, the meta-analysis indicated an increase in gaze and positive affect and a decrease in neutral affect. The level of negative affect remained high during the reunion episode.

With regard to another stress-eliciting procedure, in which a robot approaches the child after mother left the room, 12-month-old infants showed facial fear, behavioral fear and distress vocalizations (Baker, Baibazarova, Ktistaki, Shelton & Van Goozen, 2012). Mullen, Snidman & Kagan (1993) examined the behavioral responses of inhibited and uninhibited children during a play episode with a stranger and a robot. Children who were highly inhibited showed more fearful behavior during the stress episode than children who scored low on behavioral inhibition.

In addition to behavior related to stress reactivity, infants also show regulatory behaviors such as withdrawal and distraction from the stimulus, self-soothing behaviors and looking at the experimenter during a stressful period (Buss & Goldsmith, 1998; Conradt & Ablow, 2010; Ekas et al., 2013; Haley & Stansburry, 2003; Tarabulsy et al., 2003). For example, Jean & Stack (2012) found that 5-month-old infants showed more self-soothing behaviors, escape behavior and attention seeking of the mother during the still-face episode compared to the baseline episode. A meta-analysis indicated that infants' gaze at mother's face decreased from baseline to still-face episode and increased from the stress-inducing period to the recovery (Mesman et al., 2009). Whether the used regulatory behaviors in infants effectively decrease emotional reactivity during stress is not yet clear. For example, in a study using a fear-invoking remote-controlled spider and dog approaching the child, the regulatory behaviors such as withdrawal from the stimulus, distraction from the stimulus and looking at the experimenter did not decrease the level of fear expression of infants at ages 6, 12 and 18 months (Buss & Goldsmith, 1998). However, a study examining 3- to 7-month-old infants using the still-face paradigm revealed that self-soothing behaviors and distraction from the unresponsive parent were associated with a decrease in negative affect (Ekas et al., 2013).

Physiological reactivity and regulation: Autonomic nervous system

In addition to the behavioral responses during stress, physiological measures can be used to examine emotional reactivity and emotion regulation during infancy as well. According to many recent theories, the autonomic nervous system is an important biological system related to the experience of emotions (Kreibig, 2010). The autonomic nervous system consists of the sympathetic and the parasympathetic nervous system, which function complementary to maintain a state of homeostasis in the body (Graham, Ablow & Measelle, 2010). Activation of the sympathetic nervous system is related to coping with environmental threats, while activation of the parasympathetic nervous system is associated with internal processes such as resting, restoration and growth (Diamond & Cribbet, 2013).

Heart rate. Heart rate is influenced by both the sympathetic and parasympathetic nervous system (Thayer, Åhs, Fredrikson, Sollers III & Wager, 2012; Task Force of ESC/NASPE, 1996). Heart rate is an indicator of physiological reactivity: it is indicated that heart rate adaptively increases during stress (Hessler & Katz, 2007). This physiological reaction in response to stress has also been observed in infants: several studies using the still-face paradigm found that 3- to 6-month-old infants showed an increase in heart rate from the baseline period to the stressful still-face episode (Bazhenova et al., 2001; Conradt & Ablow, 2010; Gunning, Halligan & Murray, 2013; Haley, Handmaker & Lowe, 2006; Haley & Stansburry, 2003; Mattson et al., 2013; Moore et al., 2009; Moore & Calkins, 2004). Although some studies found that the heart rate decreased or returned to baseline after the stressful period (Bazhenova et al., 2001; Haley et al., 2006), other studies found that heart rate remained high during the reunion (Conradt & Ablow, 2010; Mattson et al., 2013). Also in other stress paradigms an effect on heart rate was found: compared to a baseline period, heart rate increased in 12-month-old infants during a stress-inducing procedure, in which a robot approached the child after the mother had left the room (Baker et al., 2012).

Cardiac vagal tone. Because heart rate is influenced by both the sympathetic and parasympathetic nervous system, a more specific indicator of emotion regulation is cardiac vagal tone, which is only influenced by the parasympathetic nervous system (Grossman & Svebak, 1987). According to the Polyvagal theory, vagal tone is related to the ventral vagus: when the vagal tone is high, the ventral vagus acts like a brake, inhibiting the influences of the sympathetic nervous system and restricting the heart rate, which provides a more calm state and supports social engagement behaviors (Porges, 2007). In response to challenge, the vagal brake is reduced, which is related to withdrawal of the vagal tone, causing an increase in heart rate to quickly mobilize the individual. Because the vagal tone cannot be measured directly, vagal tone is operationalized as the respiratory sinus arrhythmia (RSA): the heart rate variability at the rate of respiration (Grossman & Svebak, 1987; Mills-Koonce et al., 2009).

This vagal regulation mechanism has also been found in very young children: 3-month-old children showed a decrease in RSA from baseline to the still-face episode, indicative of coping (Moore & Calkins, 2004). At 5 and 6 months of age, infants showed a decrease in RSA during the stressful still-face period (Bazhenova et al., 2001; Conradt & Ablow, 2010). In other stress paradigms this pattern was found as well: using the strange situation procedure, in which the child is playing in a room while the mother and a stranger enter and leave the room, Hill-Soderlund et al. (2008) found that infants showed RSA reduction from the baseline period to the stressful episodes in which the child was left alone and left alone with a stranger. In accordance with the literature about heart rate, for RSA it is also not clear whether the level of RSA returns to baseline or remains low during the reunion episode of the still-face paradigm (Bazhenova et al., 2001; Conradt & Ablow, 2010).

Relation between infants' behavioral and physiological responses during stress

Several studies examined the association between infants' behavioral and physiological responses during stress. Regarding heart rate, negative affect was positively correlated to heart rate during the still-face paradigm: higher levels of negative affect were related to a greater increase in heart rate from baseline to the still-face episode and to higher levels of heart rate during the reunion (Moore & Calkins, 2004). Using a robot approach task, increased heart rate was related to more behavioral fear in 1-, 2- and 3-year-old children (Baker et al., 2012).

With respect to vagal tone, Baznehova et al. (2001) examined the physiological and behavioral responses in two groups of 5-month-old infants during the still-face paradigm: children who showed a decrease in RSA from the baseline to the still-face episode and an increase from the still-face episode to the reunion and children who had a stable level of RSA during the still-face paradigm. Although both groups showed a decrease in positive engagement and an increase in negative affect from baseline to the still-face episode, the group with the variable RSA levels showed behavioral recovery during the reunion period, while the group with stable levels of RSA did not recover during the reunion. Although several studies found associations between the behavioral and physiological responses during stress, no relation between facial fear and RSA reduction was found using a stranger approach paradigm in 6-month-old infants (Brooker et al., 2013). Also among 24-month-old children, no association was found between the level of behavioral fear and the physiological indices heart rate and RSA during a stranger approach paradigm, in which the child was strapped into a chair (Buss, Davidson, Kalin, Goldsmith, 2004). This study did find a difference for freezing behavior: children who showed more freezing behavior had lower heart rate during the stress task compared to children showing less freezing behavior.

Caregiver influences on infants' emotion regulation

The development of emotion regulation in children is influenced by many factors (Morris, Silk, Steinberg, Myers, & Robinson, 2007). Besides the influences of the characteristics of the child, such as temperament (Gunning et al., 2013) and gender (Domes et al., 2010), the ability to regulate emotions is also influenced by social interactions (Calkins & Hill, 2007). Other people provide external regulatory influences, described as the extrinsic processes in the previously cited definition of emotion regulation (Thompson, 2011). Although these regulatory effects of other individuals continue to influence emotion regulation until adulthood, for example by providing support when someone is anxious (Cole, 2014), the extrinsic factors are especially important during the development of children (Thompson, 2011). Very young children are dependent on their caregivers with respect to emotion regulation: caregivers teach the infant how to modulate stress and frustration (Calkins & Fox, 2002). From infancy onwards, children become more and more independent in regulating their emotions (Sameroff, 2010).

Several mechanisms are proposed in the literature to describe the influences of caregivers on the child's emotion regulation (Morris et al., 2007). First, the ability of children to regulate emotions is shaped by observing and imitating their parents experiencing emotions. Second, emotion regulation is influenced by parenting practices related to emotion regulation, for example the way a parent reacts to the child's emotions. Third, the ability to regulate emotions is affected by the emotional climate of the family, including for example the attachment relationship and parenting practices such as responsiveness and negativity. This study focuses on the influence of the third factor: the parenting practices of the mother.

Parenting influences on the behavioral indices of infants' emotion regulation

According to Sroufe (1996), warm and responsive caregivers are better able to teach their children regulation strategies during stressful situations. The mother's ability to perceive and interpret their child's signals and respond to them promptly in a warm and responsive way is called maternal sensitivity (Ainsworth, Bell & Stayton, as cited in Mesman & Emmen, 2013). Although some studies did not find an effect of maternal sensitivity on infants' behavioral reactivity (Moore et al., 2009), other studies did find support for the theory that maternal behavior towards the child influences emotional reactivity during stressful situations. For example, it was found that infants of mothers who were more sensitive showed less dysregulated behavior (Gunning et al., 2013), more positive affect and less negative affect during the still-face paradigm (Braungart-Rieker, Garwoord, Powers & Wang, 2001). 4- and 9-month-old infants of more responsive mothers who used more contingent responding interactions showed more positive affect during the baseline and reunion of the still-face paradigm (Lowe et al., 2012). Mothers who used more attention seeking play (drawing infant's attention by strategies such as clapping her hands), which is considered less responsive compared to contingent responding, had infants showing less positive affect. Infants of mothers who mirrored their infant's behavior during the play episode showed more smiling, positive vocalizations, visual attention during all the episodes of the still-face paradigm (Bigelow & Walden, 2009). Maternal sensitivity was also related to the behavioral distress in 15-month-old infants during a novelty task in which a person wearing a green monster costume entered the room: higher maternal sensitivity during the stressful task was related to less infant distress (Leerkes & Wong, 2012). A meta-analysis examining the effect of maternal sensitivity on the behavioral responses during the still-face paradigm showed that higher maternal sensitivity was related to more positive affect, although no effect on infants' negative affect was found (Mesman et al., 2009). Another meta-analysis indicated that more restrictive parenting was related to higher levels of negative emotionality in young infants and pre-schoolers during a fearful situation (Paulussen-Hoogeboom, Stams, Hermanns, & Peetsma, 2007). Supportive parenting was not related to the levels of infants' negative emotionality.

Empirical support for the relation between maternal behavior and emotional reactivity is also found in the literature regarding infant-parent attachment. Infant attachment reflects the quality of the mother-infant relationship: securely attached infants experience especially maternal sensitivity, while insecurely attached infants experience maternal rejection (avoidantly attached infants) or inconsistent maternal behavior (resistantly attached infants) (Cassidy, 1994). Securely attached 12-month-olds displayed more positive affect and less distress compared to insecurely resistant attached infants during an emotion eliciting situation without toys (Diener, Mangelsdorf, McHale & Frosch, 2002). Leerkes & Wong (2012) also found that resistantly-attached 15-month-old infants showed more behavioral distress during a frustration task and a stress paradigm compared to securely and avoidantly attached infants. Resistant infants also cried more than secure infants (Zelenko et al., 2004).

With regard to behaviour related to emotion regulation, 5- to 6-month-old children of responsive mothers looked more at their mother during the still-face procedure compared to infants of unresponsive mothers (Haley and Stansburry, 2003). Using two novelty tasks in which a fire truck with a siren and flashing lights approached the infant and a bubble ball bounced in close proximity to the infant, 6-month-old children showed a decrease in distress when mother provided engagement and support (Crockenberg & Leerkes, 2004). In addition, infants of mothers who responded contingently when their infant looked away from the novel toy were less distressed compared to infants of mothers who did not respond contingently to their child's attention. During a stressful task in which a person wearing a green monster costume interacted with the child, 15-month-old infants of mothers classified as more sensitive engaged in more physical soothing with their mother than infants of less sensitive mothers (Leerkes & Wong, 2012). With regard to non-mother oriented regulation behaviors, infants of more sensitive mothers showed less withdrawal from the stimulus, less avoidant behaviour, and less maladaptive regulation behavior, such as yelling or pushing the experimenter. But, infants of highly sensitive mothers showed less active mother oriented regulation behaviors, such as looking at mother and seeking help of mother. There was no significant relation between maternal sensitivity and self-soothing behaviors.

With regard to emotion regulation during the recovery after stress, children of mothers judged to be more sensitive showed less resistance and greater attentional engagement during the reunion of the still-face procedure (Conradt & Ablow, 2010). According to the literature regarding attachment classification, secure infants showed more active mother-oriented regulation behavior, more withdrawal and more variation in their regulation behavior than resistant infants (Leerkes & Wong, 2012).

Parenting influences on the physiological indices of infants' emotion regulation

Studies examining the influence of parenting on the physiological reactivity and regulation during stress found mixed results. Concerning physiological reactivity, higher levels of maternal sensitivity were related to lower heart rate in 6-month-old infants during the still-face episode (Moore et al., 2009) and a greater decrease in heart rate during the reunion episode in 5- and 6-month-old children (Conradt & Ablow, 2010; Haley and Stansburry, 2003). Contrary to these results, a recent study in 3-month-old infants found no association between maternal sensitivity and infants' heart rate in the different episodes of the still-face procedure (Gunning et al., 2013). According to the attachment literature, the heart rate pattern did not differ during the strange situation procedure for infants with different attachment classifications (Zelenko et al., 2004).

With regard to emotion regulation, Conradt & Ablow (2010) found that maternal sensitivity predicted the physiological regulation of five-month-old infants during the still-face procedure: children of more sensitive mothers showed a greater increase in RSA from the still-face episode to the reunion episode. Contrary to the expectations, the RSA change from baseline to reunion was moderated by maternal sensitivity: only infants with high sensitive mothers showed a decrease in

RSA from baseline to the reunion (Moore et al., 2009). This could be explained by the suggestion that more sensitive mothers and their infants had higher levels of behavioral synchrony during the reunion. These infants had to engage actively with the environment by reacting to their mother, which could explain the decrease in RSA during the reunion episode. Hill-Soderlund et al. (2008) examined the RSA response during the strange situation paradigm in 13-month-old infants classified as insecure-avoidant and securely attached. Contrary to the literature regarding maternal sensitivity, insecure-avoidant infants showed a greater decrease in RSA during the strange situation paradigm than securely attached infants, which indicates that infants classified as insecure-avoidant showed more effort to minimize their stress. This is explained by the authors with the suggestion that avoidantly attached children show more self-oriented regulation instead of seeking proximity of the mother which could be the result of experienced maternal rejection.

Present study

The first aim of this study is to examine the patterns of the behavioral and physiological responses in 6-month-old children during the still-face paradigm and the physiological responses in 12-month-old children during a stressful robot paradigm. Based on the research discussed above, it is hypothesized that positive affect will decrease and negative affect and self-soothing behaviors will increase from baseline to the still-face period in 6-month-old infants. From the still-face period to the reunion period, positive affect will increase and negative affect and self-soothing behaviors will decrease. For the physiological indices, it is hypothesized that heart rate will increase and RSA will decrease from baseline to the stressful period in both 6- and 12-month-old infants. It is expected that the physiological effects will remain during the reunion.

The second aim of the study is to examine the associations between the physiological and behavioral indices of emotional reactivity and emotion regulation. With regard to the behavioral and physiological indices of emotional reactivity, it is expected that lower levels of positive affect and higher levels of negative affect among 6-month-old infants will be related to higher levels of heart rate during the stressful period. The same is expected for higher levels of behavioral fear among 12-month old infants. In addition, with regard to the behavioral and physiological indices of emotion regulation, it is expected that higher levels of self-soothing behaviors will be related to lower levels of RSA during a stressful episode among 6- and 12-month-old infants.

The third aim of the study is to examine the associations between maternal behavior and the physiological and behavioral indices of emotional reactivity and regulation at both ages. Based on the previously discussed research, it is hypothesized that higher levels of maternal sensitivity will be related to lower levels of behavioral and physiological reactivity. Higher levels of maternal sensitivity and lower levels of maternal intrusiveness will be related to less negative affect and more positive affect in 6-month-old infants during the stress episode of the still-face paradigm. Higher levels of maternal sensitivity and lower levels of maternal intrusiveness will be related to less behavioral fear in 12-month-old infants during a stress-inducing robot paradigm. With regard to the physiological measures, higher levels of maternal sensitivity and lower levels of maternal intrusiveness will be related to lower heart rate increases during the stressful episode among both ages.

In addition, it is hypothesized that higher levels of maternal sensitivity and lower levels of maternal intrusiveness will be related to higher levels of behavioral and physiological regulation. It is expected that higher levels of maternal sensitivity and lower levels of maternal intrusiveness are related to more self-soothing behaviors and a greater decrease in RSA during a stressful period in 6- and 12-month-old infants.

Fourth, the longitudinal relation between emotion regulation of 6- and 12-month-old infants is assessed. It is expected that the behavioral and physiological indices among 6-month-old infants during the still-face episode will be positively related to the behavioral and physiological indices among 12-month-old infants during the robot paradigm. Exploratory analyses will be used to examine the influence of maternal behavior on the longitudinal association between 6 months and 12 months.

Method

Study background

The sample consisted of mothers and their firstborn infants who participated in the study 'A Good Start', a longitudinal investigation examining the effect of an intervention to prevent anti-social behavior. Mothers were recruited during pregnancy from obstetric health services, pregnancy fairs and hospitals. Pregnant woman were eligible to participate if they were between 17 and 25 years old and were able to speak Dutch. Mothers were excluded from the study when they were addicted to drugs, had a mental disability (IQ lower than 70), had severe medical problems, gave birth to an infant with severe medical problems or had severe psychiatric problems, such as a psychosis. The study 'A Good Start' consisted of five appointments: at the 27th week of pregnancy and 6 months, 12 months, 18 months, and 25 months after childbirth. When infants were born prematurely (less than 37 weeks gestation), the due date was used to plan the appointments instead of the date of birth. This study used data from the appointment at 6 months and 12 months. Mothers received a gift card and a present for the child after each appointment. Informed consent of the mother was obtained and approval for the study was given by the ethics review board of the Faculty of Social Sciences at Leiden University and by the medical ethical committee of the Leiden University Medical Center.

Participants

The sample consisted of 66 mothers and their firstborn infants (34 boys, 32 girls). Maternal age at the 6-month appointment ranged from 17 to 27 years old (M = 23.31, SD = 2.64). Mothers were predominantly Caucasian (80.3%) and mainly from the urban regions of the Netherlands. Average family income was 2120.65 euros (*SD* = 1295.67). With regard to marital status, 4.5% of the mothers lived on their own, 59.1% lived together with their partner, 22.7% lived together with family, 10.6% lived together with their partner and family and 3.0% lived together with friends. For the 6-month appointment, the mother-infant dyads were visited at home approximately six months after birth (*M* = 5.93, *SD*= .39). For the next appointment, the mothers and their children were invited to the university laboratory when the child was approximately 12 months old (*M*= 12.08, *SD*=.51).

Procedure

Home visit. The home visit at 6 months of age was carried out by two researchers (PhD students or graduate students) and lasted for approximately 2.5 hours. After the infant got used to the researchers, mothers were asked to play for 3 minutes with their child as they would normally do at home (the free play task). The free play episode took place on a play mat with three standardized toys: a rattle, a plastic booklet and an interactive farm toy. After the free play task, the electrodes for the physiological measurements were attached to the infant, who was lying on the play mat. Several developmental tasks were conducted during the home visit, such as a frustration task and the still-face paradigm. Afterwards, mothers completed several questionnaires and carried out three cognitive tasks. When the infant was sleeping at the time the researchers arrived, the questionnaires were filled out first. In this study, data of the free play task and the still-face paradigm were used. For the still-face paradigm, the protocol by Tronick, Als, Adamson, Wise & Brazelton (1978) was applied. The mother and infant were seated face to face, while the child was strapped into a car seat. First, the mother was instructed to interact and play with their child as they would normally do for 2 minutes (the play episode/the baseline episode). Next, the mother was asked to look slightly above the infant's head with a neutral expression for 2 minutes, while not responding to and touching the infant (the still-face episode/the stress episode). Finally, mothers were instructed to interact with their infant again for 2 minutes (the reunion episode/the recovery episode).

Laboratory visit. Around 12 months of age, infants and their mothers were invited for a laboratory visit, which took place in a child-friendly room. The visit was carried out by two researchers (PhD students and graduate students) and lasted approximately 2 hours. After the infant got used to the situation, the electrodes for the physiological measurements were attached to the infant's body. During the laboratory visit, the child performed several developmental tasks, such as an inhibition task, an attention task and the robot paradigm. Afterwards, the mother completed several questionnaires. For this study, data of the robot paradigm were used. This paradigm was based on the Lab-TAB's unpredictable mechanical toy task (Goldsmith & Rothbart, 1999*)*. First, the child watched an age-appropriate film clip for 2 minutes (baseline episode). The duration of the baseline was shortened when the child became frustrated or began to show a lot of motor activity. After the baseline, the researcher and the mother left the room, while a second unknown researcher entered the room wearing glasses and a laboratory coat. A remote-controlled robot was placed approximately 1.5 meter from the infant, who was strapped into a low child seat. The remote-controlled robot approached the child, was stopped in front of the child, made noises and movements, returned to the starting point and stood still for 5 seconds. This procedure was performed three times (stress episode). Mothers watched the procedure behind a one-way screen and were instructed that they could stop the procedure when desired. After the procedure, mothers were instructed to enter the room and comfort their child when needed (recovery episode). The recovery period lasted for 5 minutes.

Video recordings. The free play task, the still-face paradigm and the robot paradigm were videotaped to code the behavior of the child and the mother afterwards. For the still-face paradigm, a mirror was placed above the child's seat, to capture both infant's and mother's facial expression with one camera.

Measurement instruments

Maternal behavior during the free play episode. The manual for coding maternal behavior during the free play task was based on the manual by Miller & Sameroff (1998). For this study, maternal sensitivity and maternal intrusiveness were used. One single score was assigned to each of the two maternal behaviors during the 3-minute episode. Maternal sensitivity was operationalized as the ability to read and follow infant's cues and was coded using four categories: no sensitivity (score 0), minimal or low sensitivity (score 1), mixed or moderate sensitivity (score 2), and predominantly high sensitivity (score 3). Because the statistical analyses used in this study are not robust to violations of the assumptions of normality and homogeneity of variance in the case of unequal sample sizes (Glass, Peckham & Sanders, 1972; Wilcox, 2005), mothers were divided into two groups based on the rating scale: low/moderate sensitivity (n = 34) and predominantly high sensitivity (n = 32). None of the mothers were classified as not sensitive.

Maternal intrusiveness was defined as the tendency to handle the infant roughly and interfere with the child's needs and behaviors. Maternal intrusiveness was coded using four categories: no intrusiveness (score 0), minimal intrusiveness (score 1), mixed or moderate intrusiveness (score 2) and predominantly high intrusiveness (score 3). Because only two mothers were identified as predominantly highly intrusive, analyses were conducted considering three groups: no intrusiveness (n = 32), minimal intrusiveness (n = 25) and moderate/high intrusiveness (n = 9). Coders received an extensive training in coding maternal behavior during the free play episode. Two coders independently scored the behavior of 25 mothers to evaluate inter-rater reliability. The inter-rater reliability was *ICC* = .84 for maternal sensitivity, indicating almost perfect agreement, and *ICC* = .79 for maternal intrusiveness, indicating substantial agreement (Landis & Koch, 1977).

Infant behavior during the still-face-procedure. The coding manual for coding infants' behavior during the still-face paradigm was based on the coding manual by Miller & Sameroff (1998). For the baseline episode of the still-face paradigm a global score of the infant's behavior was assigned. In contrast to the protocol by Miller & Sameroff (1998), separate scores were assigned to the first and second minute of the stress episode and the recovery episode of the still-face procedure. The scores of the first and second minute of each episode were averaged to obtain a global score. With regard to behavioral reactivity, infant's positive affect and negative affect were coded. Positive affect was operationalized as the amount of smiles, which were not necessary towards the mother. Negative affect was operationalized as the amount of time the infant fussed or cried. Both positive and negative affect were coded using four categories: no positive or negative affect (score 0), minimal positive or negative affect (score 1), mixed or moderate positive or negative affect (score 2) and predominant or intense positive or negative affect (score 3). With regard to behaviors related to emotion regulation, self-soothing behaviors were coded during the still-face paradigm, which were operationalized as the behaviors to provide self-stimulation, such as grabbing a body part or object. Self-soothing behaviors were coded using four categories: no engagement (score 0), minimal or low engagement (score 1), mixed or moderate engagement (score 2) and predominant or high engagement (score 3). The behaviors of 33 infants were scored independently by different coders to evaluate inter-rater reliability. The inter-rater reliability was *ICC* = .80 for positive affect, *ICC* = 1.00 for negative affect and *ICC* = 1.00 for self-soothing behavior, indicating almost perfect to perfect agreement (Landis & Koch, 1977). Two individuals had missing data on the variable self-soothing behavior.

Infant behavior during the robot paradigm. The coding manual for coding infants' behavior during the robot paradigm was based on Lab-TAB's coding guidelines (Goldsmith & Rothbart, 1999). Infants' behavior was only coded during the stress episode of the robot paradigm. The stress episode consisted of three identical trials in which the robot approached the infant. Each trial was divided into four epochs: the approach of the robot, the first part of the movements of the robot while standing in front of the child, the second part of the movements of the robot while standing in front of the child and the retreat of the robot. Behaviors related to emotional reactivity, including facial fear, bodily fear, and the intensity of distress vocalizations, were coded during the first three epochs of each trial. Facial fear was coded using three categories: no facial fear (score 0), mild or fleeting facial fear (score 1), moderate facial fear (score 2), strong facial fear (score 3). Bodily fear was coded using three categories: no sign of bodily fear (score 0), mild change in bodily posture indicated by an apparent increase or decrease in motor activity (score 1), sustained tensing of the muscles (score 2),

Table 1

Correlations between the behavioral reactivity measures

Measure	*1*	*2*	*3*
1. Facial fear	-		
2. Facial sadness	-.49**	-	
3. Distress vocalizations	-.44**	.95**	-
4. Bodily fear	.12	.37**	.48**

Note. *p < .05. **p < .01.

freezing of the entire body or trembling due to extreme muscular tension (score 3). The intensity of distress vocalizations was coded using six categories: no distress (score 0), mild vocalizations (score 1), definite whimpering (score 2), longer whining, fussing, mild protest or low intensity cry (score 3), definite non-muted crying (score 4) and full intensity cry or screaming (score 5).

To reduce the number of data, mean scores for all epochs were calculated for the different reactivity measures. The correlation matrix of the behavioral reactivity variables is shown in Table 1. Z-scores were used to compute a composite measure of behavioral distress, because the variables were scored on different rating scales. Because the variables distress vocalizations and facial sadness strongly correlated, $r = .95$, $p < .01$, the z-scores of these variables were averaged into one variable. The z-scores of the three remaining variables (facial fear, bodily fear and facial sadness/vocalizations) were averaged to obtain a composite measure of behavioral distress during the robot paradigm. Three individuals had missing data on the variable behavioral distress.

With regard to behaviors related to emotion regulation, self-soothing behaviors were coded during the first three epochs of each trial using four categories: no engagement (score 0), minimal or low engagement (score 1), mixed or moderate engagement (score 2) and predominant or high engagement (score 3). For self-soothing behaviors, also a mean score was calculated. Three individuals had missing data on self-soothing behavior. Coders underwent an extensive training before they were allowed to code infants' behavior independently.

Physiological measurements. Heart rate and RSA levels during the still-face paradigm and the fear paradigm were recorded using the VU University Ambulatory Monitory System (VU-AMS). After the skin of the infant had been cleaned with alcohol to improve electrode impedance, the pre-gelled silver–silver chloride electrodes were attached to the infant's body. Three electrodes were attached to the infant's chest for extracting the electrocardiogram (ECG): the first was attached below the right collar bone to the right of the sternum, the second between the two lower ribs on the right site and the third slightly below the left nipple. For the impedance cardiogram (ICG), two electrodes were placed at the infant's chest: one at the top of the sternum and one at the bottom of the sternum. In addition, two electrodes for the ICG were placed at the infant's back: one on the spine above the upper ICG electrode at the chest and one below the lower ICG electrode at the chest. The physiological data were analysed using the software program Data Analysis & Management Software v2.2 (VU-DAMS) to extract heart rate and RSA. Heart rate was operationalized as the number of heart beats per minute, indicated by the R peaks (the upward peaks with the greatest amplitude) of the ECG. RSA was obtained using the peak-valley method (De Geus, Willemsen, Klaver & Van Doornen, 1995; Grossman, van Beek, & Wientjes, 1990), which combines the inter-beat interval of the ECG with the respiration signal obtained from the change in thorax impedance (dz) signal. Automatic scoring of the physiological variables was checked manually. For the baseline episode, the stress episode and the recovery episode of the still-face paradigm at 6 months of age, the average heart rate and average RSA were determined. The inter-rater reliability was *ICC* = .95 for the B-point, indicating almost perfect to perfect agreement, and *ICC* = .74 for the Q-point, indicating substantial agreement (Landis & Koch, 1977). Two infants had missing values on all the physiological measures during the still-face paradigm. Six other infants had missing data for RSA. For the baseline episode, the stress episode and the recovery episode of the robot paradigm mean values of heart rate and RSA per episode were computed. The inter-rater reliability was *ICC* = .63 for the B-point and *ICC* = .78 for the Q-point, both indicating substantial agreement (Landis & Koch, 1977). Four infants had missing data on the physiological measures during the robot paradigm.

Data analysis

For the preliminary analysis, outliers were detected using boxplots and z-scores. The distributions of the variables were examined using histograms, p-p plots, Shapiro-Wilk tests and z-scores of the kurtosis and skewness. The associations between the background variables gender and family income and the main study variables were examined using chi-square analyses, Fisher's exact tests, t-tests, an analysis of variance and a correlation analysis.

For the main analyses, two separate correlation analyses were conducted to examine the association between the physiological and behavioral indices of emotional reactivity and emotion regulation during both stress paradigms. To examine the behavioral (positive affect, negative affect and self-soothing behavior) and physiological (heart rate and RSA) patterns in 6-month-old children during the still-face paradigm, a series of repeated measures analyses of variance were conducted. Two additional repeated measures analyses of variance were used to examine the physiological pattern (heart rate and RSA) in 12-month-old infants during the robot paradigm. When Mauchly's test indicated that the assumption of sphericity had been violated, the Greenhouse-Geiser correction or the Huynh-Feldt correction was applied to the degrees of freedom. According to Girden (1992), the Huynh-Feldt correction will be used when the estimate of sphericity is greater than $\varepsilon = .75$, while the Greenhouse-Geiser correction will be used when the estimate of sphericity is less than $\varepsilon = .75$.

To assess the effect of maternal sensitivity and maternal intrusiveness on the behavioral and physiological patterns during the still-face paradigm and the robot paradigm, the variables of maternal behavior were added as between-subject factor to the repeated measures analyses of variance. The relation between maternal behavior and infants' behavior during the robot paradigm was tested with t-tests (for maternal sensitivity) and analyses of variance (for maternal intrusiveness).

To assess the longitudinal association between the stress paradigms at 6 months and 12 months of age, a correlation analysis was conducted between the different variables. For the physiological measures delta scores (Δ) from the baseline to stress episode and delta scores from the stress to recovery episode were used. A series of repeated measures analysis of variance was used to assess the influence of maternal sensitivity and maternal intrusiveness on the longitudinal association of the physiological and behavioral indices. For behavioral distress, negative affect during the still-face paradigm and behavioral distress during the robot paradigm were included. For the repeated analyses of variance, the variables were standardized to prevent for effects due to differences in the stress paradigms. All analyses were conducted with SPSS statistics version 21.

Results

Preliminary analyses

Descriptive data of the main variables of the study are presented in Table 2 and Table 3. With regard to the RSA data of the still-face paradigm, one outlier (120.00 ms) was detected during the second 30-second period of the stress episode. This value was corrected to the second highest score of this period (63.67 ms). When the score remained an outlier after adaption, this procedure was repeated. For the delta-scores, several outliers were detected, which were corrected to the next highest score. For the still-face paradigm, there was one outlier for the difference in heart rate (38.61 bpm corrected to 27.94 bpm) and one for the difference in RSA (-60.68 ms corrected to -36.08 ms) from the baseline episode to the stress episode. In addition, one outlier was identified for the difference in RSA from baseline to the recovery episode (59.00 ms corrected to 34.75 ms). For the robot paradigm, two outliers were detected for the difference in RSA from baseline to the stress episode (64.13 ms and 60.73 ms, both corrected to 20.40 ms). In addition, two outliers were identified for the difference in RSA from the stress episode to the recovery (-79.57 ms and -68.44 ms, both corrected to -44.13 ms).

The analyses indicated that the RSA data of the stress paradigms of both the 6-month and 12-month appointment were highly positively skewed and highly peaked. Therefore a natural logarithmic transformation was applied to the RSA data. Analyses indicated that the transformed data were normally distributed. A number of the variables examining the behavioral reactions during

Table 2

Descriptives of infants' physiology and behavior during the 6-month still-face paradigm

		Sensitivity				Intrusiveness							
		Low/moderate (n = 34)		High (n = 32)		No (n = 32)		Minimal (n = 25)		Moderate/high (n = 9)		Total (n = 66)	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Heart rate	Baseline	141.57	11.33	141.15	9.60	141.05	10.18	141.65	10.05	141.65	13.38	141.36	10.43
	Stress	145.31	9.66	150.12	9.67	148.38	10.42	146.15	9.77	149.54	8.73	147.68	9.89
	Recovery	145.23	12.98	152.75	11.36	150.31	11.99	145.89	11.98	152.74	16.19	148.99	12.68
lnRSA	Baseline	3.44	.35	3.45	.43	3.47	.39	3.41	.40	3.45	.39	3.45	.39
	Stress	3.38	.43	3.23	.42	3.24	.38	3.35	.46	3.41	.51	3.31	.43
	Recovery	3.46	.46	3.18	.51	3.27	.47	3.40	.39	3.31	.80	3.33	.50
Positive affect	Baseline	1.79	1.01	1.78	.97	1.75	.88	1.80	1.08	1.89	1.17	1.79	.98
	Stress	.35	.67	.25	.36	.34	.53	.26	.56	.28	.57	.30	.54
	Recovery	1.49	.93	1.09	.82	1.31	.90	1.34	.89	1.11	.96	1.30	.89
Negative affect	Baseline	.82	.97	.56	.80	.56	.80	.80	.96	.89	1.05	.70	.89
	Stress	.96	.94	1.16	1.07	1.08	1.02	.84	.95	1.56	.98	1.05	1.00
	Recovery	1.04	.98	1.55	1.07	1.41	1.00	.98	1.00	1.72	1.18	1.29	1.05
Self-soothing beh.	Baseline	1.00	1.08	.91	1.03	.91	.93	.83	1.13	1.50	1.20	.95	1.05
	Stress	.88	.98	.84	1.10	.84	1.11	.82	.96	1.06	1.05	.86	1.03
	Recovery	.61	.74	.81	1.01	.71	.90	.60	.85	1.00	.89	.70	.88

Table 3

Descriptives of infants' physiology and behavior during the 12-month robot paradigm

		Sensitivity				Intrusiveness							
		Low/moderate (*n* = 34)		High (*n* = 32)		No (*n* = 32)		Minimal (*n* = 25)		Moderate/high (*n* = 9)		Total (*n* = 66)	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Heart rate	Baseline	127.78	10.53	125.68	7.99	126.88	8.65	128.09	9.12	122.87	12.09	126.75	9.35
	Stress	144.68	19.46	151.12	21.41	149.78	21.67	146.19	19.00	144.89	21.68	147.80	20.52
	Recovery	137.15	10.76	135.82	8.10	135.55	9.88	139.76	8.60	131.83	8.56	136.51	9.52
lnRSA	Baseline	3.73	.42	3.71	.33	3.74	.30	3.62	.45	3.88	.41	3.72	.38
	Stress	3.46	.41	3.60	.42	3.52	.44	3.55	.44	3.47	.27	3.52	.42
	Recovery	3.45	.43	3.51	.42	3.51	.42	3.37	.43	3.64	.39	3.48	.42
Behavioral distress		-.02	.65	.02	.53	-.05	.65	.05	.57	.04	.45	.00	.59
Self-soothing behavior		.91	.70	.98	.78	1.14	.80	.79	.65	.68	.58	.95	.74

the 6-month stress paradigm were skewed or peaked, but transformation of the values did not improve the distribution of the variables.

Prior to conducting the main analysis, the potential effects of infants' gender and family income on the independent and dependent variables were examined. The analyses revealed that infants' gender and family income were not significantly related to maternal sensitivity, maternal intrusiveness, heart rate, RSA and infants' behavior during the stress paradigms at 6 months and 12 months.

Association between the infants' behavior and physiology during stress

Table 4 shows the correlations of the behavioral and physiological indices of the still-face paradigm at 6 months of age. With regard to the behavioral measures, positive affect was negatively related to negative affect during the still-face paradigm. In addition, more self-soothing behavior was related to more positive affect and less negative affect. Concerning the physiological measures, heart rate was negatively related to lnRSA during the still face paradigm: the higher infants' heart rate, the lower infants' lnRSA. With regard to the association between the behavioral and physiological indices, positive affect was significantly related to heart rate and lnRSA: when children showed more positive affect, they had a lower heart rate and higher lnRSA during the stress paradigm. In addition, more negative affect was related to a higher heart rate and lower lnRSA. Self-soothing behavior was not related to infants' physiology during the stress paradigm.

Table 5 shows the correlations of the behavioral and physiological measures of the robot paradigm at 12 months of age. Concerning the behavioral indices during this stress paradigm, there was no significant correlation between behavioral distress and self-soothing behavior. In accordance with the results of the 6-month stress paradigm, the physiological measures were negatively related: the higher infants' heart rate, the lower infants' lnRSA level. With regard to the relation between the behavioral and physiological measures, the analysis revealed one significant correlation: the more behavioral distress the infant showed, the higher the heart rate during the stress episode.

Association between maternal behavior and infants' physiology during the still-face paradigm

Heart rate. When examining the pattern of heart rate during the still-face paradigm, Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2) = 6.62$, $p = .04$, which indicates that the variances of the differences between the different conditions were unequal. Therefore the degrees of freedom were corrected ($\varepsilon = .95$). Results of the repeated measures analysis of variance indicated that heart rate was significantly influenced by the different episodes, F (1.90, 117.51)= 18.79, $p < .01$, $\eta_p^2 = .23$. As shown in Figure 1, contrasts revealed that the heart rate significantly increased from the baseline episode (M = 141.27, SD = 1.32) to the stress episode (M = 147.69, SD = 1.22), F (1, 62) = 28.89, $p <$. 01, $\eta_p^2 = .32$. The heart rate during the stress episode did not significantly differ from the heart rate during the recovery episode.

Table 4

Correlations between the physiological and behavioral variables of the still-face paradigm

Measure	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1. Pos. affect Basel	-													
2. Pos. affect Stress	.38**	-												
3. Pos. affect Recov	.50**	.49**	-											
4. Neg. affect Basel	-.37**	-.17	-.24**	-										
5. Neg. affect Stress	-.01	-.20	-.33**	.51**	-									
6. Neg. affect Recov	-.13	-.08	-.49**	.32**	.64**	-								
7. Self-Sooth. Basel	.10	-.07	-.12	-.14	-.03	.01	-							
8. Self-Sooth. Stress	.27**	.12	.15	-.31*	-.10	-.17	.26*	-						
9. Self-Sooth. Recov	.12	.01	-.07	-.26*	-.08	-.10	.34**	.36**	-					
10. HR Baseline	-.45**	-.14	-.04	.19	-.13	-.18	.14	-.07	-.04	-				
11. HR Stress	-.04	-.11	-.11	.14	.42**	.19	.09	.05	.12	.54**	-			
12. HR Recovery	-.13	-.10	-.33**	.09	.35**	.61**	.08	-.10	.05	.39**	.61**	-		
13. lnRSA Baseline	.31*	.08	.05	.07	.22	.23	.07	.00	.25	-.42**	-.03	-.07	-	
14. lnRSA Stress	-.03	.06	.02	.00	-.09	.00	-.02	-.10	-.09	-.29*	-.50**	-.35**	.23	-
15. lnRSA Recovery	.20	.17	.28*	-.09	-.16	-.27*	-.04	.20	.12	-.31*	-.24	-.57**	.55**	.56**

Note. Pos. affect= Positive affect; Neg. affect = Negative affect; Self-sooth. = Self-soothing behavior; HR = Heart rate; RSA = Respiratory Sinus Arrhythmia; Basel = Baseline episode; Stress = Stress episode; Recov = Recovery episode.

*p < .05. **p < .01.

Table 5

Correlations between the physiological and behavioral variables of the robot paradigm

Measure	*1*	*2*	*3*	*4*	*5*	*6*	*7*
1. Beh. distress Stress episode	-						
2. Self-sooth. Stress episode	-.19	-					
3. HR Baseline episode	.09	.19	-				
4. HR Stress episode	.58**	-.01	.15	-			
5. HR Recovery episode	.20	.09	.62**	.39**	-		
6. lnRSA Baseline episode	.03	.06	-.33**	.03	-.13	-	
7. lnRSA Stress episode	-.24	-.24	-.17	-.31*	-.20	.23	-
8. lnRSA Recovery episode	.11	-.02	-.38**	.10	-.42**	.46**	.21

Note. Beh. Distress = Behavioral distress; Self-sooth. = Self-soothing behavior; HR = Heart rate; RSA = Respiratory Sinus Arrhythmia.

*p < .05. **p < .01.

Results showed a trend for the main effect of maternal sensitivity on heart rate, *F* (1, 62) = 3.30, *p* = .07, η_p^2 = .05. The heart rate of infants of low/moderate sensitive mothers (*M* = 143.96, *SD* = 1.58) was lower than the heart rate of infants of high sensitive mothers (*M* = 148.01, *SD* = 1.58). The analysis also indicated an interaction effect between episode and maternal sensitivity, *F* (1.90, 117.51) = 4.26, *p*= .02, η_p^2 = .06, which indicates that the pattern of heart rate during the still-face paradigm differed between infants of low/moderate and high sensitive mothers. As shown in Figure 1, heart rate of high sensitive mothers increased more from the baseline episode to the stress episode compared to infants of low/moderate sensitive mothers, *F* (1, 62) = 4.57, *p* = .04, η_p^2 = .32.

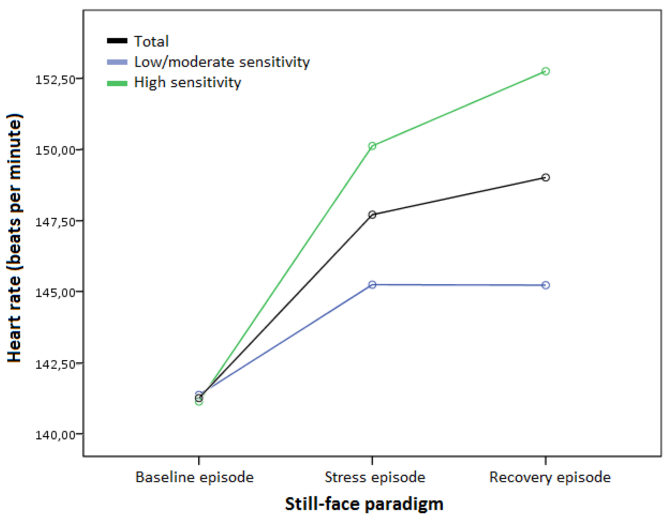

Figure 1. Patterns of infants' heart rate during the still-face paradigm in relation to maternal sensitivity.

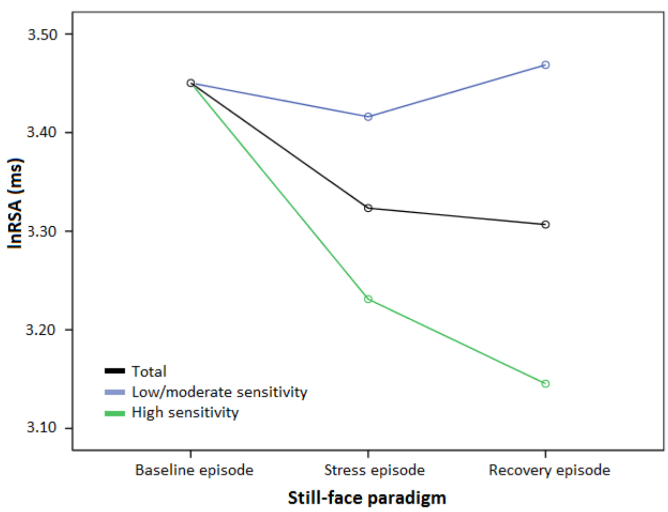

Figure 2. Patterns of infants' lnRSA during the still-face paradigm in relation to maternal sensitivity.

The pattern from the stress episode to the recovery episode did not significantly differ for more or less sensitive mothers.

When examining maternal intrusiveness, the assumption of sphericity had been violated, $\chi^2(2) = 7.27$, $p = .03$. Therefore the degrees of freedom were corrected ($\varepsilon = .95$). No significant main effect of maternal intrusiveness, nor an interaction effect between episode and maternal intrusiveness on heart rate was found.

lnRSA. When examining the pattern of lnRSA, the analysis showed that the assumption of sphericity had been violated, $\chi^2(2) = 7.41$, $p = .03$. Therefore the degrees of freedom were corrected ($\varepsilon = .93$). There was a significant main effect of episode on lnRSA, F (1.86, 104.32) = 3.26, $p = .046$, $\eta_p^2 = .06$. Contrasts revealed a trend: as shown in Figure 2, lnRSA decreased from the baseline episode ($M = 3.45$, $SD = .05$) to the stress episode ($M = 3.32$, $SD = .06$), F (1, 56) = 3.17, $p = .08$, $\eta_p^2 = .05$. There was no significant difference between lnRSA during the stress episode and the recovery episode. lnRSA significantly decreased from the baseline episode to the recovery episode ($M = 3.31$, $SD = .06$), F (1, 56) = 7.28, $p < .01$, $\eta_p^2 = .12$.

There was a trend for a main effect of maternal sensitivity on lnRSA, F (1, 56) = 3.29, $p = .08$, $\eta_p^2 = .06$. The lnRSA level of infants of low/moderate sensitive mothers ($M = 3.45$, $SD = .07$) was higher than the lnRSA level of infants of high sensitive mothers ($M = 3.28$, $SD = .07$). Furthermore, a significant interaction between episode and maternal sensitivity was observed, F (1.86, 104.32) = 3.49, $p = .04$, $\eta_p^2 = .06$. As shown in Figure 2, the pattern of lnRSA from the baseline episode to the recovery episode of infants of high sensitive mothers significantly differed from the pattern of infants of low/moderate sensitive mothers, F (1, 56) = 9.26, $p < .01$, $\eta_p^2 = .14$.

When examining maternal intrusiveness, the analysis revealed neither a main effect of maternal intrusiveness, nor an interaction effect between episode and maternal intrusiveness on lnRSA.

Association between maternal behavior and infants' behavior during the still-face paradigm

Positive affect. There was a significant main effect of episode on positive affect, F (2, 128) = 97.50, $p < .01$, $\eta_p^2 = .60$. As shown in Figure 3, positive affect significantly decreased from the baseline episode ($M = 1.79$, $SD = .99$) to the stress episode ($M = .30$, $SD = .54$), F (1, 64) = 168.41, $p < .01$, $\eta_p^2 = .73$, and significantly increased during the recovery episode ($M = 1.30$, $SD = .89$), F (1, 64) = 107.36, $p < .01$, $\eta_p^2 = .63$. There was no significant main effect of maternal sensitivity, indicating that the infants' level of positive affect did not differ for more or less sensitive mothers. There was no interaction effect between episode and maternal sensitivity either.

When examining maternal intrusiveness, the analysis revealed no main effect of maternal intrusiveness, neither an interaction effect between episode and maternal intrusiveness on positive affect.

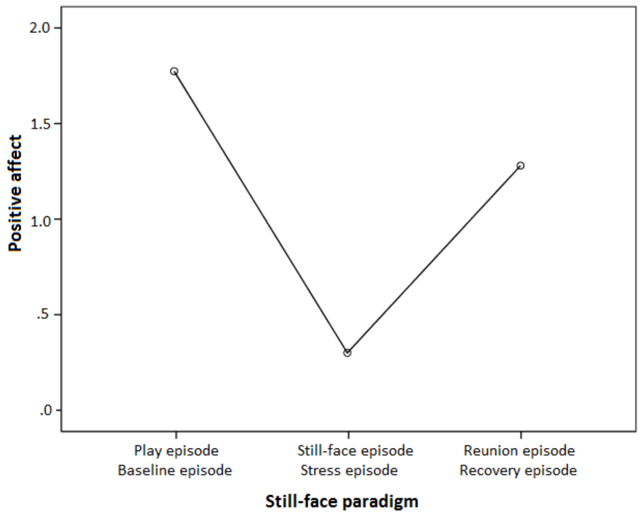

Figure 3. Pattern of infants' positive affect during the still-face paradigm.

Negative affect. There was a significant main effect of episode on negative affect, F (2, 128) = 13.18, p < .01, η_p^2 = .17. As shown in Figure 4, negative affect significantly increased from the baseline episode (M = .70, SD = .89) to the stress episode (M = 1.05, SD = 1.00), F (1, 64) = 8.69, p < .01, η_p^2 = .24, and further increased during the recovery episode (M = 1.29, SD = 1.06), F (1, 64) = 3.78, p = .03, η_p^2 = .07.

There was no significant main effect of maternal sensitivity. As shown in Figure 4, the analysis revealed a significant interaction effect between episode and maternal sensitivity, F (2, 128) = 5.30, p < .01, η_p^2 = .08. Contrasts indicated a greater increase in negative effect from the baseline episode to the stress episode for infants of high sensitive mothers compared to infants of low/moderate sensitive mothers, F (1, 64) = 4.09, p = .047, η_p^2 = .06. Infants of high sensitive mothers also showed a

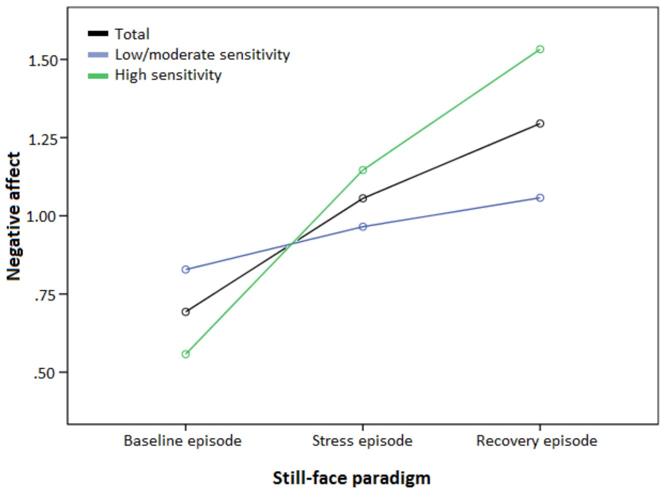

Figure 4. Patterns of infants' negative affect during the still-face paradigm in relation to maternal sensitivity.

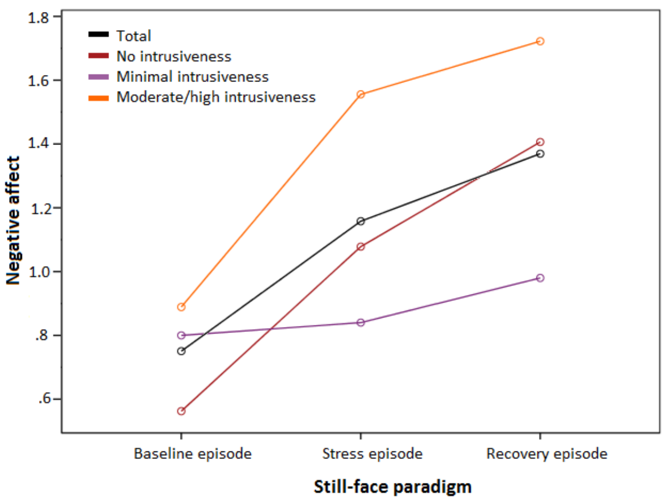

Figure 5. Patterns of infants' negative affect during the still-face paradigm in relation to intrusiveness.

greater increase in negative affect from the baseline episode to the recovery episode compared to infants of low/moderate sensitive mothers, *F* (1, 64) = 8.22, *p* = .01, η_p^2 = .11.

For maternal intrusiveness, the analysis indicated no main effect of maternal intrusiveness. There was a trend for the interaction effect between episode and maternal intrusiveness on negative affect, *F* (4, 126) = 2.02, *p* = .096, η_p^2 = .06. Contrasts indicated a trend for the difference in increase in negative affect between the different groups of maternal intrusiveness from the baseline episode to the stress episode, *F* (2, 63) = 2.43, *p* = .096, η_p^2 = .07, and also for the increase from the baseline episode to the recovery episode, *F* (2, 63) = 2.76, *p* = .07, η_p^2 = .08. As shown in Figure 5, infants of moderate/high intrusive mothers showed a greater increase in negative affect compared to infants of non-intrusive mothers, while negative affect of infants with minimal intrusive mothers remained relatively low during the still-face paradigm.

Self-soothing behavior. When examining self-soothing behavior during the still-face paradigm, the repeated measures analysis of variance neither showed main or interaction effects of episode and maternal sensitivity, nor of maternal intrusiveness.

Association between maternal behavior and infants' physiology during the robot paradigm

Heart rate. Because the assumption of sphericity had been violated, $\chi^2(2)$ = 56.23, *p* < .01, the degrees of freedom were corrected (*ε* = .62). There was a significant main effect of episode on heart rate, *F* (1.24, 74.33)= 47.75, *p* < .01, η_p^2 = .44. As shown in Figure 6, heart rate significantly increased from the baseline episode (*M* = 126.94, *SD* = 9.29) to the stress episode (*M* = 147.80, *SD* = 20.52), *F* (1, 60) = 61.83, *p* < .01, η_p^2 = .51, and significantly decreased during the recovery episode (*M* = 136.51, *SD* = 9.52), *F* (1, 60) = 23.09, *p* < .01, η_p^2 = .28. There was neither a significant main effect of maternal sensitivity, nor an interaction effect between episode and maternal sensitivity.

For maternal intrusiveness, Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2(2)$ = 57.89, *p* < .01. Therefore the degrees of freedom were corrected (*ε* = .61).

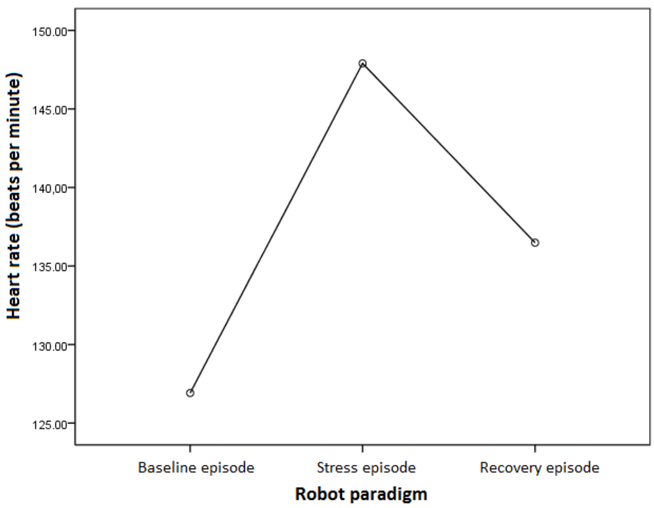

Figure 6. Pattern of infants' heart rate during the robot paradigm.

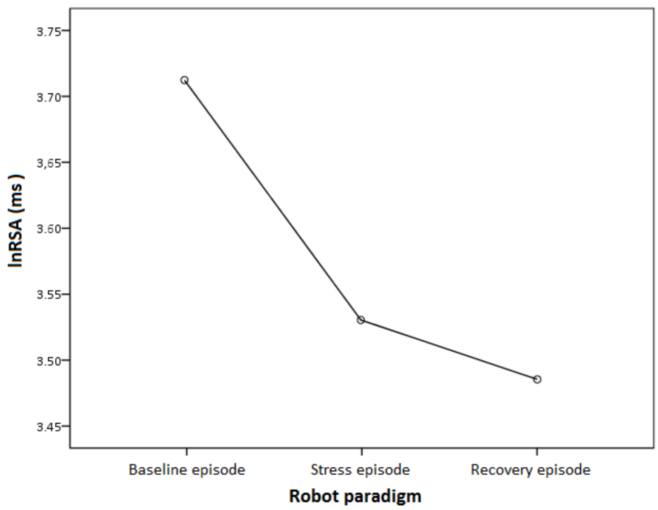

Figure 7. Patterns of infants' lnRSA during the robot paradigm.

There was no main effect or interaction effects of maternal intrusiveness on infants' heart rate.

lnRSA. For lnRSA, there was a significant main effect of episode, F (2, 120) = 7.64, p < .01, η_p^2 = .11. As shown in Figure 7, lnRSA significantly decreased from the baseline episode (M = 3.71, SD = .38) to the stress episode (M = 3.52, SD = .42), F (1, 60) = 8.50, p < .01, η_p^2 = .12. lnRSA did not significantly change from the stress episode to the recovery episode. There were no main or interaction effects of maternal sensitivity on infants' lnRSA.

When examining maternal intrusiveness, the analysis indicated no significant main effect of maternal intrusiveness, nor an interaction effect between episode and maternal intrusiveness on lnRSA.

Association between maternal behavior and infant behavior during the robot paradigm

Behavioral distress. An independent samples t-test revealed no significant difference between infants of low/moderate sensitive mothers and infants of high sensitive mothers in behavioral distress during the stress episode. An analysis of variance indicated no effect of maternal intrusiveness on infants' behavioral distress either.

Self-soothing behavior. An independent samples t-test indicated that there was no difference in the amount of self-soothing behavior between infants of low/moderate sensitive mothers and infants of high sensitive mothers. An analysis of variance revealed that there was a trend for maternal intrusiveness, F (2, 62) = 2.86, p = .07, η_p^2 = .09. LSD post-hoc tests indicated a trend for a difference between non-intrusive mothers (M = 1.11, SD = .79) and low intrusive mothers (M = .73, SD = .63), p = .05, and between non-intrusive mothers (M = 1.11, SD = .79) and moderate/high intrusive mothers (M = .61, SD = .53) in the amount of self-soothing behavior, p = .07.

The longitudinal association between the variables of the 6-month and 12-month stress paradigm

A correlation analysis was used to examine the associations between infants' emotional reactivity and emotion regulation on the still-face paradigm and the robot paradigm. For the physiological variables, delta scores were computed between the sequential episodes of the stress paradigms. As shown in Table 6, the only measure that was modestly stable from 6 months to 12 months was the difference in RSA from stress to the recovery: the greater the decrease in RSA during the recovery period at 6 months of age, the greater the decrease in RSA during the recovery at 12 months of age. Further, a significant relation between the difference in heart rate from the baseline to the stress episode of the still-face paradigm and the difference in RSA from the stress episode to the recovery episode of the robot paradigm was observed, indicating that the greater the increase in heart rate during the stressful episode at 6 months of age, the greater the increase in RSA during the recovery period at 12 months of age. In addition, the greater the decrease in heart rate during the recovery episode at 6 months of age the greater the increase in RSA during the recovery episode at 12 months of age.

Table 6

Correlations between the physiological and behavioral indices of the stress paradigms

Still-face paradigm (6 months)	Robot paradigm (12 months)					
	Δ HR (Base-Str)	Δ RSA (Base-Str)	Δ HR (Str-Rec)	Δ RSA (Str-Rec)	Beh. distress (Stress)	Self-soothing (Stress)
Δ HR (Baseline-Stress)	.06	-.08	-.17	.27*	.03	.02
Δ RSA (Baseline-Stress)	-.03	-.01	.12	-.21	.11	-.20
Δ HR (Stress-Recovery)	.00	.09	.02	-.27*	-.01	-.12
Δ RSA (Stress-Recovery)	-.01	-.17	-.02	.28*	-.12	.12
Positive affect Baseline	-.20	-.15	.11	.31*	-.14	.13
Positive affect Stress	-.18	-.29*	.10	.14	-.21	.09
Positive affect Recovery	-.15	-.11	.10	.21	-.20	.17
Negative affect Baseline	.25	.00	-.22	.02	.31*	.02
Negative affect Stress	.21	-.09	-.26*	.31*	.23	.06
Negative affect Recovery	.12	.05	-.15	-.01	.04	-.10
Self-sooth. beh. Baseline	-.04	-.18	.07	.29*	.04	-.05
Self-sooth. beh. Stress	-.06	-.13	.09	.10	.00	.02
Self-sooth. beh. Recovery	.13	-.27*	-.15	.15	.12	.03

Note. HR = Heart rate; RSA = Respiratory sinus arrhythmia; Beh. Distress = Behavioral distress; Bas = Baseline episode; Str = Stress episode; Rec= Recovery episode.

*$p < .05$.

Regarding the behavioral indices, negative affect during the baseline episode of the still-face paradigm was significantly correlated with behavioral distress during the stress episode of the robot paradigm. When examining the associations between the physiological measures and behavioral measures, the analysis indicated that more positive affect during the baseline episode of the still-face paradigm was related to a greater increase in RSA during the recovery period of the robot paradigm. Less positive affect during the stress episode of the still-face paradigm was related to a smaller decrease in RSA from the baseline period to the stress episode of the robot paradigm. Negative affect during the stress episode of the still-face paradigm was significantly related to difference in heart rate and RSA, from the stress to the recovery period of the robot paradigm, which indicates that the infants showing more negative affect during the still-face paradigm, showed a greater decrease in heart rate and a greater increase in RSA during the recovery of the robot paradigm. Self-soothing behavior during the baseline was significantly related to the difference in RSA from the stress episode to the recovery period of the robot paradigm, which indicates that the more an infant showed self-soothing behavior, the greater the increase in RSA was during the recovery period of the robot paradigm. In addition, more self-soothing behavior during the recovery of the still-face paradigm was associated with a greater decrease in RSA during the stress episode. The physiological measures of the still-face paradigm were not significantly related to the behavioral distress or self-soothing behavior during the robot paradigm.

The influence of maternal behavior on the longitudinal association of heart rate. To assess the longitudinal association between the stress paradigm at 6 months and at 12 months in relation to maternal behavior, several repeated measures analyses of variance were conducted using standardized values of the delta scores. First, maternal sensitivity was examined in relation to the difference in heart rate from the baseline episode to the stress episode. As shown in Figure 8, the repeated measures analysis of variance indicated a significant main effect of maternal sensitivity on the difference in heart rate, F (1, 59) = 6.44, p = .01, η_p^2 = .10, indicating that infants of high sensitive mothers (M = .23, SD = .12) showed a greater increase in heart rate from the baseline to stress episode compared to infants of low sensitive mothers (M = -.22, SD = .13). The interaction between infants' age and maternal sensitivity was not significant.

In addition, the difference in heart rate from the stress episode to the recovery was examined. The repeated measures analysis of variance indicated no significant main effect of maternal sensitivity on the difference in heart rate from the stress episode to the reunion or recovery. There was a trend for an interaction effect between infants' age and maternal sensitivity, F (1, 58) = 3.35, p = .07, η_p^2 = .06, indicating that infants of high sensitive mothers showed a relatively greater decrease in heart rate when they became older, but infants of low/moderate sensitive

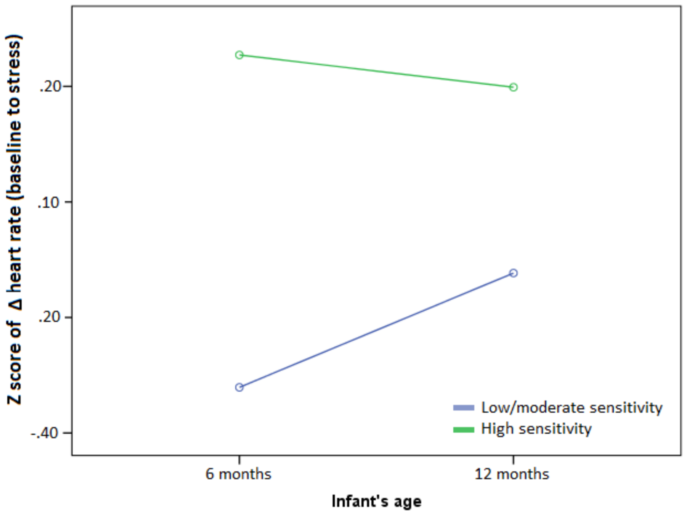

Figure 8. Longitudinal development of Δ heart rate during stress in relation to maternal sensitivity.

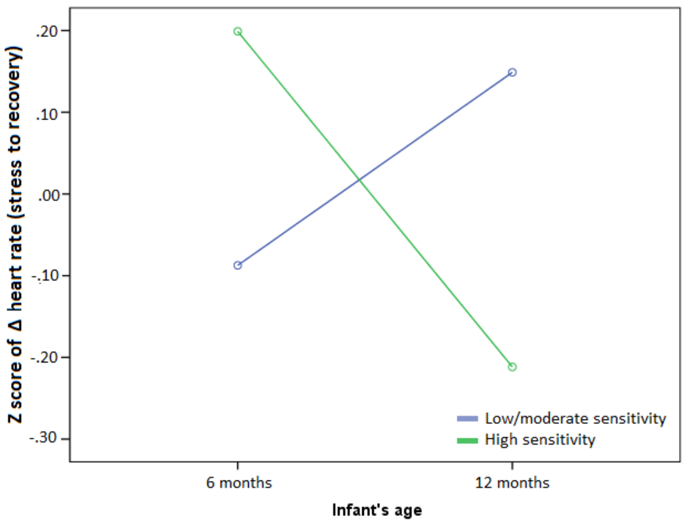

Figure 9. Longitudinal development of Δ heart rate during recovery in relation to maternal sensitivity.

mothers showed a smaller decrease in heart rate when they became older. Results are shown in Figure 9.

Concerning the relation between maternal intrusiveness and the difference in heart rate from baseline to stress, there was no main effect of maternal intrusiveness and no interaction effect between infants' age and maternal intrusiveness. With regard to the difference in heart rate from stress to recovery, the analysis indicated no main or interaction effects of infants' age and maternal intrusiveness either.

The influence of maternal behavior on the longitudinal association of RSA. For the difference in RSA from baseline to the stress episode at 6 months and 12 months of age, there were no main or interaction effects of infants' age and maternal sensitivity. For the difference in RSA from the stress episode to the recovery episode, the analysis indicated neither a significant main effect of maternal sensitivity, nor a significant interaction effect between infants' age and maternal sensitivity.

Next, the relation between maternal intrusiveness and the difference in RSA during stress was examined. The analysis revealed no significant main effect of maternal intrusiveness and no interaction effect between infants' age and maternal intrusiveness on the difference in RSA from baseline to the stress episode. With regard to the difference in RSA from the stress episode to the recovery, no significant main effect or interaction effects of infants' age and maternal intrusiveness were found either.

The influence of maternal behavior on behavioral distress and self-soothing behavior. A repeated measures analysis of variance examining the standardized scores of behavioral distress revealed neither main or interaction effects of infants' age and maternal sensitivity, nor for maternal intrusiveness. For self-soothing behavior no main or interaction effects were observed either.

Discussion

This study confirmed that maternal behavior towards her child influences the development of infants' emotional reactivity and emotion regulation. Although all of the infants showed behavioral and physiological emotional arousal and emotion regulation during stress, 6-month-old infants of more sensitive mothers showed more emotional reactivity, indicated by a greater increase in negative affect and heart rate compared to infants of less sensitive mothers. These infants were also better able to regulate their emotions: they showed a greater decrease in RSA during stress than infants of less sensitive mothers. No significant influence of maternal intrusiveness was observed. The results indicate the importance to get more insight in the environmental aspects influencing children's emotion regulation. The results could be relevant for intervention programs preventing negative child outcomes related to problems in emotion regulation, such as behavioral problems

(Crockenberg et al., 2008; Hill et al., 2006; Roll et al., 2012) and academic failure (Graziano et al., 2007).

Behavioral reactivity and regulation at 6 months

As expected, 6-month-old infants showed the classic still-face effect during the stress paradigm: infants showed a decrease in positive affect and an increase in negative affect from the baseline to the stress episode. These results are consistent with previous studies conducting the still-face procedure (Bazhenova et al., 2001; Bigelow & Walden, 2009; Haley & Stansburry, 2003; Mesman et al., 2009; Moore et al., 2009; Moore & Calkins, 2004). This study also confirmed the partial recovery after the stressful period found in a meta-analysis (Mesman et al., 2009): although infants' positive affect increased while interacting with the mother after stress, this study did not find a decrease in negative affect. In contrast, negative affect increased during the recovery after the stress-inducing period.

Although previous studies found that infant behavior related to emotion regulation increased during stress (Jean & Stack, 2012), the amount of self-soothing behavior in this study remained stable during the 6-month stress paradigm. The operationalization of the self-regulatory behaviors of the two studies largely correspond, but Jean & Stack (2012) measured the duration of the behaviors second by second, while in this study a global score was assigned to each minute for the number of instances of self-soothing behaviors. This difference in coding approach could possibly explain the difference in results.

Physiological reactivity and regulation at 6 and 12 months

Heart rate and RSA showed the opposite pattern in both 6- and 12-month-old infants during stress. As in previous research (Baker et al., 2012; Bazhenova et al., 2001; Conradt & Ablow, 2010; Gunning et al., 2013; Haley et al., 2006; Haley & Stansburry, 2003; Hill-Soderlund et al., 2008; Mattson et al., 2013; Moore et al., 2009; Moore & Calkins, 2004), infants' heart rate increased during the periods in which the mother was not available, which indicates that both paradigms were stress-inducing. RSA, an operationalization of cardiac vagal tone, decreased at both ages during the stressful episodes, indicating adaptive emotion regulation. This is consistent with the Polyvagal theory, which states that the vagal tone decreases in response to challenge to cope with the environmental demands (Porges, 2007).

There is no consensus in the literature regarding infants' physiological recovery quickly after stress. Although some studies found that the heart rate and vagal tone recovered after a stress-inducing task (Bazhenova et al., 2001; Haley et al., 2006), other studies found that heart rate remained high and RSA remained low (Conradt & Ablow, 2010; Mattson et al., 2013). This study showed that infants' heart rate recovered among 12-month-old children during interaction with the mother after the stress-inducing period, but did not among 6-month-old infants. The fact that heart rate recovered at 12 months and did not recover at 6 months, may be due to normative developmental changes in cognitive processes related to emotion regulation (Rothbart & Bates, 1998). For example, inhibitory control develops during the second half of the first year of life, which increases the infants' ability to inhibit emotional reactions. Therefore, 12-month-old infants could be more able to regulate their emotional reactivity after stress. The results could also be due to the difference in the duration of the recovery period, which was three minutes longer during the stress paradigm at 12 months.

Among both 6- and 12-month-old infants, RSA did not recover, but remained low during the final episode in which the mother regains the interaction after with the child. Because of this social engagement during the recovery, the environmental demands remain high, which could explain the absence of an increase of RSA quickly after stress (Porges, 2007).

Association between behavioral and physiological reactivity and regulation

Consistent with our hypothesis, it was found that infants' behavioral reactivity was related to infants' physiological reactivity. At both ages, more behavioral distress during a stress-inducing period was related to a higher heart rate. This finding was in accordance with previous research examining behavioral distress and heart rate among 6- and 12-month-old infants (Baker et al., 2012; Moore & Calkins, 2004). Behavioral distress was not associated with RSA during stress. This was in accordance with Brooker et al. (2013), who also did not find an association between facial fear and RSA. Regarding the recovery period, less negative affect and more positive affect were associated with lower heart rate and higher RSA in 6-month-old infants. Behavior related to regulation was not related to the physiological indices.

The influence of maternal behavior on infants' emotional reactivity and emotion regulation

Based on previous research, it was hypothesized that infants of more sensitive and less intrusive mothers would show less behavioral and physiological reactivity in response to stress. For example, Haley & Stansburry (2003) found that higher maternal responsiveness was related to lower heart rate during the recovery period after the second still-face episode. Contrary to the expectations, in this study it was found that 6-month-old infants of high sensitive mothers showed more behavioral and physiological arousal compared to infants of less sensitive mothers, indicated by a greater increase in negative affect and heart rate during stress. For positive affect, no effect of maternal sensitivity was found. The fact that infants of less sensitive mothers showed less arousal could be explained by the previous experiences with stressful situations in their first year of life: infants of low sensitive mothers might be more used to less positive interactions with the mother, while infants of high sensitive mothers might have less experience with stressful situations. Greater emotional arousal during stress could be an adequate response for infants that are used to sensitive maternal support during stress.

With regard to the methodological aspects, most studies using the still-face paradigm examined maternal behavior during the baseline episode or reunion episode of the paradigm, which directly influences the infants' behavior. This study assessed maternal behavior during a task independent of the stress paradigm, which may have had an influence on the results. In addition, the difference in results can be due to differences in sample characteristics. In the first place, this study focused on young mothers between 17 and 25 years old. Previous research indicated that maternal age can moderate the relation between maternal behavior and infants' behavioral distress (Tarabulsy et al., 2003). Infants of older mothers (mean age 29 years) showed the expected direction of the effect of maternal sensitivity: higher maternal sensitivity was related to less negative affect during the stress-inducing period of the still-face paradigm. However, infants of adolescent mothers (mean age 17 years) showed the opposite direction: higher maternal sensitivity was related to more infant distress during stress. The authors suggest that the results imply that in the different age groups, different developmental processes could be relevant. Secondly, more than half of the sample in this study had a high social risk status, for example because of a small social network or maternal psychopathology. Field et al. (2007) found that infants and their depressed mothers showed less interactive behavior than non-depressed mothers. In addition, infants of depressed mothers were less emotionally aroused during stress. Because the low/moderate sensitive group in this study involved more mothers with a high risk status compared to the high sensitive group, this may explain the discrepancy in results with previous research.

As expected, 6-month-old infants of high sensitive mothers showed a decrease in RSA during the stressful period, while infants of low/moderate sensitive mother did not show RSA reduction during the still-face paradigm, indicating that infants of high sensitive mothers showed more physiological regulation. The fact that RSA further decreased among infants of high sensitive mothers when mother resumed the interaction during the recovery is in accordance with the study of Moore et al. (2009). The decrease in RSA during the recovery can be explained by the behavioral synchrony between mother and infant. Because more sensitive mothers are better able to interact with their infant, the Polyvagal theory predicts a decrease in RSA to facilitate more environmental engagement during social interaction (Porges, 2007).

With regard to emotional reactivity, for maternal intrusiveness only a trend was found for the pattern of negative affect among 6-month-old infants. The other behavioral and physiological indices related to emotional reactivity and emotion regulation were not related to maternal intrusiveness. It is important to note that maternal behavior was coded during a play task during which most infants were not distressed. Some researchers suggest that maternal behavior should be assessed during a situation in which the infant is distressed, because maternal sensitivity and intrusiveness towards the child may differ for stressful and non-stressful episodes (Goldberg, Grusec

& Jenkins, 1999). For example, Conradt & Ablow (2010) found that maternal sensitivity during distress was predictive of the child's emotional reactivity over and above maternal behavior during the play episode, which implicates the importance to examine infants' emotion regulation in relation to maternal sensitivity in different contexts. It could be that maternal intrusiveness during distress is a better predictor of infants' behavior than maternal intrusiveness during non-stressful periods.

Among 12-month-old infants, maternal behavior was not related to infants' emotional reactivity and emotion regulation during stress. In the current study, maternal sensitivity and intrusiveness were observed at 6 months of age, but it is unclear whether maternal behavior is stable during infancy. For example, Joosen, Mesman, Bakermans-Kranenburg & IJzendoorn (2012) found that maternal sensitivity and intrusiveness during the baseline and recovery of the still-face paradigm were stable from 3- to 6-months of age. Maternal sensitivity measured during a bath session was also stable over time, but sensitivity during a play session did not show stability. Lohaus, Keller, Ball, Voelker & Elbe (2004) examined the stability of maternal sensitivity during a play task between 3 and 12 months of age. It was found that overall sensitivity, but also the different indices of maternal sensitivity, such as signal perception and appropriate reaction, had low stability over time. It was suggested that the child's needs during interaction change when they become older and that first time mothers may develop their ability to interact with the infant over time. In the current study, maternal behavior could have changed during the 6 months after observing maternal sensitivity and maternal intrusiveness. Therefore the predictive value of the observed maternal behavior can be decreased.

Longitudinal association between 6 and 12 months

Regarding the longitudinal relation, it was expected that the behavioral and physiological indices during the 6-month stress paradigm would be positively related to the behavioral and physiological indices during the 12-month stress paradigm. The difference in RSA from stress to recovery was the only physiological index that showed stability from 6- to 12 months: the greater the decrease in RSA during the recovery period at 6 months of age, the greater the decrease in RSA during the recovery at 12 months of age. The difference in heart rate and RSA from baseline to stress and the difference in heart rate from stress to recovery were not stable from 6 to 12 months. These results correspond with previous research of Propper et al. (2008). They examined the longitudinal stability of emotional reactivity conducting the still-face paradigm at 3 and 6 months of age, and the strange situation procedure at 12 months of age. The results indicated that the difference in heart rate from baseline to stress was stable from 3 to 6 months, but not from 6 to 12 months. The difference in RSA from baseline to stress was also not stable during infancy.

In this study no longitudinal associations were found for behavioral reactivity and behavior related to regulation. Kochanska (2001) found stability of fear expression from 14 months to 33 months, but the fear expression in 9-month-old infants was not associated with fear expressions at later ages. The failure to find stability over a period of 6 months for the behavioral and physiological indices, could imply that at this young age the development of emotional reactivity and emotion regulation is influenced by changing external circumstances.

Exploratory analyses were used to assess the influence of maternal behavior on the longitudinal association between 6 months and 12 months. Results indicated that infants of high sensitive mothers showed a greater increase in heart rate during stress compared to infants of low sensitive mothers. Infants of high sensitive mothers also showed a larger decrease in heart rate during the recovery when they became older, but infants of low/moderate sensitive mothers showed a smaller decrease in heart rate when they became older. There was no effect of maternal behavior on RSA, behavioral distress or self-soothing behavior. These results should be replicated as this was the first study to examine this relation.

Limitations and future directions

Several limitations of the current study should be noted. In this study, only two groups of maternal sensitivity were compared, because only a few mothers showed low sensitivity towards their child. Future research should involve a larger sample to better differentiate between different levels of maternal sensitivity. In addition, this study examined maternal behavior during non-distress. Future research should focus on maternal behavior during different situations in relation to infants' emotion regulation.

In addition, this study used different paradigms at 6 months and 12 months to elicit stress. The tasks were different because the paradigm should be age appropriate to ensure infants would experience the procedure as stressful. Although the two paradigms are different procedures, both involve maternal separation. The robot paradigm also includes an external stressor. The results showed that for both paradigms infants showed increased heart rate and decreased RSA during stress. Although these results suggest some equivalence, it cannot be said with certainty that both paradigms elicit the same emotion with the same intensity.

This study focused on the influence of maternal behavior on infants' emotion regulation, but did not involve fathers in the study. Because previous research indicated that fathers and mothers differed in their behavior towards the infant and infants responded differently to the mother and father (Forbes, Cohn, Allen & Lewinsohn, 2008), future research should examine the role of fathers in the development of infants' emotional reactivity and emotion regulation.

It is important to note that this study did not examine the causal relationship between maternal behavior and infants' emotional reactivity and emotion regulation. Although it was found that maternal sensitivity is related to infants' emotional reactivity and emotion regulation, it is likely that this relation is bidirectional. According to transactional model, the child's behavior can provoke different responses from their parents, because the parent and child react to each other's behavioral signals (Sameroff, 2009). Several studies found bidirectional effects between parenting and the child's behavior, such as social competence (Barnett, Gustafsson, Deng, Mills-Koonce & Cox, 2012; Newton, Laible Carlo, Steele & McGinley, 2014), temperament (Lengua, 2006) and problem behavior (Yamagata et al., 2013). For example, Lee, Zhou, Eisenberg & Wang (2012) found a bidirectional relation between effortful control and frustration in 6- to 9-year-old children and authoritarian parenting. Children of parents who used a more authoritarian parenting style became less regulated and more frustrated over time, while lower effortful control and higher frustration also predicted a more authoritarian parenting style four years later. These results emphasize the importance to get more insight in de bidirectional relationship between infants' emotion regulation and maternal behavior using longitudinal studies. The effects beyond the first years of life should be examined as well.

Conclusions

In summary, the current study replicates previous studies examining infants' behavioral and physiological reactions in response to stress. With regard to emotional reactivity, infants' behavioral distress and heart rate increased during the stress-inducing procedures. Infants' RSA decreased, indicative of emotion regulation. In addition, this study indicates that environmental characteristics, such as maternal behavior, have an effect on the development of infants' emotion regulation. Infants of high sensitive mothers were behaviorally and physiologically more reactive, but also showed more physiological regulation than infants of low/moderate sensitive mothers. This knowledge can be used for intervention programs preventing problems during the child's development which are associated with emotion dysregulation, such as externalizing behavior (Hill et al., 2006; Roll et al., 2012), academic failure (Graziano et al., 2007), cognitive problems and social problems (NICHD Early Child Care Research Network, 2004). The stability of the emotional reactivity and emotion regulation among infants between 6 and 12 months was low: only the difference in RSA from stress to the recovery showed was modestly stable. The failure to find robust longitudinal stability emphasizes the importance of investigating possible external factors influencing the development of emotion regulation.

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