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# Physiological Reactivity to Infant Crying and Observed Maternal Sensitivity

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Relations between maternal sensitivity and physiological reactivity to infant crying were examined using measures of heart rate (HR) and respiratory sinus arrhythmia (RSA) in 49 mothers of second-born infants. Using the Ainsworth Sensitivity Scale, an independent assessment of maternal sensitiv-

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ity was made during maternal free play and bathing of their infants. Physiological reactivity was measured while mothers listened to three blocks of infant cry sounds in a standard cry paradigm. Mothers scoring high on sensitivity were compared to less sensitive mothers on both their physiological reactivity to the presented crying sounds and their physiological mean-level differences. Significant interaction effects were found for both HR and RSA. Highly sensitive mothers showed a larger increase in HR and stronger RSA withdrawal in response to the first block of cry sounds compared to less sensitive mothers. Main effects showed that highly sensitive mothers had lower mean overall HR, and higher mean RSA levels across all three blocks of crying sounds compared to less sensitive mothers. RSA withdrawal and accompanying HR increases are discussed from a polyvagal perspective as indicative of a better capability in responding to infant signals of negative affect.

The sound of infant crying is the first acoustic signal a newborn infant sends to the parent. The functionality of this intense signal lies in evoking parenting responses (Bowlby, 1969/1982; LaGasse, Neal, & Lester, 2005; Zeifman, 2001; Zeskind & Lester, 2001), partly by eliciting physiological reactions (Frodi & Lamb, 1980; Frodi, Lamb, Leavitt, & Donovan, 1978; Groh & Roisman, 2009; Wiesenfeld, Malatesta, & Deloach, 1981). Individual differences in parental physiological reactivity to infant crying have been linked to differences in the quality of parenting. Greater heart rate (HR) reactivity to negative infant stimuli, for example, distinguishes those at risk of child abuse from controls (for a review see McCanne & Hagstrom, 1996). However, greater HR reactivity to infant crying has also been related to more prompt maternal responses to these negative infant signals (Del Vecchio, Walter, & O'Leary, 2009), which is one of the aspects defining maternal sensitivity (Ainsworth, Bell, & Stayton, 1974). Thus, a greater HR reactivity to infant crying has been associated with negative as well as positive parenting behaviors, which indicates a need for further examination of the mechanisms underlying physiological reactivity to infant crying. In this study, we examine the relation between observed maternal sensitivity and physiological reactivity to infant crying following the theoretical framework of Porges' polyvagal theory (1995, 2001, 2007).

In his polyvagal theory, Porges (1995, 2001, 2007) describes how the autonomic nervous system developed in three phylogenetic stages, resulting in three distinct autonomic subsystems: the social communication circuit (involving the myelinated vagus and parasympathetic nervous system; PNS), the mobilization circuit (involving the sympathetic nervous system [SNS] and fight–flight behaviors), and the most primitive circuit of immobilization (involving the unmyelinated vagus and e.g., feigning death or freezing behaviors). These subsystems are hierarchically organized, and when responding to external stressors, humans first rely on the newest circuit. This newest circuit of social communication depends on the functioning of the ventral vagal complex (VVC), which originates in the nucleus ambiguous. The VVC functions as an active vagal brake by controlling cardiac output via the sinoatrial node (Porges, 2001, 2007). The degree of cardiac control by the vagal brake can be quantified by the measurement of the amplitude of respiratory sinus arrhythmia (RSA; Porges, 1995). Efficient disinhibition of the vagal brake (i.e., RSA withdrawal) seems to be associated with increased behavioral and emotional control, which enables rapid mobilization as well as calm and self-soothing behavioral states in response to environmental demands (Porges, 1996). In other words, an efficiently functioning vagal brake points to physiological flexibility when reacting to environmental demands. Individuals with stronger RSA withdrawal are supposedly better able to respond adequately to external stressors (Porges, Doussard-Roosevelt, & Maiti, 1994). As parental sensitivity refers to an adequate and prompt response to infant signals (Ainsworth et al., 1974), sensitivity in response to infant distress may be related to functioning of the vagal brake, with more sensitive parents showing stronger RSA withdrawal.

In line with this suggestion, a stronger RSA withdrawal has been linked to indices of positive parenting behavior in reaction to negative infant signals. For example, maternal RSA withdrawal was shown to moderate the relation between negative infant affect and maternal sensitivity. More infant negative affect was related to higher maternal sensitivity only in case of stronger maternal RSA withdrawal (Mills-Koonce et al., 2007). In addition, stronger maternal RSA withdrawal has been related to mobilization of maternal soothing behaviors during infant distress (Ham & Tronick, 2006; Moore et al., 2009). Owing to its function of rapid mobilization, partly through control of the sinoatrial node, RSA withdrawal would likely lead to increased HR (Porges, 2001). Thus, it seems that the existing literature is somewhat contradictory. Greater HR reactivity has been linked to a risk of child abuse (e.g., McCanne & Hagstrom, 1996) while at the same time, greater HR reactivity as well as stronger RSA withdrawal has been related to a greater ability for adequate responsiveness to negative child signals (e.g., Del Vecchio et al., 2009; Mills-Koonce et al., 2007). These seemingly contradictory findings may be the result of different underlying neurophysiological mechanisms influencing HR reactivity. As RSA withdrawal enables physiological flexibility to environmental stressors, HR increases in response to infant crying may be related to parasympathetic functioning, especially among highly sensitive mothers.

In addition to physiological reactivity to specific stressors, some authors have also examined overall mean physiological levels regardless of experimental phase. For instance, Disbrow, Doerr, and Caulfield (1977) compared three groups (physical abusers, neglectors, and controls) on their HR reactivity, and HR variability in response to videotaped parent–child interactions of a pleasant or stressful nature. Their results showed higher HR levels and lower HR variability during the entire stimulus presentation for abusers and neglectors as compared to the controls. In another study of Pruitt and Erickson (1985), high and low abuse potential groups were created based on Child Abuse Potential Inventory (CAPI) scores. HR levels in response to videotapes of smiling, crying, or quiescent infants were higher in the high-risk group during all presented videotapes as compared to HR levels of the low-risk group. Thus, abusive/neglecting parents and at-risk individuals may have higher HR levels in general. Their results concerning HR variability suggested overall lower RSA levels for the abuse-prone group.

Empirical research linking observations of actual parenting behavior to physiological reactivity to negative infant signals is very limited. Furthermore, existing literature does not yet provide a clear answer to the question whether greater HR reactivity to infant crying should be seen either as a risk factor for abuse or as a correlate of sensitive parenting behavior. Regarding overall physiological mean levels, highly sensitive parents could have opposite mean-level patterns compared to abusive and at-risk parents, meaning lower overall HR levels in combination with higher levels of RSA for highly sensitive parents. Several studies have shown an empirical link between harsh parenting and insensitivity; low levels of maternal sensitivity during infancy predicted later use of harsh discipline (Engfer & Gavranidou, 1987; Joosen, Mesman, Bakermans-Kranenburg, & Van IJzendoorn, 2012). Harsh parents seem to lack the skills necessary for sensitive parenting behavior (Milner, 1993, 2003), which could possibly be related to different physiological overall mean-level patterns for highly sensitive parents.

The current study tests the hypothesis that increased HR reactivity and stronger RSA withdrawal in response to repeated infant cry sounds are related to higher levels of maternal sensitivity. Sensitive mothers are hypothesized to have a more efficient vagal brake in comparison with less sensitive mothers, which would be shown by a stronger RSA withdrawal as well as greater HR reactivity for sensitive mothers, especially from baseline to the first presented cry sounds. Furthermore, in exploratory analyses, we examine whether highly sensitive and less sensitive mothers differ in their overall mean levels of HR and RSA across the entire cry paradigm.

## METHODS

### Participants and procedure

In the context of a longitudinal study on early indicators of harsh discipline, mothers with a newborn second child were recruited by mail with help of the Regional Coordination Programs of the Dutch National Institute for Public Health and Environment. Two-child families were deliberately chosen to enable a selection of families based on the level of problem behavior of the first child. This strategy was used to increase the likelihood of observing a wider range in the quality of parenting practices. Caucasian mothers with a low or medium educational level living with a partner and both children were selected. Participating families also had to fit the following additional criteria for selection: (1) the oldest child scored either low or high on externalizing behavior (cutoffs based on Koot, Van den Oord, Verhulst, & Boomsma, 1997; Van Zeijl et al., 2006), (2) the oldest child was younger than 6 years old, (3) the newborn second child was neither premature nor handicapped, and (4) both parents were Caucasian and of Dutch ethnicity. A total of 76 families were selected of which 53 participated in the study. Three families were excluded from the analyses because of missing data and one because of a third pregnancy (and related changes in HR) at the time of assessment, resulting in a final sample size of 49. In these 49 families, 25 firstborns (51%) had low levels of problem behavior, while 24 firstborns (49%) had high levels of problem behavior at the time of selection. Maternal mean age was 29.2 years (*SD*, 5.1; 19–38 years).

Mothers participated in a series of home visits during the first 2 years after the birth of the second child. The first home visit was scheduled when the second child was 3 months old and included the assessments used in the current paper: observations of the dyad in a variety of naturalistic situations (i.e., bathing and free play), and a 20-min cry paradigm (Out, Pieper, Bakermans-Kranenburg, & Van IJzendoorn, 2010; Zeskind & Lester, 1978) with the mothers, during which an electrocardiogram (ECG) signal was recorded. In all participating families, both parents signed informed consent forms. Families were compensated for the home visit by means of a gift coupon with a value of 20 euros and a small present for the baby.

### Measures

#### *Maternal sensitivity*

Maternal sensitivity was assessed with the Ainsworth Sensitivity scale (Ainsworth et al., 1974) during free play on the mother's lap without toys

(5 min) and bathing (10–20 min). Mothers were instructed to interact with their infants as they would normally do. Observations of the bathing ritual included the undressing and redressing of the infant. Maternal behavior during the bath and lap sessions was rated on a 9-point scale with higher scores indicating more maternal sensitivity, resulting in two separate scores for both sessions. Maternal sensitive behavior was defined as an accurate perception of the infant's signals, followed by a prompt and appropriate response (Ainsworth et al., 1974). In the Ainsworth Sensitivity scale, each uneven score is labeled: 9 = highly sensitive, 7 = sensitive, 5 = inconsistently sensitive, 3 = insensitive, and 1 = highly insensitive. The same coder rated both sessions ($r = .48$, $p < .01$) after which scores were averaged into an overall score for maternal sensitivity. Intercoder reliabilities (intraclass correlation, single rater, absolute agreement) for six coders ranged from .75 to .92. The overall sensitivity score was used to create two groups based on a cutoff score of 7. This cutoff was chosen to distinguish mothers labeled as (highly) sensitive ($n = 17$) from those labeled as (partially) insensitive ($n = 32$), given that ratings below seven necessarily include a moderate level of insensitive behavior.

### *Cry paradigm*

The cry paradigm was administered using a laptop with E-prime software. The cry stimuli as well as the design of this particular paradigm have been used in previous studies on physiological reactivity to infant crying (Out et al., 2010; Riem, Pieper, Out, Bakermans-Kranenburg, & Van IJzendoorn, 2011). Mothers listened to three blocks of each three cry sounds that varied in fundamental frequency within each block. Cry stimuli were derived from the spontaneous crying of a healthy 2-day-old, full birthweight, and full-term female infant and were recorded midway between scheduled feedings. A 10-sec portion of the sustained period of crying, containing seven expiratory sounds, was selected for presentation. The seven cry expirations had a mean duration of 1055 msec (range, 0.6195 to 1899 msec) and a mean peak $F_0$ of 452.6 Hz (range, 425.2 to 515.6 Hz). To provide cry stimuli with a wide range of fundamental frequencies, the original cry (averaging approximately 500 Hz) was digitally altered to increase the fundamental frequency while holding temporal and other spectral aspects of the cry constant. Two new 10-sec cry stimuli were created by digitally increasing the original cry by approximately 200 and 400 Hz, respectively, resulting in two new cry sounds with an overall peak $F_0$ of 714.5 Hz (700 Hz Cry) and 895.8 Hz (900 Hz Cry) (see Out et al., 2010). Each of the three blocks of cry sounds contained each of the three cry sounds (i.e., 500, 700, 900 Hz) presented in a random order. Significant associations between perception and frequency have been found in previous studies using digitally increased cry sounds (Schuetze & Zeskind, 2001; Schuetze, Zeskind, & Eiden, 2003). The cry stimuli were presented at a constant volume through Sennheiser HD202 headphones.

Prior to the cry paradigm, mothers were asked to fill out a short questionnaire on smoking and physical exercise. Furthermore, following every cry sound, mothers answered four questions on perceived characteristics of the cry sound (not aroused – aroused, not aversive – aversive, healthy – sick, and not urgent – urgent) on a 5-point rating scale (Zeskind & Lester, 1978; Zeskind & Marshall, 1988). Given the high internal consistencies (alphas ranging from .77 to .83), answers to the four questions were averaged in an overall perceived urgency score for each of the three frequencies. Following a 4-min baseline period (during which neutral pictures were presented on the screen) and a practice trial in which the 500-Hz cry was presented, mothers listened to the three blocks of three cry sounds each. After each cry sound, mothers paused for a minimum of 1 min to answer the perception questions before the next cry sound was presented. The paradigm was concluded with a 2-min recovery period. Mothers' ECG signals were recorded continuously during the entire cry paradigm.

## HR and RSA

The ECG signal was measured with an ambulatory monitoring system (VU-AMS5fs; TD-FPP, Vrije Universiteit, Amsterdam, the Netherlands) and recorded continuously using three disposable pre-gelled Ag–AgCl electrodes (ConMed, New York, USA) that were placed below the right collar bone 4 cm to the right of the sternum, 4 cm under the left nipple, and at the lateral right side. The full ECG signal was stored at a 16-bit sampling rate. HR responses were synchronized to the cry sounds using a marker button on the AMS device. The experimenter pushed the button 2 sec before the stimulus was presented, leaving markers that allowed for accurate labeling of each cry sound.

Interbeat interval time series (IBIs) were derived by visual peak detection of the R-wave through accompanying VU-AMS5fs software packages. Each recorded ECG complex was inspected and corrected by hand when necessary. The mean IBI per labeled segment was used to calculate mean HR during baseline, recovery, and each cry presentation. RSA was indexed by calculation of the root mean square of successive differences (RMSSD) of interbeat intervals for each of the labeled segments. RMSSD has been shown to highly correlate with other time and frequency domain measures of RSA across various ambulatory conditions (Goedhart, Van der Sluis, Houtveen, Willemsen, & De Geus, 2007). Considering the small sample size, a careful check for outliers was conducted. We checked for outliers within each variable (prior to calculation of block means) as well as within the pattern for each individual subject. No outliers were detected for mean HR levels. For RMSSD, values for one participant were winsorized to values corresponding to a standardized value of 3.29, while preserving the participant's response pattern. Finally, based on earlier findings by Out et al. (2010), which showed significant differences in maternal responses across blocks instead of between frequencies, mean HR and RMSSD levels were aggregated within each of the three blocks (i.e., average of three consecutive episodes of 10 sec).

### Data analysis

Pearson's chi-square tests were run to compare sensitive mothers to less sensitive mothers on smoking and physical exercise. *T*-tests were performed to examine differences in age between the two groups of mothers and to check for the influence of smoking and physical exercise on HR and RMSSD baseline values. Pearson's correlation coefficients were calculated for the relation between maternal age and both physiological baseline values. To examine the relation between maternal sensitivity and the perceived urgency per frequency, a repeated measures analysis was performed with perceived urgency as outcome measure, frequency as within-subjects factor, and maternal sensitivity (highly sensitive vs. less sensitive) as between-subjects factor. Another two repeated measures analyses were administered to examine the association between maternal sensitivity and the development of HR and RMSSD reactivity across the cry paradigm, with HR or RMSSD as the outcome measure, episode (baseline, three blocks of cry sounds, and recovery) as the within-subjects factor, and maternal sensitivity (highly sensitive vs. less sensitive) as the between-subjects factor. Greenhouse–Geisser epsilon was used to correct for violation of sphericity in all repeated measures analyses. To examine maternal sensitivity group differences in mean HR and RMSSD values per block, separate analyses of covariance were run for each block and the recovery, in which baseline values for, respectively, HR and RMSSD were entered as covariates.

## RESULTS

### Preliminary analyses

Highly sensitive mothers did not differ significantly from less sensitive mothers concerning smoking, physical exercise, or age (all $p > .05$). Sample dis-

TABLE 1
Background and Physiological Data of Highly Sensitive and Less Sensitive Mothers

| | *Observed maternal sensitivity* | | | | | |
|---|---|---|---|---|---|---|
| | *Highly sensitive mothers* | | | *Less sensitive mothers* | | |
| | *N (%)* | *M* | *SD* | *N (%)* | *M* | *SD* |
| Smoking during day of homevisit (yes) | 2 (4.1) | | | 12 (24.5) | | |
| Physical exercise during week prior to homevisit (yes) | 10 (20.4) | | | 18 (36.7) | | |
| Age in years | | 30.59 | 5.33 | | 28.44 | 4.89 |
| Mean perceived urgency 500 Hz | | 1.75 | 0.41 | | 1.76 | 0.67 |
| Mean perceived urgency 700 Hz | | 2.41 | 0.56 | | 2.60 | 0.79 |
| Mean perceived urgency 900 Hz | | 2.37 | 0.83 | | 2.61 | 0.83 |
| Baseline mean HR | | 64.79** | 9.07 | | 73.69 | 7.82 |
| Mean HR during block 1 | | 68.84* | 8.69 | | 74.83 | 8.12 |
| Mean HR during block 2 | | 69.54* | 9.37 | | 75.76 | 8.20 |
| Mean HR during block 3 | | 69.69** | 9.30 | | 76.03 | 8.75 |
| Mean HR during recovery | | 66.86 | 9.75 | | 74.33 | 9.24 |
| Baseline mean RMSSD | | 63.92* | 35.29 | | 41.60 | 19.08 |
| Mean RMSSD during block 1 | | 52.72 | 28.43 | | 40.62 | 20.01 |
| Mean RMSSD during block 2 | | 53.55 | 26.54 | | 42.18 | 22.21 |
| Mean RMSSD during block 3 | | 55.45 | 28.98 | | 40.15 | 21.60 |
| Mean RMSSD during recovery | | 56.63 | 32.30 | | 41.22 | 19.91 |
| Total | 17 (34.7) | | | 32 (65.3) | | |

*$p < .05$, **$p < .01$.

tributions, means, and standard deviations are presented in Table 1. Neither smoking nor maternal age had a significant influence on baseline levels of mean HR and RMSSD, nor were these variables significant covariates in any of the repeated measures analyses. Physical exercise was significantly related to RMSSD baseline values, but was not significant as covariate in the repeated measures analysis for mean RMSSD. Therefore, analyses are reported without these variables.

## Perception of urgency

Means and standard deviations are presented in Table 1. A repeated measure for perceived urgency of the three cry sounds (500, 700, and 900 Hz) showed that all mothers perceived the 700- as well as the 900-Hz cry sound as significantly more urgent than the 500-Hz cry sound, $F(1.80, 84.73) = 51.07$, $p < .01$, partial $\eta^2 = .52$. No significant differences in perceived urgency were found between the 700- and 900-Hz cry sound, $F$(1,

47) = 0.06, $p > .05$, partial $\eta^2 = .00$. Harsh mothers and non-harsh mothers also did not show different patterns in their ratings of perceived urgency for all three cry frequencies, $F(1.80, 84.73) = 1.07$, $p > .05$, partial $\eta^2 = .02$.

## Heart rate

Means and standard deviations are presented in Table 1. The independent *t*-test showed a significantly lower baseline HR for highly sensitive mothers compared to less sensitive mothers, $t(47) = 3.59$, $p < .01$, $r = .46$. Separate analyses of covariance showed lower mean HR for highly sensitive mothers compared to less sensitive mothers in block 1 ($F(1,46) = 4.71$, $p < .05$, partial $\eta^2$ .09), block 2 ($F(1,46) = 7.30$, $p < .05$, partial $\eta^2$ .14), and block 3 ($F(1,46) = 9.97$, $p < .01$, partial $\eta^2$ .18) when correcting for baseline HR values.

A repeated measures analysis showed a significant rise in mean HR from baseline to all three cry sound blocks as well as a significant decrease in mean HR from block 3 to recovery, $F(2.64, 124.20) = 20.88$, $p < .01$, partial $\eta^2 = .31$. Furthermore, an interaction effect between HR increase and maternal sensitivity was found. Highly sensitive mothers showed a significantly more pronounced increase in HR from baseline to all three cry sound blocks compared to less sensitive mothers, $F(2.64, 124.20) = 3.34$, $p < .05$, partial $\eta^2 = .07$. The repeated measures analysis did not show a significantly different pattern in HR reactivity between the two groups from block 3 to the recovery. Concerning overall mean-level HR (across the paradigm), a significant between-subjects effect showed that highly sensitive mothers had lower mean HR levels compared to less sensitive mothers across the cry paradigm, $F(1,47) = 7,51$, $p < .05$, partial $\eta^2 = .14$. Mean HR response patterns for both groups are presented in Figure 1.

## Respiratory sinus arrhythmia

Means and standard deviations are presented in Table 1. The independent *t*-test showed a significant higher baseline RMSSD value for highly sensitive mothers compared to less sensitive mothers, $t(21.09) = -2.43$, $p < .05$, $r = .47$. Separate analyses of covariance did not show group differences for mean RMSSD in any of the blocks or the recovery, when controlling for baseline values. Means and standard deviations are presented in Table 1. A repeated measures analysis for mean RMSSD showed a significant drop in mean RMSSD from baseline to block 1 and from baseline to block 2, but only for the highly sensitive mothers, $F(3.17, 149.11) = 2.96$, $p < .05$, partial $\eta^2 = .06$, indicating a stronger RSA withdrawal for highly sensitive

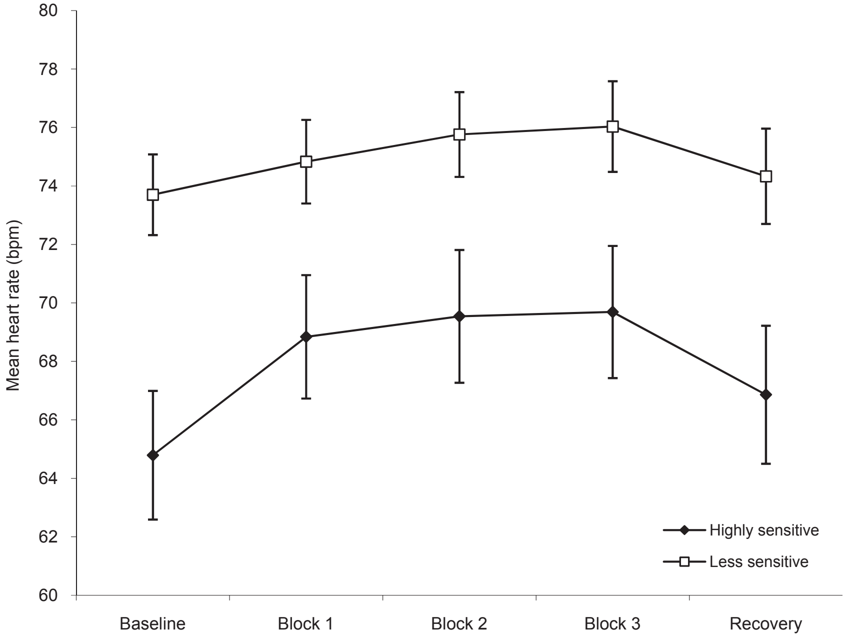


**Figure 1** Heart rate reactivity to infant crying (*M*, *SE*) in highly sensitive and less sensitive mothers.

mothers than for less sensitive mothers. The drop in mean RMSSD for sensitive mothers from baseline to block 3 approached significance ($p$ = .07). With regard to overall mean-level RMSSD, highly sensitive mothers had higher mean RMSSD values compared to less sensitive mothers across the cry paradigm, $F(1,47) = 4.82$, $p < .05$ partial $\eta^2 = .09$. Mean RMSSD response patterns for both groups are presented in Figure 2.

## DISCUSSION

The aim of the present study was to examine physiological reactivity to cry sounds comparing highly sensitive with less sensitive mothers. We hypothesized that highly sensitive mothers would have a greater HR reactivity in combination with stronger RSA withdrawal in response to repeated cry sounds when compared to less sensitive mothers. Our results showed that highly sensitive mothers indeed had a greater increase in HR and a stronger RSA withdrawal in reaction to infant crying than less sensitive mothers, even though both groups did not differ in perceived urgency of the various

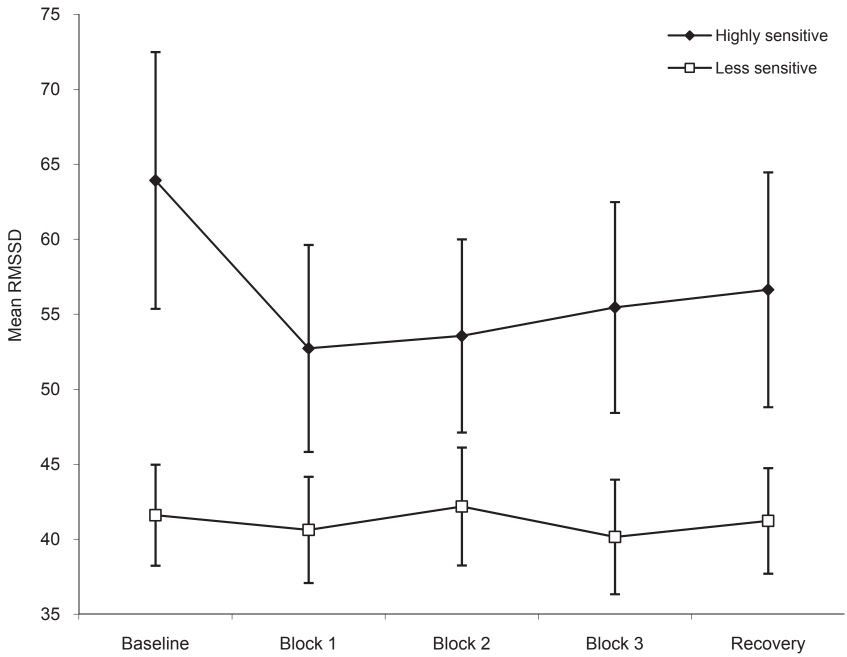


**Figure 2** Respiratory sinus arrhythmia withdrawal in response to infant crying (*M, SE*) in highly sensitive and less sensitive mothers.

frequencies. In other words, mothers who were highly sensitive during interaction with their own infants showed greater physiological reactivity to repeated cry sounds.

Our results on RSA withdrawal are in line with earlier research showing stronger RSA withdrawal in mothers of secure infants than in mothers of insecure-avoidant infants during the final reunion episode of the Strange Situation Procedure (Hill-Soderlund et al., 2008). Our results on HR reactivity are partially in line with the finding that greater reactivity to infant crying is related to more prompt caregiving (Del Vecchio et al., 2009), because the promptness of caregiving is an integral part of the sensitivity construct. However, as mentioned in the introduction, greater HR reactivity to negative infant signals has also been reported for parents at risk of abuse (McCanne & Hagstrom, 1996). This apparent contradiction may be explained by the fact that HR increases can be driven both by the PNS through withdrawal of the vagal brake and by the activation of the SNS (see Berntson, Cacioppo, Quigley, & Fabro, 1994).

The three subsystems of the autonomic nervous system as described by Porges (1995, 2001, 2007) are hierarchically activated when responding to external stressors. The activation of a specific subsystem further depends on the perception of the environment as either safe or threatening. In a safe environment, the circuit for social communications is activated to promote survival by facilitating social interactions and social bonds. With an activated social communications circuit fostering calm behavioral states, maternal sensitivity during dyadic interaction would also be promoted. Among highly sensitive mothers, a well-functioning vagal brake may then be responsible for a heightened and adequate physiological reactivity to external demands such as infant crying, without activation of the ''older'' and biologically more taxing sympathetic system (Porges, 2001, 2009). However, when the environment is perceived as dangerous or threatening, the autonomic system switches to the more primitive circuits and activates the SNS to regulate defensive strategies through a fight-or-flight response. Heightened perceptions of danger and threat have been found in parents at risk of abuse, as evidenced by more hostile interpretations of child behaviors, often in combination with feelings of powerlessness (e.g., Bugental & Happaney, 2004; Leung & Slep, 2006; Linn, Bugental, Turek, Martorell, & Olster, 2002; Smith & O'Leary, 1995). Furthermore, the behavioral overreactivity to infant signals seen in parents at risk of abuse (Milner, 2003) may signal a chronically overactivated SNS resulting from a poorly functioning vagal brake (Porges, 2001). Thus, greater HR reactivity to child negative affect signals in parents at risk of abuse (as compared to controls) is likely to stem from activation of the SNS.

In sum, we suggest that parents at risk of abuse as well as highly sensitive parents may show heightened HR reactivity to negative child signals, but that this HR reactivity originates from different autonomic subsystems. Abusive parents may perceive infant signals of negative affect such as crying as threatening, resulting in a stronger activation of the SNS (and greater HR increases). Highly sensitive parents are unlikely to perceive infant signals of negative affect as threatening. Operating from a safety rather than a threat perspective, in these mothers such infant signals lead to efficient activation of the (parasympathetic) social communication circuit in responding to the environmental demands of infant crying, resulting in greater HR increases compared to less sensitive parents.

To test this hypothesis, future studies may examine differences between harsh/abusive parents and highly sensitive parents in both sympathetic and parasympathetic reactivity to negative infant signals such as crying. To further specify the influence of each branch of the nervous system, salivary alpha-amylase, skin conductance level, and pre-ejection period (PEP) should be collected simultaneously. In addition, measures of cortisol indicating the activity of the hypothalamic–pituitary–adrenal axis could also be included as a correlate of SNS activation as both systems are involved in stress management (e.g., El-Sheikh, Erath, Buckhalt, Granger, & Mize, 2008; Gordis, Granger, Susman, & Trickett, 2008; Van Stegeren, Wolf, & Kindt, 2008). However, even though harsh and sensitive parenting are linked both empirically (Engfer & Gavranidou, 1987; Joosen et al., 2012) and conceptually (Milner, 1993, 2003), it should be noted that some subtypes of insensitive parenting may be unrelated to harsh parenting. An overall absence of responses to infant signals also results in low scores on maternal sensitivity. Therefore, distinguishing between insensitive-passive mothers and insensitive-intrusive mothers is highly relevant for understanding the underlying physiological processes of maternal responses to infant signals.

Concerning overall mean-level differences in HR and RSA across the cry paradigm, we found that highly sensitive mothers had lower mean HR in combination with higher mean RSA levels compared to less sensitive mothers. For RSA, this result was mainly because of baseline differences between highly sensitive and less sensitive mothers. Following Porges' suggestion that baseline parasympathetic tone may represent stress vulnerability (Porges, 1995), the difference in overall levels might suggest a better capability for efficient responsiveness to environmental demands in highly sensitive mothers, both physiologically and behaviorally. Furthermore and as expected, these findings extend earlier findings showing a complementary pattern of overall high HR levels and low RSA levels for mothers at risk of abuse (Bugental, Lewis, Lin, Lyon, & Kopeikin, 1999; Disbrow et al., 1977; Pruitt & Erickson, 1985). Our results seem to suggest that a pattern of high mean HR and low mean RSA also applies to mothers showing non-optimal levels of sensitivity to infant signals, even if they are not (yet) at risk of abuse (Milner, 1993, 2003).

One might argue that according to the "law of initial values," differences in baseline values for both HR and RSA could (partially) account for lower physiological reactivity in the less sensitive group. However, even if their lower reactivity is caused by baseline levels, the implication remains that less sensitive mothers are significantly less aroused by infant crying, which could be a reason for the less optimal responsiveness in interaction with their infants. As a limitation of the current study, it should be noted that concurrent maternal stress was not measured. Stress levels may affect both physiological baseline values (Thayer, Friedman, & Borkovec, 1996) and maternal sensitivity (Belsky, Crnic, & Woodworth, 1995; Van IJzendoorn, Bakermans-Kranenburg, & Mesman, 2008). Furthermore, continuing challenges in the search for accurate baseline measurements, especially concerning vagal tone (Butler, Wilhelm, & Gross, 2006), complicate the interpretation of physiological reactivity. Therefore, extending the focus to individual differences in overall levels of physiological measures instead of studying reactivity to stressors exclusively might provide better insight into parenting correlates of physiological stress vulnerability. Last, sample sizes, especially for the highly sensitive group, were small, but to ensure valid conclusions, the data were rigorously checked for outliers.

Given the importance of the quality of maternal care for the development of infant stress reactivity (Albers, Riksen-Walraven, Sweep, & De Weerth, 2008; Hane & Fox, 2006), future studies should investigate the pathways that relate maternal stress reactivity and quality of parenting to infant stress reactivity. Furthermore, future studies should investigate the underlying mechanisms for HR reactivity in greater detail, with special attention to differences between parasympathetically and sympathetically driven HR reactivity to infant signals of negative affect in parents with different parenting profiles. Such studies may further contribute to our understanding of the nature of intergenerational transmission of physiological vulnerability beyond genetic influences, which in turn could facilitate the identification of those infants at risk of impaired stress regulation and subsequent psychopathology.

In conclusion, the current study shows that mothers who were highly sensitive during interaction with their own infants displayed greater physiological reactivity to repeated cry sounds indicative of a more flexible physiological capability in responding to infant signals of negative affect.

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